BUREAU VERITAS MARINE & OFFSHORE

RULES FOR CLASSIFICATION

RULES FOR THE CLASSIFICATION OF **NAVAL SHIPS**

PART B

HULL AND STABILITY

NR483 B DT R08

EDITION DECEMBER 2026



BUREAU VERITAS

BUREAU VERITAS MARINE & OFFSHORE
RULES FOR CLASSIFICATION

NR483 B DT R08 DECEMBER 2026

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PART A
CLASSIFICATION AND SURVEYS
NR483 A DT R08 DECEMBER 2026

PART B
HULL AND STABILITY
NR483 B DT R08 DECEMBER 2026

PART C
MACHINERY, SYSTEMS AND FIRE PROTECTION
NR483 C DT R08 DECEMBER 2026

PART D
SERVICE NOTATIONS
NR483 D DT R08 DECEMBER 2026

PART E
ADDITIONAL CLASS NOTATIONS
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Rules for Classification
NR483

RULES FOR THE CLASSIFICATION OF NAVAL SHIPS

Part B
Hull and Stability

Chapter 1	General
Chapter 2	General Arrangement Design
Chapter 3	Stability
Chapter 4	Structure Design Principles
Chapter 5	Design Loads
Chapter 6	Hull Girder Strength
Chapter 7	Hull Scantlings
Chapter 8	Other Structures
Chapter 9	Hull Outfitting
Chapter 10	Corrosion Protection and Loading Information
Chapter 11	Construction and Testing

December 2026

Table of Content

Chapter 1 General

Section 1 Application

1 General 28

1.1 Structural requirements
1.2 Limits of application to lifting appliances and weapons

2 Rule application 28

2.1 Ship parts
2.2 Rules applicable to various ship parts
2.3 Rules applicable to other ship items

3 Rounding off of scantlings 29

3.1

Section 2 Symbols and Definitions

1 Units 30

1.1

2 Definitions 30

2.1 Symbols

3 Waterlines 30

3.1 Subdivision lines
3.2 Specific lines

4 Dimensions 31

4.1 Rule length
4.2 Ends of rule length L and midship
4.3 Length between perpendiculars
4.4 Moulded breadths
4.5 Moulded depth
4.6 Moulded draught

5 Ship weights 32

5.1 Lightship
5.2 Full load
5.3 Operational load
5.4 Minimum operational load
5.5 Deadweight

6 Decks and bulkheads 33

6.1 General
6.2 Bulkhead deck (B.D.)
6.3 Exposed decks - Upper decks (E.D.)
6.4 Watertight deck (W.D.)
6.5 Damage control deck
6.6 Main transversal watertight bulkhead (M.T.W.B.)
6.7 Main watertight compartment
6.8 Auxiliary transversal watertight bulkheads (A.T.W.B.)

7 Spaces definition 35

7.1 Machinery space
7.2 Ro-ro cargo spaces
7.3 Passenger spaces
7.4 Special personnel
7.5 Special category spaces
7.6 Military special category spaces

Table of Content

8 Superstructures 36

8.1 General
8.2 Enclosed and open superstructures
8.3 Raised quarterdeck
8.4 Deckhouse
8.5 Trunk

9 Deck positions 36

9.1 Definitions

10 Reference co-ordinate system 37

10.1

Section 3 Documentation to be Submitted

1 Documentation to be submitted for all ships 38

1.1 Ships built under the Society supervision

2 Further documentation to be submitted for ships with certain additional class notations 40

2.1 General
2.2 Additional class notations

Chapter 2 General Arrangement Design

Section 1 Subdivision Arrangement

1 General 42

1.1 Definitions

2 Number and arrangement of transverse watertight bulkheads 42

2.1 Number of main watertight bulkheads
2.2 Number of auxiliary watertight bulkheads
2.3 Bulkhead arrangement

3 Collision bulkhead 43

3.1 Arrangement of collision bulkhead

4 After peak, machinery space bulkheads and stern tubes 43

4.1 General

5 Openings and crossings in watertight bulkheads and decks 43

5.1 Definitions
5.2 Regulations

6 Doors 44

6.1 General

Section 2 Compartment Arrangement

1 Flooding management 45

1.1 Protection
1.2 Detection
1.3 Pumping

2 Cofferdams 45

2.1 Definition
2.2 Cofferdam arrangement

3 Ballast compartments 45

3.1 General

4 Double bottoms 46
4.1 Auxiliary ships
4.2 Frontline ships
5 Compartments forward of the collision bulkhead 46
5.1 General
6 Machinery compartments 46
6.1 General
6.2 Two machinery compartments
7 Shaft tunnels 46
7.1 General
8 Watertight ventilators and trunks 46
8.1 General
9 Fuel oil tanks 46
9.1 General
10 Ammunition storage compartments 46
10.1 General
11 Tanks containing chemical treatment fluids for exhaust gas pollution prevention system 47
11.1 Tank protection and segregation

Section 3 Access and Openings Arrangement

1 General 48
1.1 Number and size of access and openings
2 Double bottom 48
2.1 Inner bottom manholes
2.2 Floor and girder manholes
3 Tanks, water ballast tanks and cofferdams 48
3.1 General
3.2 Access through decks
3.3 Access within tanks
3.4 Construction of ladders
4 Air pipes 49
4.1 General

Chapter 3 Stability

Section 1 General

1 Definitions 51
1.1
2 General 51
2.1 Application
3 Examination procedure 51
3.1 Documents to be submitted
3.2 Inclining test - Lightweight check

Table of Content

Section 2 Intact Stability

1 General 53

1.1 Information for the Captain
1.2 Permanent ballast

2 Design criteria 53

2.1 General intact stability criteria
2.2 Effect of free surfaces of liquids in tanks
2.3 Severe wind and rolling
2.4 Icing
2.5 High speed turning
2.6 Heavy cargo lifting in still water
2.7 Crowding of special personnel on one side
2.8 Simultaneous effect of wind and special personnel crowding

Section 3 Damage Stability

1 General 65

1.1 On board supports
1.2 Damage control

2 Conditions and criteria 66

2.1 Approaches to be followed for damage stability investigation
2.2 Progressive flooding
2.3 General
2.4 Damage and criteria

Section 4 Sea-Keeping

1 General 73

1.1 Introduction
1.2 Assessment procedure
1.3 Environmental conditions
1.4 Requirements to be complied with

2 Hull 74

2.1 General
2.2 Parameters
2.3 Criteria

Appendix 1 Inclining Test and Lightweight Check

1 Inclining test and lightweight check 77

1.1 General

Appendix 2 Trim and Stability Booklet

1 Trim and stability booklet 80

1.1 Information to be included in the trim and stability booklet
1.2 Stability curve calculation

Appendix 3 Calculation Method for Cross-Flooding Arrangements

1 Calculation method for cross-flooding arrangements 82

1.1 Cross-flooding area

Appendix 4 Buoyancy Reserve - “V” Line Method

1 Buoyancy reserve 85

1.1 Purpose

Table of Content

Appendix 5 Evaluation of the Heeling Moment due to Athwart Wind (Intact Vessel)

1 Evaluation of the heeling moment due to athwart wind (intact vessel) 87

1.1 Intact stability
1.2 Damage stability

Appendix 6 Sea-Keeping Calculations

1 Introduction 90

1.1 General
1.2 Scope

2 Short term assessment 90

2.1 General
2.2 Loading conditions
2.3 Ship speed
2.4 Wave spectrum
2.5 Hydrodynamic model
2.6 Spectral moments
2.7 RMS values

3 Long term assessment 92

3.1 General
3.2 Hydrodynamic model
3.3 Sea state scatter diagram

Chapter 4 Structure Design Principles

Section 1 Materials

1 General 95

1.1 Characteristics of materials
1.2 Testing of materials
1.3 Manufacturing processes

2 Steels for hull structure 95

2.1 Application
2.2 Information to be kept on board
2.3 Material factor k
2.4 Grades of steel
2.5 Grades of steel for structures exposed to low air temperatures
2.6 Grades of steel within refrigerated spaces

3 Steels for forging and casting 101

3.1 General
3.2 Steels for forging
3.3 Steels for casting

4 Aluminium alloy structures 101

4.1 General
4.2 Extruded plating
4.3 Influence of welding on mechanical characteristics
4.4 Material factor k

5 Other materials and products 103

5.1 General
5.2 Iron cast parts

Section 2 Net Scantling Approach

1 Application criteria 104

1.1 General

Table of Content

2 Net strength characteristic calculation 104

2.1 Designer's proposal based on gross scantlings
2.2 Designer's proposal based on net scantlings

3 Corrosion additions 105

3.1 Values of corrosion additions

Section 3 Strength Principles

1 General principles 107

1.1 Structural continuity
1.2 Connections with higher strength steel
1.3 Connections between steel and aluminium

2 Plating 108

2.1 Insert plates and doublers

3 Ordinary stiffeners 108

3.1 General
3.2 Span of ordinary stiffeners
3.3 Width of attached plating
3.4 Geometric properties
3.5 End connections

4 Primary supporting members 112

4.1 Span of primary supporting members
4.2 Width of attached plating
4.3 Geometric properties
4.4 Bracketed end connections
4.5 Bracketless end connections
4.6 Cut-outs and holes
4.7 Stiffening arrangement

Section 4 Bottom Structure

1 General 118

1.1 Application
1.2 General arrangement
1.3 Drainage and openings for air passage

2 Longitudinally framed single bottom 118

2.1 General
2.2 Floors
2.3 Longitudinal ordinary stiffeners

3 Transversely framed single bottom 119

3.1 General
3.2 Floors

4 Longitudinally framed double bottom 119

4.1 General
4.2 Double bottom height
4.3 Floors
4.4 Bottom and inner bottom longitudinal ordinary stiffeners
4.5 Brackets to centreline girder and margin plate
4.6 Duct keel
4.7 Bilge wells

5 Transversely framed double bottom 120

5.1 General
5.2 Floors
5.3 Girders
5.4 Open floors

6 Bilge keel 121
6.1 Arrangement, scantlings and connections

Section 5 Side Structure

1 General 124
1.1 Application
1.2 General arrangement
1.3 Sheerstrake

2 Longitudinally framed single side 124
2.1 Longitudinal ordinary stiffeners
2.2 Primary supporting members

3 Transversely framed single side 124
3.1 Frames
3.2 Primary supporting members

4 Longitudinally framed double side 125
4.1 General
4.2 Primary supporting members

5 Transversely framed double side 125
5.1 General
5.2 Frames
5.3 Primary supporting members

6 Frame connections 125
6.1 General
6.2 Upper brackets of frames
6.3 Lower brackets of frames

7 Openings in the shell plating 128
7.1 Position of openings
7.2 Local strengthening

Section 6 Deck Structure

1 General 129
1.1 Application
1.2 General arrangement
1.3 Construction of watertight decks
1.4 Stringer plate

2 Longitudinally framed deck 130
2.1 General
2.2 Longitudinal ordinary stiffeners

3 Transversely framed deck 130
3.1 General

4 Pillars 130
4.1 General
4.2 Connections

5 Hatch supporting structures 130
5.1 General

6 Openings in the strength deck 131
6.1 Position of openings and local strengthening
6.2 Corners of hatchways

7 Openings in decks other than the strength deck 132
7.1 General

Table of Content

Section 7 Bulkhead Structure

1 General 133

1.1 Application
1.2 General arrangement
1.3 Watertight bulkheads of trunks, tunnels, etc.
1.4 Openings in watertight bulkheads
1.5 Watertight doors

2 Plane bulkheads 134

2.1 General
2.2 End connections of ordinary stiffeners
2.3 Bracketed ordinary stiffeners

3 Corrugated bulkheads 135

3.1 General
3.2 Structural arrangement
3.3 Bulkhead stool

4 Non-tight bulkheads 136

4.1 Non-tight bulkheads not acting as pillars
4.2 Non-tight bulkheads acting as pillars

5 Wash bulkheads 137

5.1 General
5.2 Openings

Chapter 5 Design Loads

Section 1 General

1 Definitions 139

1.1 Cargo
1.2 Still water loads
1.3 Wave loads
1.4 Dynamic loads
1.5 Local loads
1.6 Hull girder loads
1.7 Loading condition
1.8 Load case

2 Application criteria 139

2.1 Fields of application
2.2 Hull girder loads
2.3 Local loads
2.4 Load definition criteria to be adopted in structural analyses based on plate or isolated beam structural models
2.5 Load definition criteria to be adopted in structural analyses based on three- dimensional structural models

Section 2 Hull Girder Loads

1 General 142

1.1 Application
1.2 Sign conventions of vertical bending moments and shear forces

2 Still water loads 143

2.1 General
2.2 Still water bending moments
2.3 Still water shear force

Table of Content

3 Wave loads 144

3.1 Vertical wave bending moments
3.2 Horizontal wave bending moment
3.3 Wave torque
3.4 Vertical wave shear force

4 Dynamic loads due to bow flare impact 146

4.1 Application
4.2 Increase in sagging wave bending moment

Section 3 Ship Motions and Accelerations

1 General 148

1.1

2 Ship absolute motions and accelerations 148

2.1 Surge
2.2 Sway
2.3 Heave
2.4 Roll
2.5 Pitch
2.6 Yaw

3 Ship relative motions and accelerations 149

3.1 Definitions
3.2 Ship conditions
3.3 Ship relative motions
3.4 Accelerations

Section 4 Load Cases

1 General 151

1.1 Load cases for structural analyses based on partial ship models
1.2 Load cases for structural analyses based on complete ship models

2 Load cases 151

2.1 Upright ship conditions (load cases “a” and “b”)
2.2 Inclined ship conditions (load cases “c” and “d”)
2.3 Summary of load cases

Section 5 Sea Pressures

1 Still water pressure 155

1.1 Pressure on sides and bottom

2 Wave pressure 155

2.1 Upright ship conditions (load cases “a” and “b”)
2.2 Inclined ship conditions (load cases “c” and “d”)

3 Exposed decks 157

3.1 Application
3.2 Sea pressures on exposed decks

4 Sea chests 158

4.1 Design pressure

Section 6 Internal Pressures and Forces

1 Liquids 159

1.1 Still water pressure
1.2 Inertial pressure

2 Dry uniform loads 161

2.1 Still water and inertial pressures

3 Dry unit cargoes 161
3.1 Still water and inertial forces
4 Vehicles and helicopters 162
4.1 Still water and inertial forces
5 Accommodation and ammunition storage 162
5.1 Still water and inertial pressures
6 Machinery 163
6.1 Still water and inertial pressures
7 Flooding 164
7.1 Still water and inertial pressures
8 Testing 164
8.1 Still water pressures
9 Weapons firing dynamic loads 165
9.1 Dynamic loads
9.2 Guidance values

Appendix 1 Inertial Pressure for Typical Tank Arrangement
1 Inertial ballast pressure 167
1.1 Introduction
1.2 Formulae for the inertial pressure calculation

Chapter 6 Hull Girder Strength

Section 1 Strength Characteristics of the Hull Girder Transverse Sections
1 Application 170
1.1 General
2 Calculation of the strength characteristics of hull girder transverse sections 170
2.1 Hull girder transverse sections
2.2 Strength deck
2.3 Section modulus
2.4 Moments of inertia
2.5 First moment
2.6 Structural models for the calculation of normal warping stresses and shear stresses

Section 2 Yielding Checks
1 Application 176
1.1 General
2 Hull girder stresses 176
2.1 Normal stresses induced by vertical bending moments
2.2 Normal stresses induced by vertical and horizontal bending moments
2.3 Shear stresses
2.4 Simplified calculation of shear stresses induced by vertical shear forces
3 Checking criteria 178
3.1 General
3.2 Normal stresses induced by vertical bending moments
3.3 Shear stresses

4 Section modulus and moment of inertia 178
4.1 General
4.2 Section modulus within 0,4L amidships
4.3 Section modulus outside 0,4L amidships
4.4 Midship section moment of inertia
4.5 Extent of higher strength steel
5 Permissible still water bending moment and shear force during navigation 180
5.1 Permissible still water bending moment
5.2 Permissible still water shear force
6 Permissible still water bending moment and shear force in harbour conditions 181
6.1 Permissible still water bending moment
6.2 Permissible shear force

Section 3 Ultimate Strength Check
1 General 182
1.1 Application
1.2 Net scantlings
1.3 Partial safety factors
2 Hull girder ultimate strength check 182
2.1 Hull girder loads
2.2 Hull girder ultimate bending moment capacities
2.3 Checking criteria

Appendix 1 Hull Girder Ultimate Strength
1 Hull girder ultimate strength check 184
1.1 Introduction
1.2 Criteria for the calculation of the curve M-χ
1.3 Load-end shortening curves σ-ε

Chapter 7 Hull Scantlings

Section 1 Plating
1 General 193
1.1 Net thicknesses
1.2 Partial safety factors
1.3 Elementary plate panel
1.4 Load point
2 General requirements 194
2.1 General
2.2 Minimum net thicknesses
2.3 Bilge plating
2.4 Sheerstrake
2.5 Stringer plate
3 Strength check of plating subjected to lateral pressure 195
3.1 General
3.2 Load model
3.3 Longitudinally framed plating contributing to the hull girder longitudinal strength
3.4 Transversely framed plating contributing to the hull girder longitudinal strength
3.5 Plating not contributing to the hull girder longitudinal strength
4 Strength check of plating subjected to wheeled loads 199
4.1 General
4.2 Load model
4.3 Plating

Table of Content

5 Buckling check 200

5.1 General
5.2 Load model
5.3 Critical stresses
5.4 Checking criteria

Section 2 Ordinary Stiffeners

1 General 208

1.1 Net scantlings
1.2 Partial safety factors
1.3 Load point
1.4 Net dimensions of ordinary stiffeners

2 General requirements 209

2.1 General
2.2 Struts of open floors

3 Yielding check 210

3.1 General
3.2 Structural model
3.3 Load model
3.4 Normal and shear stresses due to lateral pressure in intact conditions
3.5 Normal and shear stresses due to wheeled loads
3.6 Checking criteria
3.7 Net section modulus and net shear sectional area of ordinary stiffeners, complying with the checking criteria
3.8 Net section modulus and net shear sectional area of ordinary stiffeners subjected to lateral pressure in flooding conditions
3.9 Net section modulus and net shear sectional area of ordinary stiffeners subjected to lateral pressure in testing conditions

4 Buckling check 217

4.1 Width of attached plating
4.2 Load model
4.3 Critical stress
4.4 Checking criteria

5 Ultimate strength check of ordinary stiffeners contributing to the hull girder longitudinal strength 221

5.1 Application
5.2 Width of attached plating
5.3 Load model
5.4 Ultimate strength stress
5.5 Checking criteria

Section 3 Primary Supporting Members

1 General 225

1.1 Application
1.2 Net scantlings
1.3 Partial safety factors

2 Yielding check of primary supporting members analysed through an isolated beam structural model 227

2.1 General
2.2 Bracket arrangement
2.3 Load point
2.4 Load model
2.5 Normal and shear stresses due to lateral pressure in intact conditions
2.6 Checking criteria
2.7 Net section modulus and net sectional shear area complying with the checking criteria
2.8 Net section modulus and net shear sectional area of primary supporting members subjected to lateral pressure in flooding conditions

3 Yielding check of primary supporting members analysed through a three-dimensional structural model 232

3.1 General
3.2 Analysis criteria
3.3 Checking criteria

4 Yielding check of primary supporting members analysed through a complete ship structural model 233

4.1 General
4.2 Analysis criteria
4.3 Checking criteria

5 Buckling check 233

5.1 Local buckling of plate panels
5.2 Buckling of pillars subjected to compression axial load
5.3 Buckling of pillars subjected to compression axial load and bending moments

6 Dynamic analysis of main weapon mount supporting structure 237

6.1 Application
6.2 Dynamic analysis

Section 4 Fatigue Check of Structural Details

1 General 239

1.1 Net scantlings
1.2 Application
1.3 Definitions
1.4 Partial safety factors

2 Load model 241

2.1 General
2.2 Local lateral pressures
2.3 Nominal hull girder normal stresses

3 Fatigue damage ratio 244

3.1 General

4 Stress range 246

4.1 General
4.2 Hot spot stress range
4.3 Notch stress range

5 Checking criterion 247

5.1 Damage ratio

6 Structural details located at ends of ordinary stiffeners 248

6.1 General
6.2 Determination of elementary hot spot stress range

Appendix 1 Analyses Based on Three-Dimensional Models

1 General 250

1.1 Application
1.2 Information required

2 Analysis criteria 251

2.1 General
2.2 Finite element model analysis
2.3 Beam model analysis
2.4 Structural detail analysis

Table of Content

3 Structural modelling of primary supporting members 252

3.1 Model construction
3.2 Model extension
3.3 Finite element modelling criteria
3.4 Finite element models
3.5 Beam models
3.6 Boundary conditions of the whole three-dimensional model

4 Load models of primary supporting members 256

4.1 General
4.2 Local loads
4.3 Hull girder loads

5 Stress calculation 258

5.1 Analysis based on finite element models
5.2 Analysis based on beam models

6 Fatigue analysis 259

6.1 Elementary hot spot stress range calculation
6.2 Hot spot stresses directly obtained through finite element analysis
6.3 Hot spot stresses directly obtained through calculation of nominal stresses

Appendix 2 Analyses of Primary Supporting Members Subjected to Wheeled Loads

1 General 261

1.1 Scope
1.2 Application
1.3 Information required
1.4 Lashing of vehicles

2 Analysis criteria 262

2.1 Finite element model analysis
2.2 Beam model analysis

3 Structural modelling of primary supporting members 262

3.1 Model construction
3.2 Model extension
3.3 Boundary conditions of the three-dimensional model

4 Load model 263

4.1 General
4.2 Local loads
4.3 Hull girder loads

5 Stress calculation 264

5.1 Stresses induced by local and hull girder loads
5.2 Analysis based on finite element models
5.3 Analysis based on beam models

6 Grillage analysis of deck primary supporting members 265

6.1 Application
6.2 Analysis criteria
6.3 Boundary conditions
6.4 Load model
6.5 Stress calculation

Appendix 3 Analyses Based on Complete Ship Models

1 General 267

1.1 Application

2 Structural modelling 267
2.1 Model construction
2.2 Model extension
2.3 Finite element modelling criteria
2.4 Finite element models
2.5 Boundary conditions of the model
3 Load model 269
3.1 General
3.2 Procedure for the selection of design waves
3.3 Load cases
4 Stress calculation 273
4.1 Stress components

Chapter 8 Other Structures

Section 1 Fore Part

1 General 277
1.1 Application
1.2 Connections of the fore part with structures located aft of the collision bulkhead
1.3 Net scantlings
2 Fore peak 277
2.1 Partial safety factors
2.2 Load point
2.3 Load model
2.4 Longitudinally framed bottom
2.5 Transversely framed bottom
2.6 Longitudinally framed side
2.7 Transversely framed side
2.8 Decks
2.9 Platforms
2.10 Central longitudinal bulkhead
2.11 Bulbous bow
3 Reinforcements of the flat bottom forward area 284
3.1 Area to be reinforced
3.2 Bottom impact pressure
3.3 Partial safety factors
3.4 Scantlings
3.5 Arrangement of primary supporting members and ordinary stiffeners: longitudinally framed bottom
3.6 Arrangement of primary supporting members and ordinary stiffeners: transversely framed double bottom
4 Reinforcements of the bow flare area 286
4.1 Area to be reinforced
4.2 Bow impact pressure
4.3 Partial safety factors
4.4 Scantlings
5 Stems 287
5.1 General
5.2 Plate stems
5.3 Bar stems
6 Transverse thrusters 288
6.1 Scantlings of the thruster tunnel and connection with the hull

Table of Content

Section 2 Aft Part

1 General 290

1.1 Application
1.2 Connections of the aft part with structures located fore of the after peak bulkhead
1.3 Net scantlings

2 Aft peak 290

2.1 Partial safety factors
2.2 Load point
2.3 Load model

3 After peak 292

3.1 Arrangement
3.2 Scantlings

4 Reinforcements of the flat area of the bottom aft 293

4.1 General

5 Connection of hull structures with the rudder horn 293

5.1 Connection of after peak structures with the rudder horn
5.2 Structural arrangement above the after peak

6 Sternframes 294

6.1 General
6.2 Connections
6.3 Propeller posts
6.4 Integral rudder posts
6.5 Propeller shaft bossing
6.6 Rudder gudgeon
6.7 Sterntubes

Section 3 Machinery Space

1 General 297

1.1 Application
1.2 Scantlings
1.3 Connections of the machinery space with structures located aft and forward

2 Double bottom 297

2.1 Arrangement
2.2 Minimum thicknesses

3 Single bottom 299

3.1 Arrangement
3.2 Minimum thicknesses

4 Side 300

4.1 Arrangement

5 Platforms 300

5.1 Arrangement
5.2 Minimum thicknesses

6 Pillaring 300

6.1 Arrangement

7 Machinery casing 301

7.1 Arrangement
7.2 Openings
7.3 Scantlings

8 Main machinery seatings 301

8.1 Arrangement
8.2 Minimum scantlings

Table of Content

Section 4 Superstructures and Deckhouses

1 General 303

1.1 Application
1.2 Net scantlings
1.3 Definitions
1.4 Connections of superstructures and deckhouses with the hull structure
1.5 Structural arrangement of superstructures and deckhouses

2 Design loads 304

2.1 Sides contributing to the longitudinal strength
2.2 Front, side and aft bulkheads not contributing to the longitudinal strength
2.3 Decks

3 Plating 306

3.1 Front, side and aft bulkheads
3.2 Decks

4 Ordinary stiffeners 307

4.1 Front, side and aft bulkheads
4.2 Decks

5 Primary supporting members 308

5.1 Front, side and aft bulkheads
5.2 Decks

Section 5 Bow Doors and Inner Doors

1 General 309

1.1 Application
1.2 Gross scantlings
1.3 Arrangement
1.4 Definitions

2 Design loads 310

2.1 Bow doors
2.2 Inner doors

3 Scantlings of bow doors 312

3.1 General
3.2 Plating and ordinary stiffeners
3.3 Primary supporting members

4 Scantlings of inner doors 312

4.1 General

5 Securing and supporting of bow doors 313

5.1 General
5.2 Scantlings

6 Strength criteria 314

6.1 Primary supporting members and securing and supporting devices

7 Securing and locking arrangement 315

7.1 Systems for operation
7.2 Systems for indication/monitoring

8 Operating and maintenance manual 316

8.1 General

Table of Content

Section 6 Side Doors and Stern Doors

1 General 317

1.1 Application
1.2 Gross scantlings
1.3 Arrangement
1.4 Definitions

2 Design loads 317

2.1 Side and stern doors

3 Scantlings of side doors and stern doors 318

3.1 General
3.2 Plating and ordinary stiffeners
3.3 Primary supporting members

4 Securing and supporting of doors 319

4.1 General
4.2 Scantlings

5 Strength criteria 319

5.1 Primary supporting members and securing and supporting devices

6 Securing and locking arrangement 320

6.1 Systems for operation

7 Operating and maintenance manual 320

7.1 General

Section 7 Watertight and Weathertight Doors

1 General 322

1.1 Application
1.2 Definitions
1.3 Partial Safety Factors

2 Design loads 322

2.1 General
2.2 Load point
2.3 Load model

3 Door leaf scantling 323

3.1 Plating
3.2 Stiffeners

4 Securing and supporting 324

4.1 General
4.2 Scantlings

5 Inspection and testing 324

5.1 General
5.2 Hydrostatic pressure testing
5.3 Hose testing

6 Type approval procedure 325

6.1 General
6.2 Documents and information to be submitted
6.3 Prototype test

Table of Content

Section 8 Hatch Covers

1 General 326

1.1 Application
1.2 Definitions
1.3 Materials
1.4 Net scantlings
1.5 Partial safety factors
1.6 Corrosion additions

2 Arrangement of large hatches 327

2.1 Height of hatch coamings
2.2 Hatch covers
2.3 Hatch coamings

3 Arrangement of small hatches 328

3.1 General
3.2 Height of hatch coamings
3.3 Hatch covers fitted on exposed decks
3.4 Hatch covers fitted on non-exposed decks
3.5 Watertight hatch covers

4 Width of attached plating 329

4.1 Ordinary stiffeners
4.2 Primary supporting members

5 Load model 329

5.1 Lateral pressures and concentrated loads
5.2 Flooding pressure
5.3 Conventional pressure for hatch covers on exposed decks
5.4 Test pressure
5.5 Load point

6 Strength check 331

6.1 General
6.2 Plating
6.3 Ordinary stiffeners and primary supporting members
6.4 Additional requirements for ordinary stiffeners and primary supporting members of hatch covers on exposed decks

7 Hatch coamings 335

7.1 Stiffening
7.2 Scantlings

8 Weathertightness, closing arrangement and securing devices of large hatches 336

8.1 Weathertightness
8.2 Gaskets
8.3 Closing arrangement and securing devices
8.4 Tarpaulins
8.5 Cleats
8.6 Wedges, battens and locking bars

9 Tightness, closing arrangement and securing devices of small hatches 338

9.1 Tightness and gaskets
9.2 Closing arrangement and securing devices

10 Testing 340

10.1 Initial test of watertight hatches
10.2 Prototype test

11 Drainage 340

11.1 Arrangement

Table of Content

Section 9 Movable Decks and Inner Ramps - External Ramps

1 Movable decks and inner ramps 341

1.1 Materials
1.2 Net scantlings
1.3 Plating
1.4 Supporting structure
1.5 Supports, suspensions and locking devices

2 External ramps 342

2.1 General

Section 10 Arrangement of Hull and Superstructure Openings

1 General 343

1.1 Application
1.2 Definitions

2 External openings 343

2.1 General
2.2 Closing devices subjected to weapon firing loads

3 Sidescuttles, windows and skylights 344

3.1 General
3.2 Opening arrangement
3.3 Glasses
3.4 Deadlight arrangement

4 Discharges 349

4.1 Arrangement of discharges
4.2 Arrangement of garbage chutes
4.3 Scantlings of garbage chutes

5 Freeing ports 350

5.1 General provisions
5.2 Freeing port area in a well not adjacent to a trunk or hatchways
5.3 Freeing port area in a well contiguous to a trunk or hatchways
5.4 Freeing port area in an open space within superstructures

6 Machinery space openings 353

6.1 Engine room skylights
6.2 Closing devices
6.3 Coamings

7 Companionway 354

7.1 General
7.2 Scantlings
7.3 Closing devices

8 Ventilators 354

8.1 Closing appliances
8.2 Coamings

9 Tank cleaning openings 355

9.1 General

Section 11 Helicopter Decks, Helicopter Platforms and Hangar Decks

1 General 356

1.1 Application
1.2 Definitions

2 General arrangement 357

2.1 General
2.2 Final approach and take-off area
2.3 Safety nets
2.4 Drainage system

3 Design principles 357

3.1 Partial safety factors

4 Design loads 358

4.1 Application
4.2 Landing loads
4.3 Parking loads
4.4 Sea pressure
4.5 Specific loads acting on helicopter platform supporting structure
4.6 Load patch dimensions

5 Scantlings 361

5.1 Plating
5.2 Ordinary stiffeners
5.3 Primary supporting members

6 Lashing 365

6.1 General
6.2 Documentation to be submitted
6.3 Design Load
6.4 Checking criteria

7 Recovery assist devices 366

7.1 Documentation to be submitted
7.2 Checking criteria

Chapter 9 Hull Outfitting

Section 1 Rudders

1 General 368

1.1 Application
1.2 Gross scantlings
1.3 Arrangements
1.4 Materials

2 Force and torque acting on the rudder 369

2.1 Rudder blade without cut-outs
2.2 Rudder blade with cut-outs (semi-spade rudders)

3 Loads acting on the rudder structure 372

3.1 General

4 Rudder stock scantlings 373

4.1 Bending moment
4.2 Scantlings

5 Rudder stock couplings 375

5.1 General
5.2 Horizontal flange couplings
5.3 Couplings between rudder stocks and tillers
5.4 Cone couplings between rudder stocks and rudder blades
5.5 Vertical flange couplings
5.6 Couplings by continuous rudder stock welded to the rudder blade
5.7 Skeg connected with rudder trunk

Table of Content

6 Rudder stock and pintle bearings 381

6.1 Forces on rudder stock and pintle bearings
6.2 Rudder stock bearing
6.3 Pintle bearings
6.4 Pintles

7 Rudder blade scantlings 383

7.1 General
7.2 Strength checks
7.3 Rudder blade plating
7.4 Connections of rudder blade structure with solid parts in forged or cast steel
7.5 Connection of the rudder blade with the rudder stock by means of horizontal flanges
7.6 Single plate rudders

8 Rudder horn and solepiece scantlings 389

8.1 General
8.2 Rudder horn
8.3 Solepieces

9 Simplex rudder shaft 393

9.1 Scantlings
9.2 Connections

10 Steering nozzles 394

10.1 General
10.2 Nozzle plating and internal diaphragms
10.3 Nozzle stock
10.4 Pintles
10.5 Nozzle coupling

11 Azimuth propulsion system 397

11.1 General
11.2 Arrangement
11.3 Design loads
11.4 Plating
11.5 Ordinary stiffeners
11.6 Primary supporting members
11.7 Hull supports of the azimuth propulsion system

Section 2 Bulwarks and Guard Rails

1 General 400

1.1 Introduction
1.2 General

2 Bulwarks 400

2.1 General
2.2 Scantlings

3 Guard rails 401

3.1

Section 3 Propeller Shaft Brackets

1 General 403

1.1 Bracket configuration

2 Double arm brackets of propeller shaft 403

2.1 General
2.2 Limit state verification - Loss of blade
2.3 Other verifications

Table of Content

Section 4 Equipment

1 General 408

1.1 General

2 Equipment number 408

2.1 Equipment number

3 Equipment 411

3.1 Anchors
3.2 Chain cables for anchors
3.3 Attachment pieces
3.4 Towlines
3.5 Hawse pipes
3.6 Windlass
3.7 Chain stoppers
3.8 Chain locker

4 Mooring arrangement 415

4.1 General
4.2 Mooring lines
4.3 Hawser for mooring to a buoy

Section 5 Masts and Other Outfitting Components

1 Masts 417

1.1 Application
1.2 Static analysis of masts
1.3 Dynamic analysis of masts

2 Outfitting components subjected to weapon firing loads 419

2.1 General

Appendix 1 Criteria for Direct Calculation of Rudder Loads

1 Criteria for direct calculation of the loads acting on the rudder structure 420

1.1 General
1.2 Data for the direct calculation
1.3 Force per unit length on the rudder body
1.4 Support spring constant

Chapter 10 Corrosion Protection and Loading Information

Section 1 Protection of Hull Metallic Structures

1 Protection by coating 425

1.1 General
1.2 Structures to be protected

2 Cathodic protection 425

2.1 General
2.2 Anodes
2.3 Impressed current systems

3 Protection against galvanic corrosion 426

3.1 General

4 Protection of bottom by ceiling 426

4.1 General
4.2 Arrangement
4.3 Scantlings

5 Protection of decks by wood sheathing 426
5.1 General
5.2 Arrangement
5.3 Scantlings

Section 2 Loading Manual and Loading Instruments
1 Definitions 427
1.1 Perpendiculars
2 Loading manual and loading instrument requirement criteria 427
2.1 General
3 Loading manual 427
3.1 Definitions
3.2 Conditions of approval
4 Loading instrument 427
4.1 Definitions
4.2 Conditions of approval
4.3 Approval procedure
4.4 Hull girder forces and moments
4.5 Intact stability
4.6 Damage stability

Chapter 11 Construction and Testing

Section 1 Welding and Weld Connections
1 General 433
1.1 Application
1.2 Base material
1.3 Documentation to be submitted
1.4 Design
1.5 Welding consumables and procedures
1.6 Personnel and equipment
2 Type of connections and preparation 435
2.1 General
2.2 Butt welding
2.3 Fillet welding
2.4 Partial and full T penetration welding
2.5 Lap-joint welding
2.6 Slot welding
2.7 Plug welding
3 Specific weld connections 442
3.1 Corner joint welding
3.2 Bilge keel connection
3.3 Connection between propeller post and propeller shaft bossing
3.4 Bar stem connection
4 Workmanship 444
4.1 Welding procedures and consumables
4.2 Welding operations
4.3 Crossing of structural elements
5 Modifications and repairs during construction 446
5.1 General
5.2 Gap and weld deformations
5.3 Defects
5.4 Repairs on structures already welded

Table of Content

6 Inspections and checks 446

6.1 General
6.2 Non-destructive examination (NDE)
6.3 Radiographic testing

Section 2 Special Structural Details

1 General 449

1.1 Application
1.2 Design requirements
1.3 Constructional requirements
1.4 Material requirements
1.5 Welding requirements
1.6 Survey requirements

2 List and characteristics of special structural details 450

2.1 General

Section 3 Testing

1 General 451

1.1 Introduction
1.2 Application
1.3 Definitions

2 Test conditions and selection of test procedures 452

2.1 General
2.2 Structural test
2.3 Leak test

3 Test procedures 453

3.1 General
3.2 Structural test
3.3 Leak test

Appendix 1 Welding Details

1 Contents 457

1.1 General
1.2 Butt welding edge preparation
1.3 Lap-joint, slot and plug welding

Appendix 2 Reference Sheets for Special Structural Details

1 Contents 459

1.1 General

Part B
Hull and Stability

CHAPTER 1
GENERAL

Section 1 Application

Section 2 Symbols and Definitions

Section 3 Documentation to be Submitted

Section 1 Application

1 General

1.1 Structural requirements

1.1.1 Part B of the Rules contains the requirements for determination of the minimum hull scantlings, applicable to all types of seagoing single hull displacement ships of normal form, speed and proportions, made in welded steel construction, with a length not less than 65m. These requirements are to be integrated with those specified in Part E, as applicable, depending on the additional class notations assigned to the ships.

1.1.2 The requirements of Part B and Part E apply also to those steel ships in which parts of the hull, e.g. superstructures or movable decks, are built in aluminium alloys.

1.1.3 Ships whose hull materials are different than those given in [1.1.2] and ships with novel features or unusual hull design are to be individually considered by the Society, on the basis of the principles and criteria adopted in the Rules.

1.1.4 The strength of ships constructed and maintained according to the Rules is sufficient for the draught corresponding to the loading conditions as defined in Ch 5, Sec 1, [2.4.3]. The scantling draught considered when applying the Rules is to be not less than that corresponding to the assigned intact ship deepest full load waterline.

1.1.5 Where scantlings are obtained from direct calculation procedures which are different from those specified in Part B, Chapter 7, adequate supporting documentation is to be submitted to the Society, as detailed in Ch 1, Sec 3.

1.2 Limits of application to lifting appliances and weapons

1.2.1 The fixed parts of lifting appliances, considered as an integral part of the hull, are the structures permanently connected by welding to the ship's hull (for instance crane pedestals, masts, king posts, derrick heel seatings, etc., excluding cranes, derrick booms, ropes, rigging accessories, and, generally, any dismountable parts). The shrouds of masts embedded in the ship's structure are considered as fixed parts.

1.2.2 The fixed parts of lifting appliances and weapons and their connections to the ship's structure are covered by the Rules.

1.2.3 As far as the weapons are concerned, the load effects of blast and recoil on the structures are covered by the Rules. The safety aspects regarding personnel and other systems are not covered by the Rules.

2 Rule application

2.1 Ship parts

2.1.1 General

For the purpose of application of the Rules, the ship is considered as divided into the following three parts:

- the fore part
- the central part
- the aft part.

2.1.2 Fore part

The fore part includes the structures located forward of the collision bulkhead, i.e.:

- the fore peak structures
- the stems.

In addition, it includes:

- the reinforcements of the flat bottom forward area
- the reinforcements of the bow flare area.

2.1.3 Central part

The central part includes the structures located between the collision bulkhead and the after peak bulkhead.

Where the flat bottom forward area or the bow flare area extend aft of the collision bulkhead, they are considered as belonging to the fore part.

2.1.4 Aft part

The aft part includes the structures located aft of the after peak bulkhead.

2.2 Rules applicable to various ship parts

2.2.1 The various Chapters and Sections of Part B are to be applied for the general arrangement and scantling of ship parts according to Tab 1.

Table 1 : Rule requirements of Part B applicable for the general arrangement and scantling of ship parts

Parts	Applicable Chapters and Sections	
	General	Specific
Fore part	Part B, Chapter 1 Part B, Chapter 2 Part B, Chapter 3 Part B, Chapter 4 Part B, Chapter 8 **(1)**, excluding: • Ch 8, Sec 1 • Ch 8, Sec 2 Part B, Chapter 10 Part B, Chapter 11	Ch 8, Sec 1
Central part		Part B, Chapter 5 Part B, Chapter 6 Part B, Chapter 7
Aft part		Ch 8, Sec 2
(1) See also [2.3].		

2.3 Rules applicable to other ship items

2.3.1 The various Chapters and Sections of Part B are to be applied for the general arrangement and scantling of other ship items according to Tab 2.

Table 2 : Rule requirements of Part B applicable for the general arrangement and scantling of other items

Items	Applicable Chapters and Sections
Machinery space	Ch 8, Sec 3
Superstructures and deckhouses	Ch 8, Sec 4
Bow doors and inner doors	Ch 8, Sec 5
Slide shell doors and stern doors	Ch 8, Sec 6
Hatch covers	Ch 8, Sec 8
Movable decks and inner ramps External ramps	Ch 8, Sec 9
Rudders	Ch 9, Sec 1
Hull outfitting and masts	Ch 9, Sec 2 Ch 9, Sec 3 Ch 9, Sec 4 Ch 9, Sec 5

3 Rounding off of scantlings

3.1

3.1.1 Plate thicknesses

The rounding off of plate thicknesses is to be obtained from the following procedure:

a) the net thickness (see Ch 4, Sec 2) is calculated in accordance with the rule requirements

b) corrosion addition t_C (see Ch 4, Sec 2) is added to the calculated net thickness, and this gross thickness is rounded off to the nearest half-millimetre

c) the rounded net thickness is taken equal to the rounded gross thickness, obtained in item b), minus the corrosion addition t_C.

3.1.2 Stiffener section moduli

Stiffener section moduli as calculated in accordance with the rule requirements are to be rounded off to the nearest standard value; however, no reduction may exceed 3%.

Section 2 Symbols and Definitions

1 Units

1.1

1.1.1 Unless otherwise specified, the units used in the Rules are those defined in Tab 1.

Table 1 : Units

Designation	Usual symbols	Units
Ship dimensions	See Article [2]	m
Hull girder section modulus	Z	m^3
Density	ρ	t/m^3
Concentrated loads	P	kN
Linearly distributed loads	q	kN/m
Surface distributed loads (pressures)	p	kN/m^2
Thickness	t	mm
Span of ordinary stiffeners and primary supporting members	ℓ	m
Spacing of ordinary stiffeners and primary supporting members	s	m
Bending moment	M	kN.m
Shear force	Q	kN
Stresses	σ, τ	N/mm^2
Section modulus of ordinary stiffeners and primary supporting members	w	cm^3
Sectional area of ordinary stiffeners and primary supporting members	A	cm^2

2 Definitions

2.1 Symbols

2.1.1

L : Rule length, in m, defined in [4.1]

L_1 : L, but to be taken not greater than 200 m

L_2 : L, but to be taken not greater than 120 m

B : Moulded breadth, in m, defined in [4.4]

B_{WS} : Breadth at full load waterline, in m, defined in [4.4]

D : Depth, in m, defined in [4.5]

T : Moulded draught, in m, defined in [4.6]

Δ : Moulded displacement, in tonnes, at draught, in sea water (density ρ = 1,025 t/m^3)

C_B : Total block coefficient:

$$C_B = \frac{\Delta}{1,025 L B_{WS} T}$$

3 Waterlines

3.1 Subdivision lines

3.1.1 Subdivision load line

Subdivision load line is a waterline used in determining the subdivision of the ship.

3.1.2 Deepest subdivision load line

Deepest subdivision load line is the waterline which corresponds to the greatest draught permitted by the subdivision requirements which are applicable.

3.2 Specific lines

3.2.1 Margin line

Margin line is an imaginary line drawn at side of the hull above which the presence of water is not allowable when the ship, after damage, is in condition of static equilibrium.

Such line divides the hull into two parts:

- the part below the margin line

  Such part when damaged may be floodable according to Ch 3, Sec 3.

- the part above the margin line

  Such part cannot be flooded according to Ch 3, Sec 3 because the buoyancy and stability requirements might result highly compromised (for example for progressive flooding).

Generally the margin line is positioned 76 mm (3") below the Watertight Deck (W.D.).

If, for the purpose of complying the damage stability requirements, some of the Main Transversal Watertight Bulkheads (M.T.W.B.) are extended to a higher deck, here called Bulkhead Deck (B.D.), by means of Auxiliary Transversal Watertight Bulkheads (A.T.W.B.), the margin line may be referred:

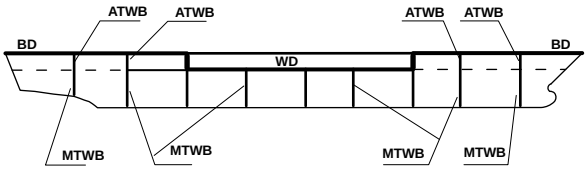
a) to the Bulkhead Deck (B.D.), where the Main Transversal Watertight Bulkheads (M.T.W.B.) are extended by Auxiliary Transversal Watertight Bulkheads (A.T.W.B.)

b) to the Watertight Deck (W.D.), in the other parts.

This represents really the upper limit of the floodable volumes supplied with watertight closure devices which stop the flooding of the undamaged neighbour volumes.

See Fig 1.

Figure 1 : Deck to which the margin line may be referred



3.2.2 Submersible areas

Some areas of the vessel on the Watertight Deck (W.D.) as mooring and quartering areas, in any case may result immersed provided that every access or openings to the buoyant compartments are watertight, so that progressive flooding will be avoided. The bounding bulkheads have to be considered as the hull.

To the purpose of considering an area submersible, the following requirements are to be complied:

- all the openings are to be closed before sailing by means of watertight closure such to face the hydrostatic head corresponding to the maximum draught. These openings are to be of reduced size, such as access hatches
- not to compromise, when immersed, the access to area essential for surviving.

In the submersible areas, the margin line is described as follows:

- in the fore part of the longitudinal extent of the submersible area of the ship, the margin line is limited to the aft main transverse watertight bulkhead bounding this submersible area
- in the aft part of the longitudinal extent of the submersible area of the ship, the margin line is limited to the fore main transverse watertight bulkhead bounding this submersible area.

3.2.3 "V" Lines

At each ship section, "V" Lines are the envelope of the damaged ship waterlines at final flooding stage and during intermediate stages of flooding (see Ch 3, App 4).

4 Dimensions

4.1 Rule length

4.1.1 The rule length L, see Fig 2, is the distance, in m, measured on the full load waterline between the aft end (AE) and the fore end (FE), as defined in [4.2].

4.1.2 In ships with unusual stem or stern arrangements, the rule length L is considered on a case-by-case basis.

Figure 2 : Rule length



4.2 Ends of rule length L and midship

4.2.1 Aft end

The aft end (AE) of the rule length L is the perpendicular to the deepest full load waterline at the lowest corner between the transom and the bottom plating.

4.2.2 Fore end

The fore end (FE) of the rule length L, is the perpendicular to the full load waterline at the forward side of the stem.

4.2.3 Midship

The midship is the perpendicular to the deepest full load waterline at the distance 0,5L aft of the fore end FE.

4.3 Length between perpendiculars

4.3.1 The length between perpendiculars L_{bp} is the length, in metres, at the waterline corresponding to the full load as defined in Tab 2.

4.4 Moulded breadths

4.4.1 The moulded breadth B is the greatest moulded breadth, in m, measured amidships below the uppermost continuous deck, excluding sponsons.

4.4.2 The breadth B_{WS} is the moulded breadth, in m, measured amidships at the full load waterline "end of life".

4.5 Moulded depth

4.5.1 The moulded depth D is the distance, in m, measured vertically on the midship transverse section, from the moulded base line to the top of the deck at side on the uppermost continuous deck.

In the case of a ship with a solid bar keel, the moulded base line is to be taken at the intersection between the upper face of the bottom plating and the solid bar keel at the middle of length L.

4.6 Moulded draught

4.6.1 The moulded draught T is the distance, in m, measured vertically on the midship transverse section, from the moulded base line to the full load waterline "end of life".

4.6.2 In the case of ships with a solid bar keel, the moulded base line is to be taken as defined in [4.5.1].

5 Ship weights

5.1 Lightship

5.1.1 The lightship is a ship complete in all respects, but without consumables, stores, and crew and effects, and without any liquids on board except for machinery and piping fluids, such as lubricant and hydraulic, which are at operating levels.

Considering the evolution of mass as described in Ch 3, Sec 2, [2.1.4], a lightship condition "at delivery" and a lightship condition "end of life" are to be considered for the assessment of the stability and strength effects.

5.2 Full load

5.2.1 The full load condition corresponds to the ship loaded departure as defined in Tab 2.

Considering the evolution of mass as described in Ch 3, Sec 2, [2.1.4], a full load condition "at delivery" and a full load condition "end of life" are to be considered for the assessment of the stability and strength effects.

Table 2 : Definition of loading cases (% of mass or specified maximum loads)

Components	Full load condition	Operational load condition	Minimum operational condition	Comments
Lightship	100%	100%	100%	See [5.1.1]
Crew with luggage	100%	100%	100%	
External personnel with equipment	100%	100%	100%	Personnel not belonging to the crew
Ship logistic material	100%	100%	100%	On board documents, equipment for repairs
Foods	100%	66,6%	33,3%	Otherwise specified uniformly distributed in storage spaces
Ammunition	100%	66,6%	33,3%	In storage spaces above the ship centre of gravity
Helicopters with their logistic	100%	100%	100%	At location as specified
Fuels (propulsion, auxiliaries, helicopters,...)	100%	66,6%	33,3%	Otherwise specified uniformly distributed in storage spaces The filling of the overflow fuel oil tanks is to be limited to 75% of the net volume of these tanks
		100%	100%	For capacity provided with an automatic continuous compensation system
Lubricant storage	100%	66,6%	33,3%	Otherwise specified uniformly distributed in storage spaces
Other consumable materials	100%	66,6%	33,3%	Otherwise specified uniformly distributed in storage spaces
Drinking water	100%	66,6%	66,6%	When produced on board
Drinking water	100%	66,6%	33,3%	When not produced on board
Industrial waters	100%	66,6%	66,6%	
Grey and black waters	0%	33,3%	33,3%	
Ballast waters	0%	0%	0%	For the minimum operation condition, ballast necessary to comply with the stability criteria may be accepted, subject that the total displacement including the ballast tanks does not exceed the displacement corresponding to the operational condition
Stabilizing tanks	op. level	op. level	op. level	At the operational level
Non consumables and pumping residues	100%	100%	100%	Corresponding to 2% of the net volume of the capacities; if a value lower than 2% is used, this value is to be justified
Miscellaneous	100%	100%	100%	Mobile liquid or solid ballast

5.3 Operational load

5.3.1 The operational load condition is defined in Tab 2.

Considering the evolution of mass as described in Ch 3, Sec 2, [2.1.4], an operational load condition “at delivery” and an operational load condition “end of life” are to be considered for the assessment of the stability and strength effects.

5.4 Minimum operational load

5.4.1 The minimum operational load is defined in Tab 2.

5.5 Deadweight

5.5.1 The deadweight is the difference, in t, between the displacement, at the full load draught in sea water of density $\rho = 1,025$ t/m^3, and the lightship.

6 Decks and bulkheads

6.1 General

6.1.1 From the point of view of subdivision and stability of surface vessels, two kinds of tightness are to be defined:

- watertight
- weathertight.

6.1.2 Watertight

The watertight elements assure the tightness even with a constant hydrostatic head.

6.1.3 Weathertight

The weathertight elements assure the tightness under the action of weather agents, hose or temporary phase during rolling periods.

6.2 Bulkhead deck (B.D.)

6.2.1 The bulkhead deck is the highest deck to which auxiliary watertight transversal bulkheads are raised. The watertight boundaries after damage are limited to the bulkhead deck.

6.3 Exposed decks - Upper decks (E.D.)

6.3.1 Above the volume limited by the bulkhead deck, weathertight volumes under exposed decks or part of them may exist.

The sum of such volumes plus those defined in [6.2] (compressive volume watertight and weathertight) constitute the intact stability reserve.

The enclosed superstructures as defined in [8.2.1] may be considered as intact stability reserve.

6.4 Watertight deck (W.D.)

6.4.1 The watertight deck is the first continuous watertight deck above the waterline, up to which the main transversal watertight bulkheads (M.T.W.B.) are to be extended.

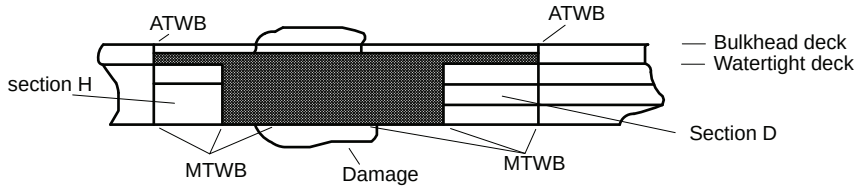
The watertight deck acts a vertical limit (see Fig 3, function 2) for flooding of the ship caused by damage to the sideshell below the waterline and thus prevents progressive flooding of undamaged compartments in a transverse direction (see Fig 3, function 3). Similarly it prevents progressive flooding in a longitudinal direction (see Fig 3, function 1) when the sideshell breach involves the entire height of the ship and when not all M.T.W.B. are extended up to the bulkhead deck.

The watertight deck is the deck below which all openings in the sideshell and all passages crossing main transversal bulkheads are forbidden or otherwise guided according to the requirements of Ch 2, Sec 1, Tab 2 “Requirements for openings and crossing in several water (weather)tight elements”.

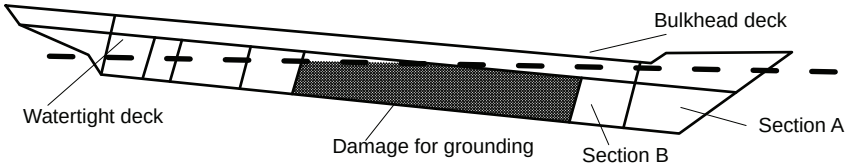
The watertightness of elements crossing the watertight deck is to be ensured and openings in this deck are to be supplied with devices which make them watertight.

As a rule, the watertight deck generally serves as the “damage control deck”.

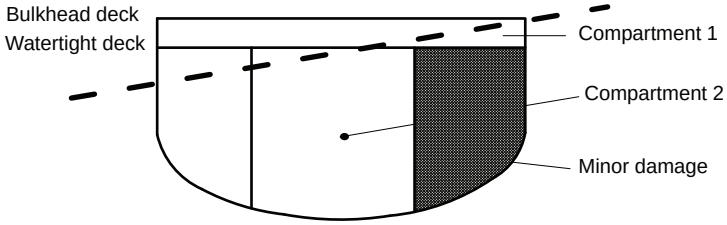
Figure 3 : Functions of the watertight deck (W.D.)



Function 1 : the damage is conventional, the watertight deck avoids the flooding of the sections H and D below this deck



Function 2 : the damage has longitudinal extension longer than the conventional damage, but a limited height, the watertight deck avoids the progressive flooding of the sections A and B



Function 3 : the damage is extended less than the conventional damage, the watertight deck avoids the flooding of the compartments 1 and 2, so limiting the major effects of the damage

6.5 Damage control deck

6.5.1 The damage control deck is a deck above the waterline after damage that permits access along the length of the vessel, for the purpose of efficiently coordinating and conducting damage control. It is, in general, continuous and is typically the lowest deck upon which movement from forward to aft and vice versa is possible, via watertight openings in the transversal watertight bulkheads.

The damage control deck is to be positioned above point A shown in Ch 3, App 4, Fig 2, at each transverse watertight bulkhead. Where this is not possible, it is to be shown that alternate arrangements are able to permit the safe and effective conduct of damage control activities, including control of progressive flooding, to the satisfaction of the Society.

The deck structure constituting the damage control deck, along with all elements crossing this deck are to be watertight. Openings in the damage control deck are to be supplied with devices which make them watertight

6.6 Main transversal watertight bulkhead (M.T.W.B.)

6.6.1 The adequate subdivision of the internal volume by main transversal watertight bulkheads is essential to achieve an adequate buoyancy and stability in case of damage.

The main transversal watertight bulkheads extend up to the watertight deck from side to side.

Their essential task is to limit compartments and therefore to avoid the progressive flooding from a damaged to an intact compartment.

6.7 Main watertight compartment

6.7.1 A main watertight compartment is a volume bounded by two main transversal watertight bulkheads up to the watertight deck and by two auxiliary transversal watertight bulkheads between the watertight deck and the bulkhead deck and topped by the watertight deck (W.D.).

It has to be distinguished from the safety zone of fire protection.

The minimum distance between M.T.W.B., therefore the minimum length of a compartment, is provided by the formulae:

- 3 m + 3% L_{bp} , for ships of length between perpendiculars less than 250 m
- 10,5 m for ships of length between perpendiculars not less than 250 m.

6.8 Auxiliary transversal watertight bulkheads (A.T.W.B.)

6.8.1 The auxiliary transversal watertight bulkheads (A.T.W.B.) are the extension of main transversal watertight bulkheads (M.T.W.B.) above the watertight deck (W.D.) up to the bulkhead deck (B.D.).

They give the possibility to limit the longitudinal extension of flooding above the watertight deck (W.D.) and to add a further reserve of buoyancy/stability consequent to the volume bounded by such bulkheads, watertight deck and bulkhead deck.

7 Spaces definition

7.1 Machinery space

7.1.1 Machinery space is to be taken as extending from the moulded base line to the margin line and between the extreme main transverse watertight bulkheads, bounding the spaces containing the main and auxiliary propulsion machinery, boilers serving the needs of propulsion.

7.2 Ro-ro cargo spaces

7.2.1 Ro-ro cargo spaces are spaces not normally subdivided in any way and extending to either a substantial length or the entire length of the ship in which goods (packaged or in bulk, or in land vehicles, or in barges or crafts) can be loaded and unloaded normally in a horizontal direction.

7.3 Passenger spaces

7.3.1 Passengers

Passengers means every person other than:

- the captain and the members of the crew or other persons employed or engaged in any capacity on board a ship on the business of that ship, and
- a child under one year of age.

7.3.2 Passenger spaces

Passenger spaces are those spaces which are provided for the accommodation and use of passengers, excluding baggage, store, provisions and mail rooms.

In all cases volumes and areas are to be calculated to moulded lines.

7.4 Special personnel

7.4.1 Special personnel means all persons who are not passengers or members of the crew or children of under one year of age and who are carried on board in connection with the special purpose of that ship because of special work being carried out aboard that ship.

7.5 Special category spaces

7.5.1 Special category spaces are those enclosed spaces above or below the bulkhead deck intended for the carriage of motor vehicles, or barges or crafts, or helicopters with fuel in their tanks for their own propulsion, into and from which such vehicles can be driven and to which passengers have access.

7.6 Military special category spaces

7.6.1 Military special category spaces are special category spaces intended for the carriage of motor vehicles, or barges, crafts or helicopters with ammunition.

8 Superstructures

8.1 General

8.1.1 A superstructure is a decked structure, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 0,04 B.

8.2 Enclosed and open superstructures

8.2.1 A superstructure may be:

- enclosed, where:
  - it is enclosed by front, side and aft bulkheads complying with the requirements of Ch 8, Sec 4
  - all front, side and aft openings are fitted with efficient weathertight means of closure
- open, where it is not enclosed.

8.3 Raised quarterdeck

8.3.1 A raised quarterdeck is a partial superstructure of reduced height.

8.4 Deckhouse

8.4.1 A deckhouse is a decked structure other than a superstructure, located on the main deck or above.

8.5 Trunk

8.5.1 A trunk is a decked structure similar to a deckhouse, but not provided with a lower deck.

9 Deck positions

9.1 Definitions

9.1.1 Position 1

Position 1 includes:

- exposed main deck and raised quarter decks
- exposed superstructure decks situated forward of 0,25 L from the fore end FE.

9.1.2 Position 2

Position 2 includes exposed superstructure decks situated aft of 0,25 L from the fore end FE.

10 Reference co-ordinate system

10.1

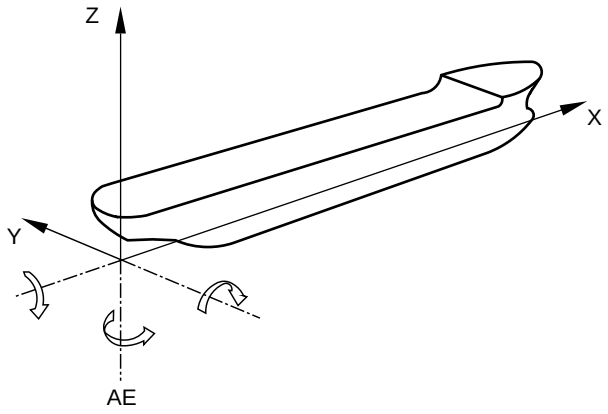
10.1.1 The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand co-ordinate system (see Fig 4):

- Origin: the intersection between the longitudinal plane of symmetry of ship, the aft end of L and the baseline
- X axis: the longitudinal axis, positive forwards
- Y axis: the transverse axis, positive towards portside
- Z axis: the vertical axis, positive upwards.

10.1.2 Positive rotations are oriented in anti-clockwise direction about the X, Y and Z axes.

10.1.3 A different co-ordinate system may be used subject that the description of the co-ordinate system is clearly indicated in the trim and stability booklet and the same co-ordinate system is used throughout the booklet.

Figure 4 : Reference co-ordinate system



Section 3 Documentation to be Submitted

1 Documentation to be submitted for all ships

1.1 Ships built under the Society supervision

1.1.1 Plans and documents to be submitted for approval

The plans and documents to be submitted to the Society for approval are listed in Tab 1.

The above plans and documents are to be supplemented by further documentation which depends on the service notation and, possibly, the additional class notation (see Pt A, Ch 1, Sec 2) assigned to the ship, as specified in Article [2].

Structural plans are to show details of connections of the various parts and, in general, are to specify the materials used, including their manufacturing processes, welded procedures and heat treatments. See also Ch 11, Sec 1, [1.4].

1.1.2 Plans and documents to be submitted for information

In addition to those in [1.1.1], the following plans and documents are to be submitted to the Society for information:

- general arrangement
- capacity plan, indicating the volume and position of the centre of gravity of all compartments and tanks, if this information is not already included in the general arrangement plan
- lines plan
- hydrostatic curves
- lightweight distribution
- design load plan, indicating all applicable design loads according to Ch 5, Sec 6.

In addition, when direct calculation analyses are carried out by the Designer according to the rule requirements, they are to be submitted to the Society.

Table 1 : Plans and documents to be submitted for approval for all ships

Plan or document	Containing also information on
Watertight subdivision decks Watertight subdivision bulkheads Watertight tunnels	Openings and their closing appliances, if any
Plan of watertight doors and scheme of relevant manoeuvring devices	Manoeuvring devices Electrical diagrams of power control and position indication circuits
Loading manual	See Ch 10, Sec 2, [3]
Calculations relevant to intact stability and damage stability	See Ch 3, Sec 3
Stability documentation	See Ch 3, Sec 1, [3.1]
Midship section Transverse sections Shell expansion Decks and profiles Double bottom Pillar arrangements Framing plan Deep tank and ballast tank bulkheads, wash bulkheads	Class characteristics Main dimensions Draught at minimum operational condition (at delivery) and associated displacement Draught at full load condition (end of life) and associated displacement Frame spacing Maximum ahead service speed Density of cargoes Design loads on decks and double bottom Steel grades Location and height of air vent outlets of various compartments Corrosion protection Openings in decks and shell and relevant compensations Boundaries of flat areas in bottom and sides Details of structural reinforcements and/or discontinuities Bilge keel with details of connections to hull structures
(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted. For azimuth propulsion systems, see Ch 9, Sec 1, [11].	

Plan or document	Containing also information on
Fore part structure	Location and height of air vent outlets of various compartments
Machinery space structures Foundations of propulsion machinery and boilers	Type, power and r.p.m. of propulsion machinery Mass and centre of gravity of machinery and boilers
Aft part structure	Location and height of air vent outlets of various compartments
Sternframe or sternpost, sterntube Propeller shaft boss and brackets **(1)**	
Rudder and rudder horn **(1)**	Maximum ahead service speed
Transverse thruster, if any, general arrangement, tunnel structure, connections of thruster with tunnel and hull structures	
Superstructures and deckhouses Machinery space casing	Extension and mechanical properties of the aluminium alloy used (where applicable)
Helicopter landing decks	General arrangement Main structure Characteristics of helicopters: maximum mass, distance between axles of wheels or skids, print area of wheels or skids, rotor diameter
Plan of ventilation	Use of spaces
Scuppers and sanitary discharges	
Bulwarks and freeing ports	Arrangement and dimensions of bulwarks and freeing ports on the watertight deck and decks above the watertight deck
Hawse pipes	
Windows and side scuttles, arrangements and details	
Sea chests, stabilizer recesses, etc.	
Plan of manholes	
Plan of access to and escape from spaces	
Plan of outer doors and hatchways	
Bow doors, stern doors and inner doors, if any, side doors and other openings in the side shell	Closing appliances Electrical diagrams of power control and position indication circuits for bow doors, stern doors, side doors, inner doors, television system and alarm systems for ingress of water
Movable decks and ramps, if any	
Hatch covers, if any	Design loads on hatch covers Sealing and securing arrangements, type and position of locking bolts Distance of hatch covers from the full load waterline and from the fore end
Derricks and lifting appliances	Design loads (forces and moments) including weapon loads Connections to the hull structures
Plan of tank testing	Testing procedures for the various compartments Height of pipes for testing
Equipment number calculation	Geometrical elements for calculation List of equipment Construction and breaking load of steel wires Material, construction, breaking load and relevant elongation of synthetic ropes
Emergency towing arrangement	See Pt E, Ch 10, Sec 2

(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted. For azimuth propulsion systems, see Ch 9, Sec 1, [11].

2 Further documentation to be submitted for ships with certain additional class notations

2.1 General

2.1.1 Depending on the additional class notation (see Pt A, Ch 1, Sec 2) assigned to the ship, other plans or documents may be required to be submitted to the Society, in addition to those in [1.1]. They are listed in [2.2] for the additional class notations which require this additional documentation.

2.2 Additional class notations

2.2.1 The plans or documents to be submitted to the Society are listed in Tab 2.

Table 2 : Plans and documents to be submitted depending on additional class notations

Additional class notation	Plans and documents
SEA-KEEP	see Pt E, Ch 9, Sec 3
MON-HULL	see Pt E, Ch 5, Sec 1, [1.2]

CHAPTER 2
GENERAL ARRANGEMENT DESIGN

Section 1 Subdivision Arrangement

Section 2 Compartment Arrangement

Section 3 Access and Openings Arrangement

Section 1 Subdivision Arrangement

1 General

1.1 Definitions

1.1.1 Ship dimensions

The ship dimensions are defined in Ch 1, Sec 2, [6].

1.1.2 Watertight decks and bulkheads

The definitions of the watertight decks and bulkheads are given in Ch 1, Sec 2.

1.1.3 V-lines

V-lines are oblique lines as defined in Ch 3, App 4 corresponding to possible water level limits in a ship transversal section after damage.

2 Number and arrangement of transverse watertight bulkheads

2.1 Number of main watertight bulkheads

2.1.1 General

All ships, in addition to complying with the requirements of [2.1.2], are to have at least the following main transverse watertight bulkheads:

- one collision bulkhead
- one aft bulkhead
- two bulkheads forming the boundaries of the machinery space in ships with machinery amidships, and a bulkhead forward of the machinery space in ships with machinery aft. In the case of ships with an electrical propulsion plant, both the generator room and the engine room are to be enclosed by watertight bulkheads.

2.1.2 Additional bulkheads

As a guidance, the minimum number of main transverse watertight bulkheads versus ship lengths can be estimated from Tab 1.

Irrespective of Tab 1, the number and spacing of main transverse watertight bulkheads are to be such as to comply with stability criteria (see Ch 3, Sec 3).

Table 1 : Minimum number of bulkheads

Length, in m	Total number of bulkheads	
	Machinery amidships	Machinery aft **(1)**
L < 65	4	3
65 ≤ L < 85	4	4
85 ≤ L < 90	5	5
90 ≤ L < 105	5	5
105 ≤ L < 115	6	5
115 ≤ L < 125	6	6
125 ≤ L < 145	7	6
145 ≤ L < 165	8	7
165 ≤ L < 190	9	8
L ≥ 190	to be considered individually	
(1) With aft bulkhead forming after boundary of machinery space.		

2.2 Number of auxiliary watertight bulkheads

2.2.1 Criteria

The number of auxiliary watertight bulkheads is defined with respect to the operational constraints and to fulfill the damage stability criteria (see Ch 3, Sec 3).

2.3 Bulkhead arrangement

2.3.1 Bulkhead effectiveness

To be effective, the distance between two adjacent main watertight bulkheads cannot be lower than 3,0 m plus 3% of the length L_{bp} of the ship or 10,5 m, whichever is the lesser.

2.3.2 Stepped bulkheads

Where it is not practicable to arrange a watertight bulkhead in one plane, a stepped bulkhead may be fitted provided that [2.3.1] is fulfilled. In this case, the part of the deck which forms the step is to be watertight and equivalent in strength to the bulkhead.

3 Collision bulkhead

3.1 Arrangement of collision bulkhead

3.1.1 A fore peak or collision bulkhead is to be fitted which is to be watertight up to the watertight deck. This bulkhead is to be located at a distance, in m, from the forward perpendicular of not less than 5% of the length L of the ship and not more than 3,0 m plus 5% of the length L of the ship.

3.1.2 Where any part of the ship below the waterline extends forward of the fore perpendicular, e.g. a bulbous bow, the distances, in metres, stipulated in [3.1.1] are to be measured from a point either:

- at mid length of such an extension, or
- at a distance 1,5% of the length L of the ship forward of the fore perpendicular, or
- at a distance 3,0 m forward of the fore perpendicular; whichever gives the smallest measurement.

3.1.3 The bulkhead may have steps or recesses provided they are within the limits prescribed in [3.1.1] or [3.1.2].

No door, manhole, ventilation duct or any other opening is to be fitted in this bulkhead.

3.1.4 The Society may, on a case by case basis, accept a distance from the collision bulkhead to the fore perpendicular greater than the maximum specified in [3.1.1] and [3.1.2], provided that subdivision and stability calculations show that, when the ship is in upright condition on full load, flooding of the space forward of the collision bulkhead will not result in any part of the bulkhead deck becoming submerged, or in any unacceptable loss of stability.

4 After peak, machinery space bulkheads and stern tubes

4.1 General

4.1.1 An after peak bulkhead, and bulkheads dividing the machinery space from the cargo and personnel spaces forward and aft, are also to be fitted and made watertight up to the watertight deck. The after peak bulkhead may be stepped, provided the degree of safety of the ship as regards subdivision is not thereby diminished.

5 Openings and crossings in watertight bulkheads and decks

5.1 Definitions

5.1.1 Openings mean a passage of large size, through which the passage and the movement of personnel or material through bulkheads, decks and hull are possible as well as the crossings of air ducts, of engine discharges and intakes.

Crossings are intended to be passages of small size for cables or pipes.

Note 1: The passages for shafting are considered as crossings.

5.2 Regulations

5.2.1 Openings and crossings in various elements are allowed according to Tab 2, provided they are watertight or weathertight as necessary to comply with intact and damage stability criteria. Additional requirements are also provided in Part C.

Openings and crossings in transverse watertight bulkheads inside the V-line (as defined in Ch 3, App 4) may be not watertight apart from particular prescriptions. The number of openings in a watertight deck (W.D.) are to be the minimum compatible with the internal arrangements and general plans. Such openings are to be supplied with devices which make them watertight.

Vertical crossings of pipes, air ducts or electrical cables in the watertight deck (W.D.) are to be supplied with a structural watertight device.

5.2.2 Bolted openings in more watertight bulkheads below the watertight deck may be accepted if mentioned in the technical specifications and on a case by case basis, provided that they are:

- necessary for maintenance purposes
- permanently closed at sea
- designed and constructed, to the satisfaction of the Society, so as to maintain the fire, smoke and watertight integrity of the bulkhead as well as their structural strength to shock.

Table 2 : Allowed openings and crossings in several water(weather)tight elements

Interested element	Hatches and bolted closures	Doors, panels, hatches	Portlights	Trunks and ventilation inlets	Engine inlets and discharges**(1)**	Cable crossings	Pipe crossings
Decks							
Bulkhead deck **(4)**	yes	yes	no	yes	yes	yes	yes
Watertight deck **(4)**	yes	yes	no	yes	yes **(2)**	yes	yes
Exposed decks	yes	yes	yes	yes	yes	yes	yes
Bulkhead							
M.T.W.B.	no **(6)**	no **(5)**	no	no	no	yes	yes
A.T.W.B. (between W.D. & M.D.)	yes	yes	no	yes	no	yes	yes
Shell							
Below W.D.	no	no **(7)**	no	no	no	no **(3)**	yes
Between B.D. & W.D.	yes	yes	yes	yes	no	yes	yes
Between B.D. & E.D.	yes	yes	yes	yes	yes	yes	yes
Other elements							
Tanks	yes	no	no	no	no	yes	yes
Double bottoms	yes	no	no	no	no	yes	yes
Watertight elements below W.D.	yes	yes	no	yes	no	yes	yes
Cofferdams	yes	no	no	no	no	yes	yes

(1) Submerged discharges are considered as pipe crossings.

(2) Provided that the watertightness of ducts between W.D. and B.D. is assured.

(3) Except for particular applications (sonar, hull sensors, ecosounders...).

(4) In case all the main transversal watertight bulkheads are extended above the watertight deck (W.D.) up to the bulkhead deck (B.D.) by an auxiliary watertight bulkhead, the tightness integrity of the first deck is to be applied to the second.

(5) With the exception of the watertight door in the bulkhead bounding the steering gear local, which is to be approved in the contract.

(6) Subject to [5.2.2].

(7) With the exception of a limited number of doors which can be accepted; such doors have to be enclosed with watertight boundaries (bulkhead and access doors) inside the ship, so that this watertight envelop provides sufficient tightness to avoid any progressive flooding.

6 Doors

6.1 General

6.1.1 Doors are not allowed in main transverse watertight bulkheads below the watertight deck (see Tab 2).

6.1.2 Doors located in auxiliary transverse watertight bulkheads between the watertight deck and the bulkhead deck are to be watertight and fitted with a notice to show if the door is normally open, normally closed or permanently closed.

6.1.3 Doors which may be immersed by the “V-lines” damage waterline as described in Ch 3, App 4 are to be normally closed at sea, i.e. kept closed, used if authorized by the notice affixed on the door, and closed again after use.

6.1.4 Watertight doors located between the watertight deck and the bulkhead deck are to be strengthened such as to resist to the static head equivalent to a water height equal to the distance between the watertight deck and the bulkhead deck.

When detailed information on the head of water after damage is available and justified, such information can be considered for the strengthening of the doors.

Section 2 Compartment Arrangement

1 Flooding management

1.1 Protection

1.1.1 The requirements for openings in watertight bulkheads and decks are given in Ch 2, Sec 1, [5] and Ch 2, Sec 3, [1.1.2].

1.1.2 All cables and piping penetrations located within the watertight boundaries of flooded compartments and below the V-line damage waterline have to be watertight when closed to the maximum waterhead.

1.2 Detection

1.2.1 For detection system applicable for **AUT-QAS** notation, see Pt E, Ch 4, Sec 1.

1.3 Pumping

1.3.1 Floodable dry spaces have to be provided with a fixed water pumping installation or access for movable pumps from above the damage control deck as defined in Ch 1, Sec 2, [6.5].

1.3.2 The pumping capacity is to be at least as required in Pt C, Ch 1, Sec 10, [6.6.3].

2 Cofferdams

2.1 Definition

2.1.1 A cofferdam means an empty space arranged so that compartments on each side have no common boundary; a cofferdam may be located vertically or horizontally. As a rule, a cofferdam is to be of sufficient size to allow inspection.

2.2 Cofferdam arrangement

2.2.1 Cofferdams are to be provided between the compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and those intended for fresh water (drinking water, water for propelling machinery and boilers) as well as between ammunition stores and tanks intended for the carriage of liquid hydrocarbons.

2.2.2 Cofferdams are only required between fuel oil double bottoms and tanks immediately above where the inner bottom plating is subjected to the head of fuel oil contained therein, as in the case of a double bottom with its top raised at the sides.

Where a corner to corner situation occurs, tanks are not considered to be adjacent.

Adjacent tanks not separated by cofferdams are to have adequate dimensions to ensure easy inspection.

2.2.3 A cofferdam is to be provided to separate tanks containing low flashpoint fuels as specified in Pt C, Ch 4, Sec 11 or carried as cargo, from any of the following spaces:

- tanks containing other liquid hydrocarbons.
- tanks for drinking water and stores containing provisions intended for human consumption
- category A machinery spaces
- ammunition stores
- accommodation spaces.

Cofferdams of this type may be used as spaces for the installation of pumps for low flashpoint fuels.

Note 1: Machinery spaces of category A are defined in Pt C, Ch 4, Sec 1, [2.24].

3 Ballast compartments

3.1 General

3.1.1 Water ballast may not be carried in tanks intended for fuel oil.

4 Double bottoms

4.1 Auxiliary ships

4.1.1 A double bottom is to be fitted extending from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

4.2 Frontline ships

4.2.1 A double bottom is to be required as far as practicable within the machinery spaces.

5 Compartments forward of the collision bulkhead

5.1 General

5.1.1 The fore peak and other compartments located forward of the collision bulkhead may not be arranged for the carriage of fuel oil.

6 Machinery compartments

6.1 General

6.1.1 When longitudinal bulkheads are fitted in machinery spaces, adequate self-operating arrangements are to be provided in order to avoid excessive heel after damage.

Where such arrangements constitute a cross-flooding system, their area is to be calculated in accordance with the requirements in Ch 3, App 3. In addition, such systems are to comply with the criteria in Ch 3, Sec 3.

6.2 Two machinery compartments

6.2.1 When the ship is fitted with two machinery compartments, the requirements in Ch 2, Sec 1, [4.1.1] are to be applied.

7 Shaft tunnels

7.1 General

7.1.1 Shaft tunnels are to be watertight to possible internal flooding.

8 Watertight ventilators and trunks

8.1 General

8.1.1 Watertight ventilators and trunks are to be carried at least up to the V-line damage waterline as described in Ch 3, App 4.

9 Fuel oil tanks

9.1 General

9.1.1 The arrangements for the storage, distribution and utilization of the fuel oil are to be such as to ensure the safety of the ship and persons on board.

9.1.2 The requirements of Pt C, Ch 1, Sec 10, [11.5.1] have also to be taken into account.

10 Ammunition storage compartments

10.1 General

10.1.1 Particular care is to be taken for the arrangement of ammunition storage compartments to prevent risk of explosion or ship loss in case of explosion.

11 Tanks containing chemical treatment fluids for exhaust gas pollution prevention system

11.1 Tank protection and segregation

11.1.1 Tanks containing chemical treatment fluids for exhaust gas pollution prevention system are to comply with requirements of Pt C, Ch 1, Sec 11, [3.2] for tank containing urea.

Section 3 Access and Openings Arrangement

1 General

1.1 Number and size of access and openings

1.1.1 The number and size of manholes for trimming and access openings to tanks or other enclosed spaces are to be kept to the minimum consistent with the satisfactory operation of the ship.

1.1.2 Opening tightness

All openings located within the watertight boundaries used for the damage stability calculations, giving access to a flooded compartment and outside the V line (as defined in Ch 3, App 4), are to be watertight when closed to the maximum waterhead.

2 Double bottom

2.1 Inner bottom manholes

2.1.1 Inner bottom manholes are to be not less than 400 mm x 400 mm or 500 mm x 380 mm clear light. Their number and location are to be so arranged as to provide convenient access to any part of the double bottom.

2.1.2 Inner bottom manholes are to be closed by watertight plate covers.

Doubling plates are to be fitted on the covers, where secured by bolts.

Where no ceiling is fitted, covers are to be adequately protected from damage by the cargo.

2.2 Floor and girder manholes

2.2.1 Manholes are to be provided in floors and girders so as to provide convenient access to all parts of the double bottom.

2.2.2 The size of manholes and lightening holes in floors and girders is, in general, to be less than 50 per cent of the local height of the double bottom.

Where manholes of greater sizes are needed, edge reinforcement by means of flat bar rings or other suitable stiffeners may be required.

2.2.3 Manholes may not be cut into the continuous centreline girder or floors and girders below pillars, except where allowed by the Society on a case by case basis.

3 Tanks, water ballast tanks and cofferdams

3.1 General

3.1.1 Tanks, water ballast tanks and cofferdams are to be served by at least one manhole and one ladder.

3.1.2 External openings required to be watertight are to be of sufficient strength and, except for hatch covers, are to be fitted with indicator in the safety control room.

3.2 Access through decks

3.2.1 Opening protection

If an access is to remain open for operational efficiency, it is to be fitted with a light panel, or equivalent device, to prevent falls of a person when the hatchway remains open.

3.3 Access within tanks

3.3.1 Manholes

Where manholes are fitted, as indicated in [2.2.2], access is to be facilitated, as far as practicable, by means of steps and hand grips with platform landings on each side.

3.4 Construction of ladders

3.4.1 General

In general, the ladders are to be vertical. The flights of ladders are not to be more than 9 m in actual length. Resting platforms of adequate dimensions are to be provided.

3.4.2 Construction

Ladders and handrails are to be constructed of steel of adequate strength and stiffness and securely attached to the tank structure by stays. The method of support and length of stay are to be such that vibration is reduced to a practical minimum.

External ladders and handrails in composites are acceptable, except if they are used to access the life saving appliances.

Side stringers are to be flat bars of not less than 60 mm by 6 mm in section, or equivalent.

3.4.3 Width of ladders

The width of ladders between stringers is not to be less than 400 mm.

3.4.4 Treads

The treads are to be equally spaced at a distance apart measured vertically not exceeding 300 mm. They are to be formed of two square steel bars of not less than 16 mm by 16 mm in section fitted to form an horizontal step with the edges pointing upward, or of equivalent construction. The treads are to be welded to the side stringers.

3.4.5 Sloping ladders

All sloping ladders are to be provided with handrails of substantial construction on both sides fitted at a convenient distance above the treads.

4 Air pipes

4.1 General

4.1.1 Internal open end of air pipes

The open end of air pipes terminating within a superstructure is to be fitted inside the V line (as defined in Ch 3, App 4) or above the V-line damage waterline when located outside the V line.

CHAPTER 3
STABILITY

Section 1 General

Section 2 Intact Stability

Section 3 Damage Stability

Section 4 Sea-Keeping

Appendix 1 Inclining Test and Lightweight Check

Appendix 2 Trim and Stability Booklet

Appendix 3 Calculation Method for Cross-Flooding Arrangements

Appendix 4 Buoyancy Reserve - “V” Line Method

Appendix 5 Evaluation of the Heeling Moment due to Athwart Wind (Intact Vessel)

Appendix 6 Sea-Keeping Calculations

Section 1 General

1 Definitions

1.1

1.1.1 General

Except otherwise specified, the definition of the parameters and ship components mentioned in this Chapter are given in Ch 1, Sec 2.

2 General

2.1 Application

2.1.1 All ships may be assigned class only after it has been demonstrated that their intact and damage stability is adequate for the service intended.

Except otherwise specified, adequate intact and damage stability means compliance with the requirements specified in this Chapter taking into account the ship's size and type. In any case, the level of intact and damage stability is not to be less than that provided by the rules of Ch 3, Sec 2 and Ch 3, Sec 3.

Additional requirements maybe indicated in the relevant chapters of Part E corresponding to the intended service notation.

2.1.2 Approval of the Naval Authority

Evidence of approval by the Naval Authority concerned may be accepted for the purpose of classification.

3 Examination procedure

3.1 Documents to be submitted

3.1.1 List of documents

For the purpose of the examination of the stability, the documentation listed in Ch 1, Sec 3, [1.1.2] is to be submitted for information.

The stability documentation to be submitted for approval, as indicated in Ch 1, Sec 3, is as follows:

- Inclining lightship test report for the ship, as required in [3.2] or:
  - where the stability data is based on a sister ship, the inclining test report of that sister ship along with the lightship measurement report for the ship in question, or
  - where lightship particulars are determined by methods other than inclining of the ship or its sister, the lightship measurement report of the ship along with a summary of the method used to determine those particulars
- trim and stability booklet, as required in Ch 3, App 2
- damage stability calculations, as required in Ch 3, Sec 3, [1.1.1]
- damage control documentation, as required in Ch 3, Sec 3, [1.2].

A copy of the trim and stability booklet, the damage control documentation and the loading computer documentation is to be available on board for the attention of the Captain.

3.1.2 Provisional documentation

The Society reserves the right to accept or demand the submission of provisional stability documentation for examination.

Provisional stability documentation includes loading conditions based on estimated lightship values.

3.1.3 Final documentation

Final stability documentation based on the results of the inclining test or the lightweight check is to be submitted for examination.

3.2 Inclining test - Lightweight check

3.2.1 Definitions

a) Lightweight

The lightship weight definition is given in Ch 1, Sec 2, [5.1].

b) Inclining test

The inclining test is a procedure which involves moving a series of known weights, normally in the transverse direction, and then measuring the resulting change in the equilibrium heel angle of the ship. By using this information and applying basic naval architecture principles, the ship's vertical centre of gravity (VCG or KG) is determined.

c) Lightweight check

The lightweight check is a procedure which involves auditing all items which are to be added, deducted or relocated on the ship at the time of the inclining test so that the observed condition of the ship can be adjusted to the lightship condition. The weight and longitudinal, transverse and vertical location of each item are to be accurately determined and recorded. The lightship displacement and the longitudinal centre of gravity (LCG) can be obtained using this information, as well as the static waterline of the ship at the time of the inclining test as determined by measuring the distance between the waterline and a reference deck or verified draught marks of the ship, the ship hydrostatic data relevant to the actual trim and the sea water density.

3.2.2 General

Any ship for which a stability investigation is requested in order to comply with class requirements is to be initially subjected to an inclining test permitting the evaluation of the position of the lightship centre of gravity, or a light-weight check of the lightship displacement, so that the stability data can be determined.

3.2.3 Inclining test

The inclining test is required in the following cases:

- any new ship, after its completion
- any ship, if deemed necessary by the Society, where any alterations are made so as to materially affect the stability.

3.2.4 Detailed procedure

A detailed procedure for conducting an inclining test and the lightweight is included in Ch 3, App 1.

Section 2 Intact Stability

1 General

1.1 Information for the Captain

1.1.1 Stability booklet

Each ship is to be provided with a stability booklet approved by the Society, which contains sufficient information to enable the Captain to operate the ship in compliance with the applicable requirements contained in this Section.

Where any alterations are made to the ship so as to materially affect the stability information supplied to the Captain, amended stability information is to be provided. If necessary the ship is to be re-inclined.

Stability data and associated plans are to be drawn up in the official language or languages of the issuing country. If the languages used are neither English nor French, the text is to include a translation into one of these languages.

The format of the trim and stability booklet and the information included are specified in Ch 3, App 2.

1.1.2 Periodical lightweight and stability check

At a time not exceeding ten years of the delivery, a lightweight survey is to be carried out to verify any changes in lightship displacement and longitudinal centre of gravity.

A new survey will have to be performed at midterm of the design ship life time.

In both case, the full process as defined in Ch 3, App 1 is to be applied.

1.1.3 Loading instrument

As a supplement to the approved stability booklet, a loading instrument approved by the Society is to be provided to facilitate the stability calculations mentioned in Ch 3, App 2.

A simple and straightforward instruction manual is to be provided.

In order to validate the proper functioning of the computer hardware and software, pre-defined loading conditions are to be run in the loading instrument periodically, at least at every periodical class survey, and the print-out is to be maintained on board as check conditions for future reference in addition to the approved test conditions booklet.

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval, are given in Ch 10, Sec 2, [4].

1.2 Permanent ballast

1.2.1 If used, permanent ballast is to be located in accordance with a plan approved by the Society and in a manner that prevents shifting of position. Permanent ballast is not to be removed from the ship or relocated within the ship without the approval of the Society. Permanent ballast particulars are to be noted in the ship's stability booklet.

1.2.2 No liquid permanent ballast is allowed.

Permanent solid ballast is to be installed under the supervision of the Society.

2 Design criteria

2.1 General intact stability criteria

2.1.1 General

The intact stability criteria specified in [2.3] to [2.8] are to be complied with for the loading conditions mentioned for project verification in Ch 1, Sec 2, [5.2] and Ch 1, Sec 2, [5.4].

2.1.2 Elements affecting stability

A number of influences such as beam-wind on ships with large windage area, icing of topsides, water trapped on deck, rolling characteristics, etc., which adversely affect stability are to be taken into account.

2.1.3 Elements reducing stability

Provisions are to be made for a safe margin of stability at all stages of the voyage, regard being given to additions of weight, such as those due to absorption of water and icing and to loss as of weight such as those due to consumption of fuel and stores.

All deck areas where water can be trapped will have to be considered with the maximum possible water level.

Effect of ship turning, crowding of special personnel, wind and rolling, liquid free surfaces, icing, cargo lifting are covered by [2.3] to [2.8].

The intact stability characteristics of the ship are to be investigated through the following analysis:

a) righting arms (GZ curve) of the ship in the different loading conditions

b) behaviour of the ship under heeling actions such as:

   1) severe wind and rolling
   2) ice accretion
   3) high speed turning
   4) heavy cargo lifting
   5) crowding of special personnel on one side of the ship
   6) Simultaneous effect of wind and special personnel crowding.

The requirement of the reactions of the ship to the above heeling actions and the criteria which the ship is to comply with are dependent on her type.

2.1.4 Ship mass evolution

Except otherwise specified, the stability is to be assessed taking into account an evolution of mass per year on the ship life time due to modernization, maintenance, etc., as defined in Tab 1.

Table 1 : Ship mass evolution

Type of ship	Displacement in % of light ship mass	Centre of gravity
All ships	+ 0,3% / year	+ 0,2% / year

2.1.5 Definition of angles of righting arms curves

θ_d : Ultimate angle of dynamic stability

It is the angle over which the reserve of dynamic stability is not sufficient any more (the dynamic capsizing happens) to face a constant inclining moment (invariable with the heeling), suddenly applied to the ship. Its value corresponds to that of the angle at which the value of the area A is the same as the value of the area B (Fig 1)

θ_0 : Limit of static stability

It is the angle corresponding to the maximum heeling moment (this moment is applied to the ship increasingly to the purpose of avoiding all the dynamic effects) which the ship may face before the capsizing

θ_s : Capsizing angle (over this angle the capsizing of the ship happens even if the inclining moment disappears)

θ_f : Flooding angle (i.e. the lowest angle at which the first opening not closed is reached)

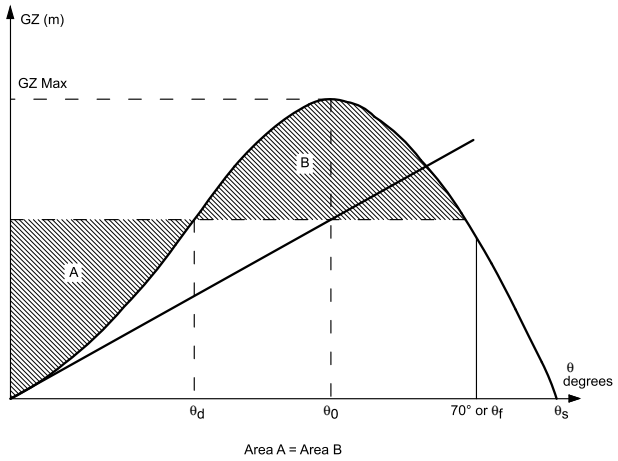
This is the angle corresponding to the minimum angle of heel to which at least one unprotected point (see [2.1.6]) is immersed

θ_r : Rolling angle

θ_c : Static equilibrium angle caused by an external action

θ_e : Equilibrium angle after damage (without external actions).

Figure 1 : Righting arms curve and angles



2.1.6 Location of the flooding angle

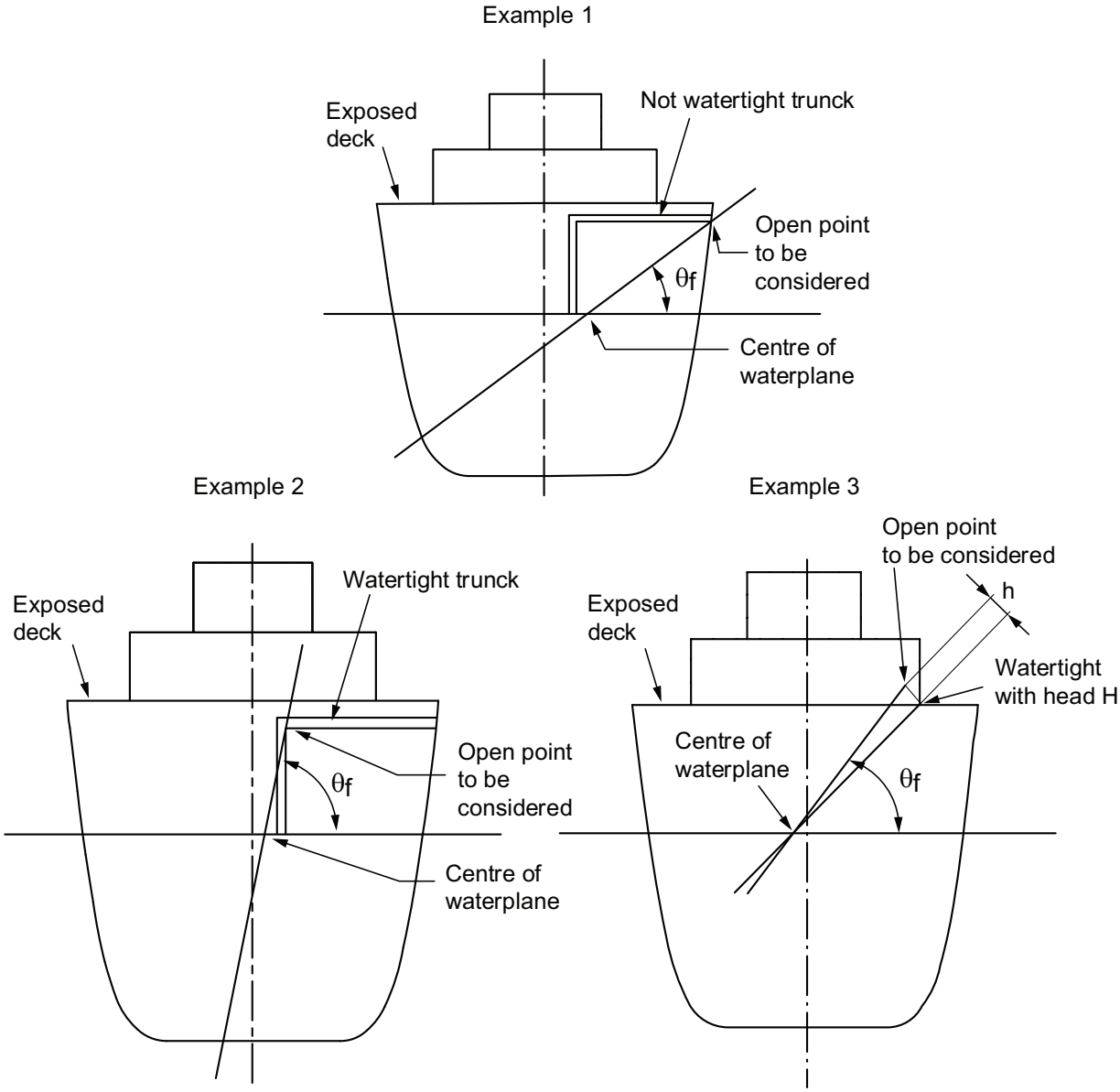
The points of flooding are only the unprotected points which may endanger the stability or the efficiency of the ship (openings leading to large volumes and of size such that the emptying means present on board are not sufficient to face the input of sea water through them), i.e. ventilators in the engine room (see Fig 2).

In the case of a trunk supplied with a closure device or an on-off valve, two cases may rise:

a) either the devise or the valve are proper for the hydrostatic head correspondent to a heeling angle of 70°; in such a case, the trunk is not considered as a point of flooding unprotected, or

b) the device or the valve are proper for a hydrostatic head h lesser than that of item a). In such a case, the point of flooding is to be positioned raised of the value h.

Figure 2 : Flooding angle - Example 1



2.1.7 Righting arms curve

In creating the righting arms curve, the following rules are to be taken into account: the calculation of the righting arms for the considered heeling angles is to be carried out taking in account the change of trim and the free surface effects.

The arms curve is to be stopped when the smallest of the following values is reached:

a) 70°

b) θ_f (angle at which openings not supplied with at least weathertight devices remain submerged), or

c) θ_s (capsizing angle).

2.1.8 Requirements for the righting arms curve

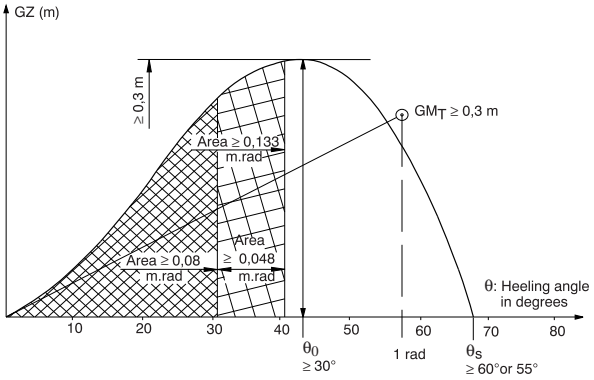
The righting arm curve is to be in compliance with the requirements listed in Tab 2 and represented in Fig 3.

The maximum value of the righting arm curve (GZ Max) is to be identified as per Fig 4 and is to be taken, in any case, between 30° and 50°.

The criteria reported in Tab 2 define the minimum requirements, not the maximum.

Anyway, it is recommended not to exceed the value of GM in order to avoid high dangerous accelerations.

Figure 3 : Righting arms curve criteria



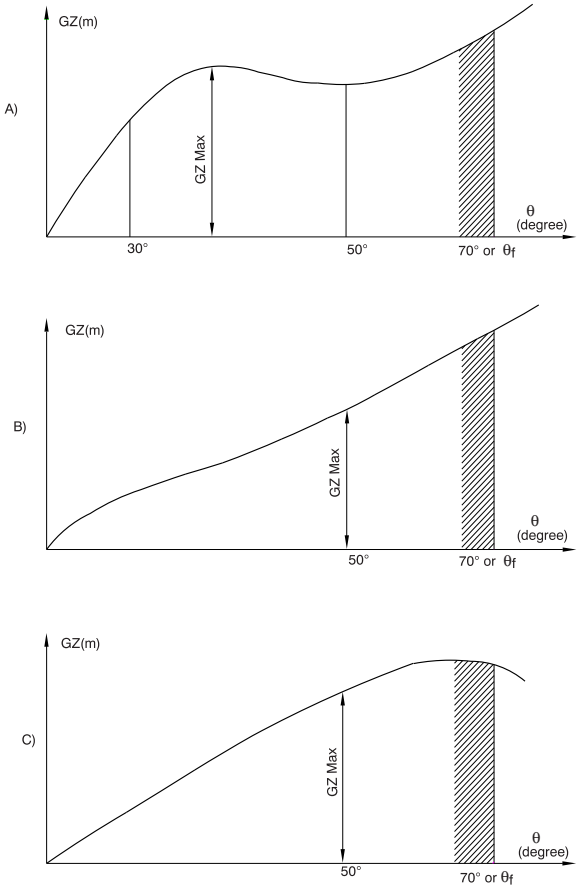
θ_0 : Extreme angle of static stability

θ_s : Capsizing angle.

Table 2 : Minimum values required for the righting arms curve in intact condition

Area under the righting arm curve (GZ) up to 30° or θ_f	Not less than 0,080 m rad (15 feet degree)
Area under the righting lever (GZ) up to 40° or θ_f	Not less than 0,133 m rad (25 feet degree)
Area under the righting arm curve (GZ) between 30° and 40°	Not less than 0,048 m rad (9 feet degree)
Value of the maximum righting arm curve between 30° and 50° (GZ Max)	Not less than 0,3 m (1 foot)
Heeling angle corresponding to the maximum righting arm curve (GZ Max)	Not less than 30°
Value of the initial metacentric height corrected for free surface effect (GM_{corr})	Not less than 0,3 m (1 foot)
Value of the capsizing angle (θ_s)	• Higher than 60° for ships with lightship displacement less than or equal to 5000 t • Higher than 55° for ships with lightship displacement greater than 5000 t

Figure 4 : GZ Max to be considered



If $\theta_f < 50°$, the value of GZ Max is to be considered between 30° and θ_f.

2.2 Effect of free surfaces of liquids in tanks

2.2.1 Tanks for liquids

For all loading conditions, the initial metacentric height and the righting lever curve are to be corrected for the effect of free surfaces of liquids in tanks.

2.2.2 Decks

Decks are provided with efficient drainage arrangement to prevent accumulation of entrapped water due to weather conditions, cleaning or fire fighting. In particular, the effect of accumulation of water is to be investigated for one single large space.

If the drainage arrangement is not considered efficient by the Society, free surface effects may be required, case by case, for the stability calculations.

2.2.3 Consideration of free surface effects

Free surface effects are to be considered whenever the filling level in a tank is less than 98% of full condition.

Free surface effects need not be considered where a tank is normally full, i.e. filling level is 98% or above.

Free surface effects for small tanks may be ignored under the condition in [2.2.9].

2.2.4 Categories of tanks

Tanks which are taken into consideration when determining the free surface correction may be one of two categories:

- tanks with fixed filling level (e.g. water ballast):
  The free surface correction is to be defined for the actual filling level to be used in each tank.
- tanks with variable filling level (e.g. consumable liquids such as fuel oil, diesel oil, and fresh water):
  Except as permitted in [2.2.6], the free surface correction is to be the maximum value attainable among the filling limits envisaged for each tank, consistent with any operating instructions.

2.2.5 Consumable liquids

In calculating the free surface effect in tanks containing consumable liquids, it is to be assumed that, for each type of liquid, at least one transverse pair or a single centreline tank has a free surface and the tank or combination of tanks taken into account is to be the one where the effect of free surface is the greatest. In particular, for the departure conditions where tanks are 100% filled, one maximum free surface for each type of liquid is to be considered. Otherwise, the free surface corresponding to the actual filling is to be considered for each capacity.

2.2.6 Water ballast tanks

Where water ballast tanks, including anti-rolling tanks and anti-heeling tanks, are to be filled or discharged during the course of a voyage, the free surface effect is to be calculated to take account of the most onerous transitory stage relating to such operations.

2.2.7 GM_0 and GZ curve corrections

The corrections to the initial metacentric height and to the righting lever curve are to be addressed separately as indicated in a) and b) below:

a) In determining the correction to the initial metacentric height, the transverse moments of inertia of the tanks are to be calculated at 0° angle of heel according to the categories indicated in [2.2.4].

b) The righting lever curve may be corrected by any of the following methods:
   - correction based on the actual moment of fluid transfer for each angle of heel calculated according to the categories indicated in [2.2.4]
   - correction based on the moment of inertia, calculated at 0° angle of heel, modified at each angle of heel calculated; corrections may be calculated according to the categories indicated in [2.2.4]
   - correction based on the summation of M_{fs} values for all tanks taken into consideration, as specified in [2.2.9].

Whichever method is selected for correcting the righting lever curve, only that method is to be presented in the ship's trim and stability booklet. However, where an alternative method is described for use in manually calculated loading conditions, an explanation of the differences which may be found in the results, as well as an example correction for each alternative, are to be included.

2.2.8 Remainder of liquid

The usual remainder of liquids in the empty tanks need not be taken into account in calculating the corrections, providing the total of such residual liquids does not constitute a significant free surface effect.

2.2.9 Small tanks

Small tanks which satisfy the following conditions using the values of k corresponding to an angle of inclination of 30° need not be included in the correction:

$$\frac{M_{fs}}{\Delta_{min}} < 0,01\,m$$

where:

Δ_{min} : Minimum operational condition ship displacement, in t (see Ch 1, Sec 2, [5.4.1]).

2.3 Severe wind and rolling

2.3.1 Purpose

A ship is to be able to withstand weather and marine adverse conditions without risking its own safety.

The wind and rolling verification ensure a good level of safety for such condition.

The speed of the wind is ruled in Tab 3.

2.3.2 Stability requirements

The wind and rolling verification shall be carried out, comparing the righting arms curve and the heeling arms curve.

The characteristics of speed and distribution of wind are specified in [2.3.3].

2.3.3 Wind speed

The wind action is to be considered cross directed, its speeds are those reported in Tab 3.

Such speeds are different according to the navigation the ship is to follow and its age (less or more than 10 years).

The heeling action of the wind is to be calculated according to Ch 3, App 5.

2.3.4 Dynamic effects

For the purpose of taking account of the heeling caused by wind combined with rolling, the value of the heeling arm GZ1 in the proximity of the angle of static equilibrium (θ_c) is to be less than 60% of the maximum value of the righting arm (GZ Max).

2.3.5 Rolling and reserve of stability

The value of the rolling angle used for the check is to be 25°.

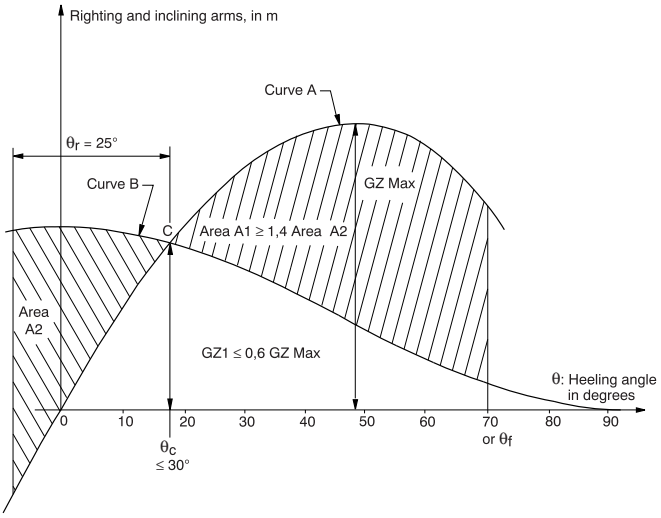
The ship is considered in condition of static equilibrium (point C in Fig 5); from that point a rolling angle of 25° is taken into account.

The following areas are considered:

- "A2", heeling area
- "A1", righting area.

To ensure a sufficient level of safety, area "A1" is to be at least 40% greater than area "A2".

Figure 5 : Severe wind and rolling criteria



Curve A: Righting arms curve (GZ)

Curve B: Wind inclining arms curve.

2.3.6 Maximum value of the angle of static equilibrium

The maximum allowable value of the static equilibrium (θ_c) is 30°.

That to be sure that the ship operates safely.

2.3.7 Stability requirements for wind and rolling

The stability requirements for wind and rolling actions are as follows:

a) GZ1 ≤ 0,6 GZ Max

b) A1 ≥ 1,4 A2

c) $\theta_c \leq 30°$.

Table 3 : Theoretical speed of the wind

Service of the ship	Speed for ships with age of service less than 10 years	Speed for ships with age of service not less than 10 years
UNRESTRICTED SERVICE		
a) Ships expected to withstand the full force of tropical cyclones	100 knots	90 knots
b) Ships expected to avoid centres of tropical cyclones	80 knots	70 knots
COASTAL SERVICE		
a) Ships expected to withstand the full force of tropical cyclones	100 knots	90 knots
b) Ships expected to avoid centres of tropical cyclones	80 knots	70 knots
c) Ships which have to return into harbour with wind force 8	60 knots	50 knots
SERVICE IN HARBOUR	60 knots	50 knots

2.4 Icing

2.4.1 General

For ships which may operate in areas North of latitude 65° and South of latitude 60° and anyway in seas where icing, in winter periods, is expected, the heeling actions due to ice accretion on superstructures and decks are to be taking into account.

In such areas, an icing mass is expected in the more exposed zones of the ship to the adverse conditions (fore part), with the triple effect of:

- the increasing of displacement
- the trim changing
- the centre of gravity elevation.

2.4.2 Calculation assumption

For the purpose of evaluating the stability of a ship in the condition of ice accretion, the following assumptions are to be considered:

a) the curve of righting arms relevant to the loading conditions is to take into account the effects of the ice accretion mass (see [2.4.3]) and the free surfaces

b) the check of the stability of the ship under the combined action of wind and rolling is to be performed similarly to [2.3], but taking into account values of wind speeds 30% less than those in Tab 3.

For ships where devices for removing ice are available, the action of such devices is to be disregarded.

2.4.3 Guidance relating to ice accretion

For ships with lightship displacement not greater than 1000 t, the weight of ice accretion to be considered is 10% of its full load displacement.

For ships with lightship displacement greater than 1000 t, the weight distribution of the ice accretion to be considered is as follows:

- just the fore third of the length of the ship from the exposed deck and the decks above, including the sides, is to be taken into account. Masts are excluded from the calculation.

A uniform weight distribution of ice accretion, of 140 kg/m^2 for the horizontal areas and 70 kg/m^2 for the vertical or oblique areas, is to be considered.

2.4.4 Centre of gravity of ice accretion

For ships with lightship displacement not greater than 1000 t, the centre of gravity of the ice accretion is to be considered coincident with the centre of gravity of the ship in the different loading conditions.

For ships with lightship displacement greater than 1000 t, the centre of gravity of the ice accretion is to be considered in its own position.

2.4.5 Stability requirements for icing and wind

The effect of ice accretion is to be considered in accordance with the requirements of Tab 4 and Fig 6.

Figure 6 : Icing criteria without wind

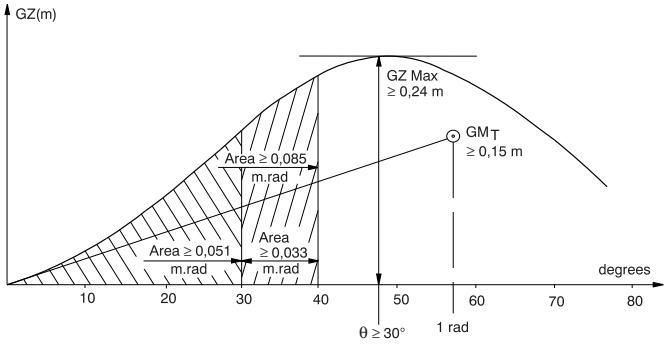


Table 4 : Requirement for righting lever curve for the loading conditions with ice accretion

Area under the righting lever curve (GZ curve) up to 30°, or θ_c, if less than 30°	Higher than 0,051 m·rad (9,60 feet-degrees)
Area under the righting lever curve (GZ curve) up to 40°, or θ_c, if less than 40°	Higher than 0,085 m·rad (16 feet-degrees)
Area under the righting lever curve (GZ curve) between the angles of heel 30° and 40°, or θ_c, if less than 40°	Higher than 0,033 m·rad (6,20 feet-degrees)
The maximum righting lever GZ	At least 0,24 m (0,8 feet)
Heeling angle corresponding to the maximum righting arm (GZ Max)	Higher than 30° (not less than 25°)
Initial metacentric height (liquid) corrected for the actions of free surfaces moments (GM_{corr})	Not less than 0,15 m (0,5 feet)

For the effects of wind and roll, the following criteria are to be complied with:

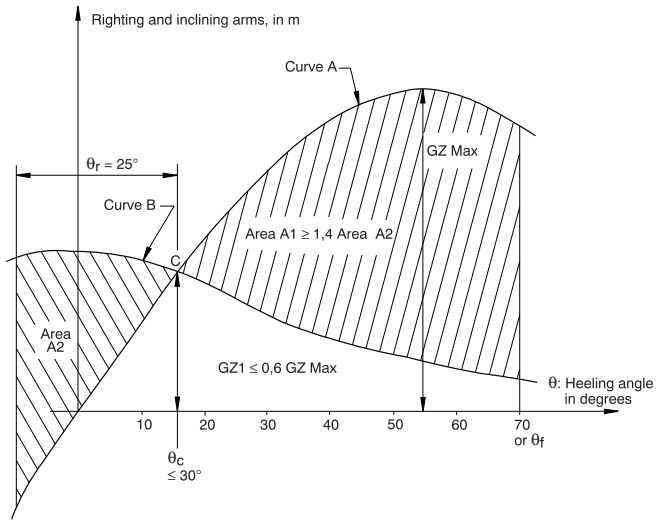
a) GZ1 ≤ 0,6 GZ Max

b) A1 ≥ 1,4 A2

c) $\theta_c \leq 30°$.

See Fig 7.

Figure 7 : Icing criteria with wind



Curve A : Righting arms curve corrected for icing

Curve B : Wind inclining arms curve.

2.5 High speed turning

2.5.1 When the ship turns at high speed, an inclining moment arises which may be prominent.

The purpose of the stability checking for high speed turning is the behaviour of the ship in such an occasion.

2.5.2 High speed turning

The inclining lever (IL) due to the high speed turning is to be considered based on the following formula:

$$IL = \left(\frac{V^2}{R}\right) \cdot \left(\frac{a \cos\theta}{g}\right)$$

where:

V : Speed, in m/sec, of the ship in the turning operating. Such a value may be assumed equal to 80% of the maximum speed when the ship starts the turning

R : Turning radius, in m (if unknown, it may be assumed equal to 3,3 L_{bp})

g : Gravity acceleration

a : Vertical distance, in m, between the centre of gravity of the ship and its drifting centre (if unknown, it may be taken the half of mean draught)

θ : Heeling angle, in degrees (see Fig 8).

2.5.3 Stability requirements for high speed turning

The stability requirements for high speed turning are the following (see Fig 8):

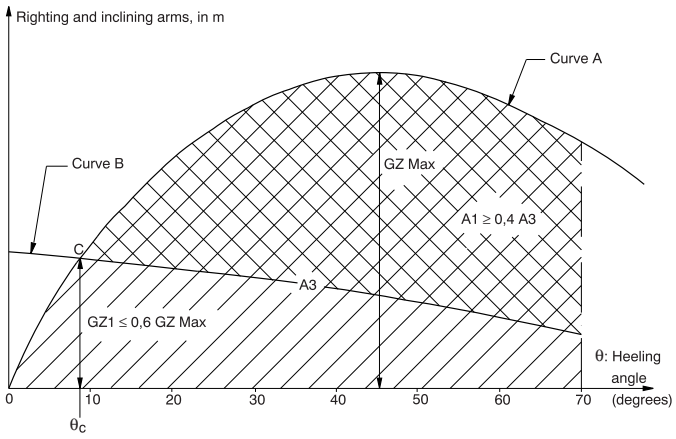
a) GZ1 ≤ 0,6 GZ Max

b) A1 ≥ 0,4 A3

c) $\theta_c \leq 15°$

Note 1: Such a value corresponds to the maximum value of the equilibrium angle corresponding to that allowable for a good working of the essential devices of the ship.

Figure 8 : High speed turning criteria



Curve A : Righting arms curve of the ship in the intact condition

Curve B : Inclining arms (IL) curve for evolution at high speed

A1 : Area between righting curve (curve A) and inclining curve (curve B)

A3 : Total area below the righting arms curve.

2.6 Heavy cargo lifting in still water

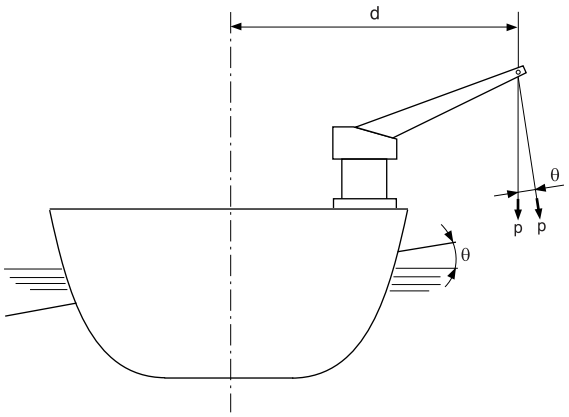
2.6.1 The lifting of weights is a decisive factor in checking the stability of a ship of small dimensions.

In fact the lifted mass, applied to the upper end of the derrick, raises the centre of gravity, reducing, consequently, the value of the initial metacentric height (see Fig 9).

The present sub-article deals with raising of weights in still water.

It is strongly suggested to avoid raising of weights in rough sea. For that, if essential, particular considerations are required.

Figure 9 : Heavy cargo lifting



2.6.2 Intact stability criteria

Two cases may arise:

a) The weight of the cargo is known:

In such a case the stability requirements in [2.6.3] are to be complied with.

b) The weight of the cargo is unknown:

In such a case, the maximum allowable weight, complying with requirement [2.6.3], is to be determined.

In both cases, the righting arms curve (GZ) built, taking into account the increasing of:

- displacement
- raising of the centre of gravity, and
- conditions set up in [2.1.7],

is to be compared with the heeling arms curve defined according to the following formula:

$$H_a = \frac{p\ d \cos\theta}{\Delta}$$

where:

H_a : Heeling arms, in m

p : Weight to be raised, in t

d : Transverse distance, in m, between the centreline of the ship and the more external end of the derrick

Δ : Displacement, in t, of the ship with the raised weight

θ : Heeling angle, in degrees.

2.6.3 Stability requirements for heavy cargo lifting

To comply the stability criteria, the ship is to meet the following requirements (see Fig 10):

a) The value of the static equilibrium angle θ_c caused by the heeling for the cargo raising is to be not more than 15° or the value of the dynamic equilibrium angle θ_d (see [2.1.5]), if lesser:

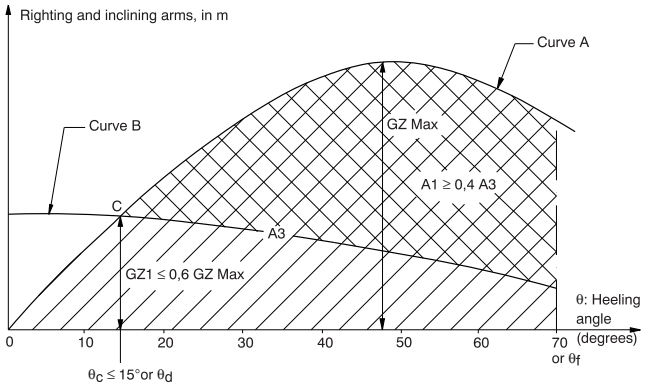
$\theta_c \leq$ Min (15° ; θ_d)

b) GZ1 ≤ 0,6 GZ Max (as in [2.3.4]).

c) The value of the area of the residual stability diagram, represented as area A1 in Fig 10, is to be not less than 40% of the total area below the stability curve, represented by area A3 in Fig 10:

A1 ≥ 0,4 A3.

Figure 10 : Heavy cargo lifting criteria



Curve A : Righting arms curve of the ship in the intact condition

Curve B : Inclining arms (H_a) curve due to cargo lifting

A1 : Area between righting curve (curve A) and inclining curve (curve B)

A3 : Total area below the righting arms curve.

2.7 Crowding of special personnel on one side

2.7.1 The crowding of special personnel (as defined in Ch 1, Sec 2, [7.3.1]) on a ship of small dimensions where a large number of personnel is embarked may be the cause of stability problems. In fact, the crowding on one side of the ship causes a heeling moment which produces a considerable reduction of the dynamic stability reserve.

2.7.2 Calculation assumption

All the special personnel is considered crowded on the upper deck where the personnel is allowed to be located and as more as possible at side, taking into account the following requirements:

a) 4 persons by square metre

b) mean weight of each person: 75 kg.

The heeling arms curve is to be calculated (see [2.7.3]) and compared with the righting lever curve defined in [2.1.7].

2.7.3 Heeling arms calculation

The heeling arms H_a (see Fig 11), in m, caused by the transversal movement of special personnel is calculated by the following formula:

$$H_a = \frac{p\ d \cos\theta}{\Delta}$$

where:

p : Weight of moved special personnel, in t

d : Transverse distance, in m, from the centreline of the ship to the centre of gravity of the area on which the special personnel is crowed

Δ : Displacement of the ship, in t

θ : Heeling angle, in degrees.

2.7.4 Stability requirements for crowding of special personnel

To fulfil the stability criteria, the ship is to comply with the following requirements (see Fig 11):

a) The value of the static equilibrium angle (θ_c) caused by the crowding of special personnel at side is to be not higher than 15° or the value of the dynamic equilibrium angle θ_d (see [2.1.5]), if lesser:

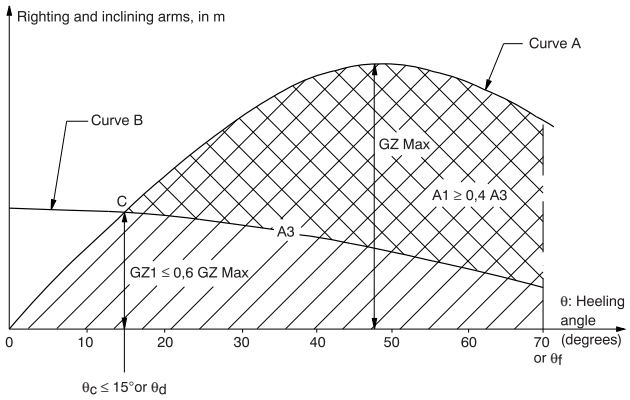
$\theta_c \leq$ Min (15° ; θ_d)

b) GZ1 ≤ 0,6 GZ Max

c) The value of the area of the residual stability diagram, consequent to the crowding of special personnel at side, represented as area A1 in Fig 11 is to be not less than 40% of the total area below the stability curve, represented by area A3 in the same Figure:

A1 ≥ 0,4 A3.

Figure 11 : Special personnel crowding criteria



Curve A : Righting arms curve of the ship in the intact condition

Curve B : Inclining arms (H_a) curve due to special personnel crowding

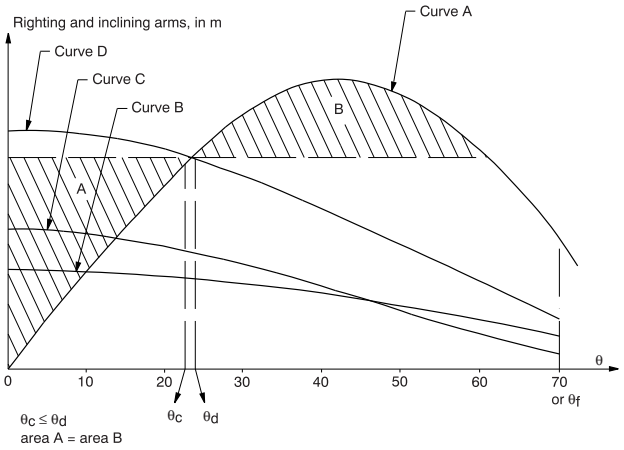
A1 : Area between righting curve (curve A) and inclining curve (curve B)

A3 : Total area below the righting arms curve.

2.8 Simultaneous effect of wind and special personnel crowding

2.8.1 The heeling action reported in [2.3] and [2.7] may be arranged together considered simultaneously. Anyway, in such a case, the only requirement is that the static equilibrium angle resulting from both heeling actions be not higher than the value of the dynamic equilibrium angle θ_d as defined in [2.1.5] and Fig 12. The wind speed to be considered is the maximum speed for which special personnel is allowed to be located on the exposed decks.

Figure 12 : Special personnel crowding criteria with wind



θ_d : Extreme angle of dynamic stability

θ_c : Balancing angle

Curve A : Righting arms curve of the ship in the intact condition

Curve B : Inclining arms curve due to special personnel crowding

Curve C : Wind inclining arms curve

Curve D : Inclining arms curve due to both actions of wind and special personnel crowding.

Section 3 Damage Stability

1 General

1.1 On board supports

1.1.1 Damage stability documentation

For all ships, documents including damage stability calculations are to be submitted.

The damage stability calculations are to include:

a) the list of characteristics (volume, centre of gravity, permeability) of each compartment which can be damaged

b) a table of openings in bulkheads, decks and side shell reporting all the information about:
- identification of the opening
- vertical, transverse and horizontal location
- type of closure: sliding, hinged or rolling for doors
- type of tightness: watertight, weathertight or unprotected
- operating system: remote control, local operation, indicators on the bridge, television surveillance, water leakage detection, audible alarm, as applicable; foreseen utilisation: open at sea, normally closed at sea, kept closed at sea

c) the list of all damage cases corresponding to the applicable requirements

d) the detailed results of damage stability calculations for all the loading conditions foreseen in the applicable requirements

e) the limiting GM/KG curve, if foreseen in the applicable requirements

f) the capacity plan

g) the arrangement of cross flooding pipes, showing the location of remote controls for valves or special mechanical means for correcting the list due to flooding, if any

h) a plan showing the doors (location, tightness), if this information is not already included in the general arrangement plan.

1.1.2 Loading instrument

As a supplement to the approved damage stability documentation, a loading instrument, approved by the Society, is to be provided to facilitate the damage stability calculations mentioned in [1.1.1].

The following loading instrument documentation is to be provided:

- loading instrument approved by Society
- on board user's manual for examination.

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval, are given in Ch 10, Sec 2, [4.6].

1.2 Damage control

1.2.1 Documentation to be supplied

The Captain of the ship is to be supplied with the data necessary to maintain sufficient intact stability under service conditions to enable the ship to withstand the critical damage. In the case of ships requiring cross-flooding, the Captain of the ship is to be informed of the conditions of stability on which the calculations of heel are based and be warned that excessive heeling might result should the ship sustain damage when in less favourable condition.

The data referred to above, to enable the Captain to maintain sufficient intact stability, are to include information which indicates the maximum permissible height of the ship's centre of gravity above keel (KG), or alternatively, the minimum permissible metacentric height (GM) for a range of draught or displacements sufficient to include all service conditions. The information is to show the influence of various trims taking into account the operational limits.

1.2.2 Damage control documentation

The damage control documentation is to include a damage control plan which is intended to provide ship's officers with clear information on the ship's watertight compartmenting and equipment related to maintaining the boundaries and effectiveness of the compartmentation so that, in the event of damage causing flooding, proper precautions can be taken to prevent progressive flooding through openings therein and effective action can be taken quickly to mitigate and, where possible, recover the ship's loss of stability.

The damage control documentation is to be clear and easy to understand. It is not to include information which is not directly relevant to damage control and is to be provided in the language or languages of the ship's officers.

Plans showing clearly, for each deck and hold, the boundaries of the watertight compartments, the openings therein with the means of closure and position of any controls thereof, and the arrangements for the correction of any list due to flooding are to be permanently exhibited for the guidance of the officer in charge of the ship. In addition, booklets containing the aforementioned information are to be made available to the officers of the ship.

Watertight doors that may be permitted to remain open during navigation are to be indicated in the damage control plan with the indication that “doors are always to be ready for immediate closure”, Detailed description of the information to be included in the damage control documentation is reported in [2.4].

1.2.3 Draught marks

Each ship is to be provided with scales of draughts marked clearly at the bow and stern.

In the case where the draught marks are not located where they are easily readable, or operational constraints trade make it difficult to read the draught marks, then the ship is also to be fitted with a reliable draught indicating system by which the bow and stern draught can be determined.

2 Conditions and criteria

2.1 Approaches to be followed for damage stability investigation

2.1.1 General

Damage stability calculations are required in order to achieve a minimum degree of safety after flooding.

The metacentric height (GM), stability levers (GZ) and centre of gravity positions for judging the final surviving conditions are to be calculated by the constant displacement (lost buoyancy) method.

2.1.2 Methodology

The approach is based on standard dimensions of damage extending anywhere along the ship's length or between transverse bulkheads depending on the relevant requirements.

The consequence of such standard of damage is the creation of a group of damage cases, the number of which, as well as the number of compartments involved in each case, depends on the ship's dimensions and internal subdivision.

For each loading condition, each damage case is to be considered and all the applicable criteria are to be complied with.

2.2 Progressive flooding

2.2.1 Definition

Progressive flooding is the additional flooding of spaces which were not previously assumed to be damaged. Such additional flooding may occur through openings or pipes, as indicated in [2.2.2] and [2.2.3], which are located within the V lines as described in Ch 3, App 4.

2.2.2 Openings

The openings may be listed in the following categories, depending on their means of closure:

a) Unprotected

Unprotected openings are openings which are not fitted with at least weathertight means of closure.

Unprotected openings which form part of the limit of the enclosed spaces included in the damage stability calculations and which are located below the waterline after damage (at any stage of flooding) are not allowed; see also [2.4.8] item a).

b) Weathertight

Openings fitted with weathertight means of closure are not able to sustain a constant head of water, but they can be intermittently immersed within the positive range of stability.

Weathertight openings may lead to progressive flooding if they are located below the waterline after damage (at any stage of flooding).

c) Watertight

Internal openings fitted with watertight means of closure are able to sustain a constant head of water corresponding to the distance between the lowest edge of this opening and the bulkhead deck. When detailed information on the head of water after damage is available and justified, such information can be considered for the determination of the constant head of water.

Air pipe closing devices may not be considered watertight, unless additional arrangements are fitted in order to demonstrate that such closing devices are effectively watertight.

Manhole covers may be considered watertight provided the cover is fitted with bolts located such that the distance between their axes is less than five times the bolt's diameter.

Access hatch covers leading to holds may be considered watertight.

Watertight openings do not lead to progressive flooding.

2.2.3 Pipes

Progressive flooding through pipes coming out into internal spaces of the ship may occur when:

a) the pipes and connected valves are located within the assumed damage, and no valves are fitted outside the damage

b) the pipes, even if located outside the damage, satisfy all of the following conditions:

- the pipe connects a damaged space to one or more space(s) located outside the damage
- the highest vertical position of the pipe is below the waterline, and
- no valves are fitted.

The possibility of progressive flooding through ballast piping passing through the assumed extent of damage, where positive action valves are not fitted to the ballast system at the open ends of the pipes in the tanks served, is to be considered. Where remote control systems are fitted to ballast valves and these controls pass through the assumed extend of damage, then the effect of damage to the system is to be considered to ensure that the valves would remain closed in that event.

If pipes, ducts or tunnels are situated within assumed flooded compartments, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed flooded.

2.3 General

2.3.1 Loading conditions

The damage stability criteria specified in [2.4] are to be complied with for the loading conditions mentioned in Ch 1, Sec 2, [5.2] and Ch 1, Sec 2, [5.4] and the loading conditions allowing to take into account the possible evolution of mass during the ship life as given in Ch 3, Sec 2, [2.1.4].

However, the lightship condition not being an operational loading case, no verification are required for this case.

2.3.2 Calculation assumptions

Calculations are to be performed in accordance with [2.4.2] to [2.4.7] and to take into consideration the proportions and design characteristics of the ship and the arrangement and configuration of the damaged compartments. For these calculations, the ship is to be assumed in the worst anticipated service condition as regards stability.

Effects of free surfaces of liquids in tanks are to be taken into account as defined in Ch 3, Sec 2, [2.2].

Damaged compartments, when filled of liquid, are to be subject to run-off, when relevant.

Where it is proposed to fit decks, inner skins or longitudinal bulkheads of sufficient tightness to seriously restrict the flow of water, the Society is to be satisfied that proper consideration is given to such restrictions in the calculations.

2.4 Damage and criteria

2.4.1 Introduction

The present sub-article defines the stability requirements to be complied with when a ship is in damage conditions.

The compliance with such requirements assumes the floating of the ship after several damage cases and the survival such that the return to the harbour is possible.

2.4.2 Damage

The damage to take into account is a continuous breach in the hull of the ship caused by a combat shot or an event at sea.

The damage is applied anywhere within the ship's length L.

All positions of the damage along the ship are to be considered.

a) Longitudinal damage extension

1) Ships of length L not greater than 91,5 m

The extension of the damage causes the flooding of two adjacent watertight compartments (see Ch 1, Sec 2, [6.7] and Fig 1)

2) Ships of length L greater than 91,5 m

They are divided into two categories:

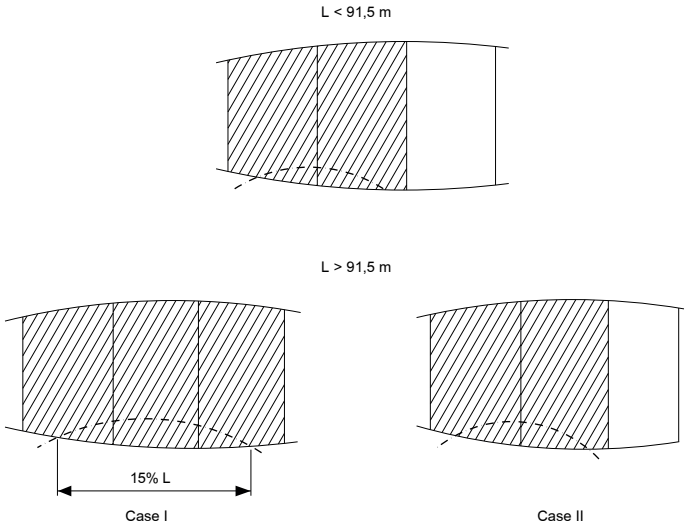
- Category I

Major warships, excluding corvettes, auxiliary ships or ships employed for carriage of important operational equipment. The longitudinal extension to be taken into account for such a category is 15% of L at each point of L. Nevertheless, if the general specification states it, such a length may be reduced to an extension interesting three adjacent compartments (see Ch 1, Sec 2, [6.7] and Fig 1)

- Category II

Ships supplied with a basin or a hangar of remarkable dimensions and all the ships which are not included in category I. The longitudinal extension of the damage to be taken into account is equivalent to the extension of two adjacent compartments (see Fig 1).

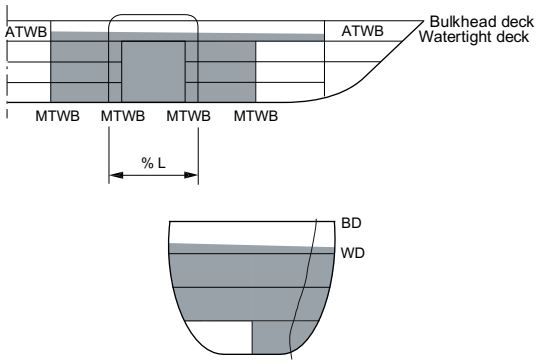
Figure 1 : Standard damage case - Longitudinal extension
(example of damage on the shell and extension of flooding)



b) Vertical damage extension

The vertical extension of the damage is to be such that all the deck closures and platforms within the damaged area are destroyed (see Fig 2).

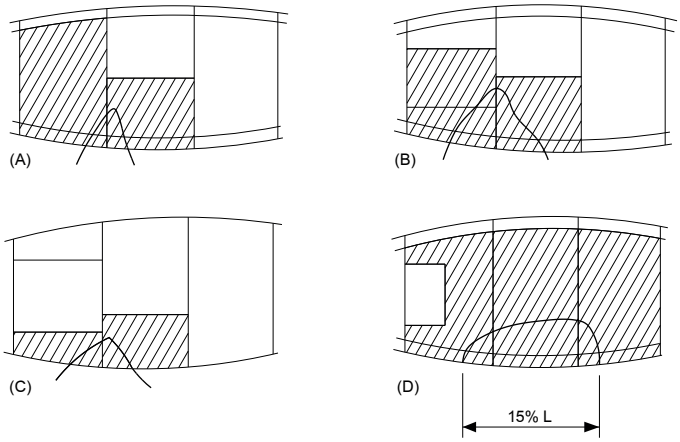
Figure 2 : Standard damage case - Vertical extension
(example of vertical penetration and flooding extension)



c) Transversal damage extension

The transversal extension of the damage may reach the centre line of the ship without nevertheless including it (see Fig 3).

Figure 3 : Standard damage case - Transversal extension
(example of transversal penetration and flooding extension)



(A) and (B): Flooding of two compartments where the longitudinal bulkhead remains undamaged

(C) : Flooding of two compartments where the longitudinal lateral bulkheads remain watertight and may generate a stability condition more unfavourable caused by the heeling

(D) : Other case of flooding.

If any damage of lesser, above indicate, would result in a more severe condition regarding the compliance with the following damage stability criteria, such damage is to be assumed in the calculations.

Table 1 : Values of permeability

Spaces	Permeability
Diesel engine and auxiliaries	0,85
Steam engines	0,90
Boilers	0,80
Pumps, steering gears and stabilisators	0,90
Mooring chains storage	0,65
Technical activities	0,95
Stores and refrigerated goods	0,80**(1)**
Intended for liquids	0 or 0,98**(2)**
Accommodation and military operational areas	0,95
Ammunition storage	0,80**(1)**
Void compartments	0,97
(1) when partially loaded: 0,95 (see Ch 1, Sec 2, [5.3]). **(2)** whichever results in the more severe requirements.	

2.4.3 Permeability

For the damage stability calculations, the volume and surface permeabilities are to be in general as reported in Tab 1. Other values can be accepted when duly justified.

The permeability for cargo spaces intended for the stowage of land vehicles, barges, helicopters and containers is to be derived by calculation in which the land vehicles, barges, helicopters and containers are to be assumed as non-watertight and their permeability equal to 0,65.

In no case is the permeability of cargo spaces in which the goods, vehicles and containers are carried to be taken less than 0,60.

2.4.4 Free surface effects

For partially filled tanks, a free surface effect is to be considered as defined in Ch 3, Sec 2, [2.2.3].

2.4.5 Run-off weights after damage

When a tank is involved in a damage, its content runs-off through the consequent breach. Such content is called run-off weight and is to be taken into account in damage stability calculation.

2.4.6 Calculation of closed openings

a) Below the watertight deck

Access in decks and watertight doors below the watertight deck may be considered open or closed. In such a case, the more unfavourable condition is to be considered in the damage stability analysis.

b) Above the watertight deck (included)

All the watertight doors (outside the “V” line), when laying out of the damaged area, are to be considered closed.

2.4.7 Cross-flooding and equalisation

a) Cross-flooding

The cross-flooding to be taken into account in the damage stability calculations may be accepted under the following conditions:

1) self acting cross-connection
2) the system is independent without any power supply
3) the flooding is to be completed in the time:
   - for D < 4500t: time < 2 min
   - for 4500t < D < 10000t: time < $0,1(D/1000)^2$ min
   - for D > 10000t: time < 10 min

where:

D : Full load displacement.

Suitable information concerning the use of cross-flooding fittings is to be supplied to the Captain of the ship.

For cross-flooding verification, see Ch 3, App 3.

b) Passive equalisation

Passive equalisation complements the effect of cross-flooding, but uses controls means which are manually operated from above the damage control deck (opening of valves). The controls are to be operable with a maximum heel angle of 20°. The equalisation system is to be independent without any power supply. The time needed for passive equalisation may not exceed 15 min.

c) Active equalisation

After the passive equalisation of the ship, all active equalisation measures including mechanically driven ones (like transfer of content of fuel tanks) may be used, if not explicitly prohibited by the stability manual, in order to right itself the ship.

2.4.8 Residual stability after damage

The residual stability of the ship at the end of flooding is calculated taking the following into account:

- characteristics of the righting arms curves for all the damage cases
- relating such curves with the heeling arms curves caused by the wind athwartship.

a) Righting arms curve

1) Characteristics of righting arms curve

Such a curve is to comply with the following requirements:

- it is to be carried out by the loss of buoyancy method. Such a method, recognised by IMO (International Maritime Organisation), studies the damage maintaining constant the displacement of the ship (the flooded volume does not take part in buoyancy of the ship)
- the calculation of the righting arms at several angles is to be performed at equilibrium of longitudinal moment (changeable trim), corrected for free surface effects
- the hull is limited to the bulkhead deck
- the righting arms curves are extending to the smallest of the following angles:
  - θ_s (capsizing angle)
  - θ_f (angle at which the first opening results submerged)
  - 45°

2) Stability criteria required

- Before the passive equalisation of the ship, if present:
  - survival condition

    Provided that particular requirements are present in the contract or in the specification, the ship at the end of flooding is to reach an equilibrium heeling angle not more than 20°:

    $\theta_e < 20°$
  - initial metacentric height

    The initial metacentric height value at a null angle is to be calculated.

  Particular considerations are necessary if, in such a case, such a value results negative or too small. Surely the value of the initial metacentric height at null angle points out the possibility of a lolling. In such a case the passive equalisation by movement of weights onboard may result dangerous. The analysis is to take into account actions (change of trim, lowering of centre of gravity, etc.) which allow the reaching of a positive value of the initial metacentric height, and therefore to avoid the lolling.
- After the passive equalisation of the ship, if present, or at the end of flooding, in any case:
  - survival condition

    Provided that particular requirements are present in the contract or in the specification, the ship at the end of flooding is to reach an equilibrium heeling angle not more than 15°:

    $\theta_e < 15°$
  - initial metacentric height

    The initial metacentric height value at a null angle is to be positive:

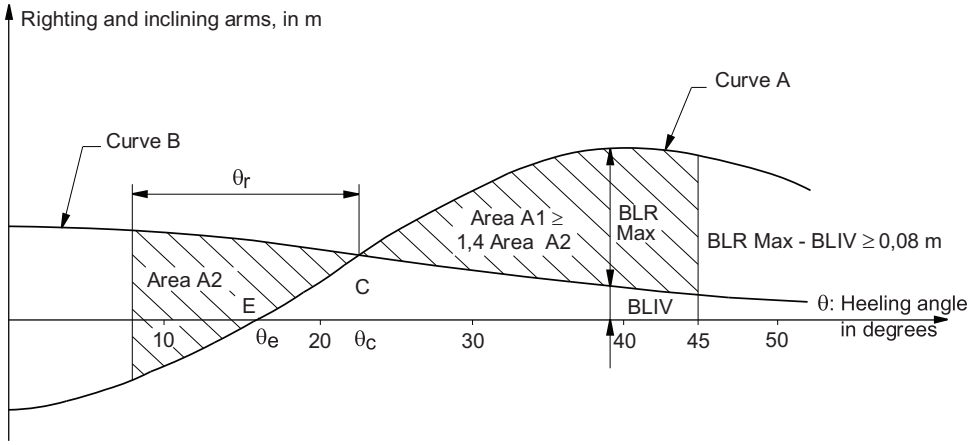
    $GM_{corr} > 0$
  - waterline after damage (margin line)

    At the end of flooding and passive equalisation, the trim and equilibrium angle is to be such that the requirements as defined in Ch 1, Sec 2, [3.2.1] are complied with.
  - stability reserve (see Fig 4)

    The area A_1, representative of the righting energy, is to be higher than the value calculated from Tab 2. It represents the results of a statistic research among several ships, and gives the amount of minimum righting energy such that the vessel can face the heeling energy caused by a moderate sea.

    $A_1 > RSA$

Figure 4 : Righting arms curve and heeling arms caused by severe wind and rolling



Curve A : Righting arms curve at the end of the flooding

Curve B : Heeling arms curve caused by severe wind and rolling.

b) Comparison between the righting arms and heeling arms curves for severe wind and rolling

1) Method to evaluate the stability

The method is the same as defined in Ch 3, Sec 2, [2.3]. Nevertheless, the values of rolling and speed of wind to be taken into account are those presented in Tab 3 and Tab 4.

2) Stability requirements

- Before the equalisation of the ship, at the end of flooding, for the contemporary action of severe wind and rolling as reported in item 1), the ship is to maintain positive initial metacentric height, i.e. she is never to capsize. The maximum value of the righting arm reduced by the value of the heeling arm at the same angle is to be positive:

  $GZ\ Max - GZ_{Heel} > 0$

- After the equalisation of the ship, if present, or at the end of flooding in any case:
  - the ship is to have a stability reserve such to make possible her return in the harbour. To this purpose the value of the maximum righting arm reduced by the value of the heeling arm at the same angle is to be not less than 0,08 m:

    $GZ\ Max - GZ_{Heel} > 0,08$
  - the value of the area A_1 is to be not less than area A_2 increased by 40%:

    $A_1 > 1,4\ A_2$

    See Fig 4.

The area A_2 is limited to the value of rolling angle θ_r determined from Tab 4.

Table 2 : Values of the areas representative of the stability reserve required at the end of the flooding (as a function of the displacement)

Displacement/1000 (in tons)	Area, (in m·deg)	Area, (in m·rad)
0	2,25	0,039
0,5	1,55	0,027
1,0	1,39	0,024
1,5	1,30	0,023
2,0	1,21	0,021
2,5	1,15	0,020
3,0	1,10	0,019
3,5	1,04	0,018
4,0	0,99	0,017
5,0	0,92	0,016
6,0	0,87	0,015
7,0	0,80	0,014
8,0	0,77	0,013
9,0	0,73	0,013
10,0	0,69	0,012

Displacement/1000 (in tons)	Area, (in m·deg)	Area, (in m·rad)
12,5	0,80	0,014
15,0	0,75	0,013
17,5	0,72	0,012
20,0	0,69	0,012
25,0	0,64	0,011
30,0	0,61	0,011
35,0	0,59	0,010
40,0	0,57	0,010
45,0	0,57	0,010
50,0	0,57	0,010
55,0	0,57	0,010
60,0	0,58	0,010
65,0	0,59	0,010
70,0	0,62	0,011
75,0	0,65	0,011
80,0	0,71	0,012

Table 3 : Determination of speed of the wind to be taken into account in damage stability calculations

Displacement/1000 (in tons)	Wind speed, (in knots)
0	20,0
0,25	21,7
0,50	22,8
0,75	23,9
1,00	24,7
1,25	25,5
1,50	26,2
1,75	26,8
2,00	27,4
2,25	28,0
2,50	28,5
2,75	29,0
3,00	29,5
3,25	30,0
3,50	30,4
3,75	30,8
4,00	31,2

Displacement/1000 (in tons)	Wind speed, (in knots)
4,25	31,6
4,50	31,9
4,75	32,2
5,00	32,4
6,50	34,5
7,00	35,0
7,50	35,4
8,00	35,7
8,50	36,1
9,00	36,5
9,50	36,8
10,0	37,1
11,0	37,7
12,0	38,4
13,0	39,0
14,0	39,6
15,0	40,1

Displacement/1000 (in tons)	Wind speed, (in knots)
16	40,7
17	41,3
18	41,8
19	42,2
20	42,8
21	43,3
22	43,7
23	44,1
24	44,5
25	45,0
30	47,1
35	49,5
40	51,7
50	55,0
60	58,3
70	61,7
80	65,0

Table 4 : Rolling angle at the end of the flooding (as a function of the initial displacement)

Displacement/1000 (in tons)	Roll angle (in degree)
0,3	13,0
0,5	12,9
0,8	12,7
1,0	12,5
1,3	12,4
1,5	12,2
2,0	11,9
2,5	11,6
3,0	11,5
3,5	11,3
4,0	11,1
5,0	10,7
6,0	10,4
7,0	10,1
8,0	9,9
9,0	9,6
10,0	9,4
11,0	9,2

Displacement/1000 (in tons)	Roll angle (in degree)
12	9,0
13	8,8
14	8,7
15	8,5
16	8,4
17	8,2
18	8,1
19	7,9
20	7,8
21	7,7
23	7,4
24	7,3
25	7,2
26	7,2
27	7,1
28	7,0
29	6,9

Displacement/1000 (in tons)	Roll angle (in degree)
30,0	6,8
31,0	6,7
32,0	6,6
33,0	6,5
34,0	6,4
35,0	6,4
37,5	6,2
40,0	6,1
42,5	5,9
45,0	5,8
47,5	5,7
50,0	5,6
55,0	5,4
60,0	5,2
65,0	5,2
70,0	5,1
80,0	5,0

Section 4 Sea-Keeping

1 General

1.1 Introduction

1.1.1 Ship operability

The operability of a military ship is directly linked to the task performance of the crew, the operability of the weapons systems and equipment and the ability of the ship to transit as required. The task performance of the crew is influenced by seasickness, fatigue and motion induced interruptions, whereas ship motions and accelerations limit the operability of weapons systems and equipment.

1.1.2 Operation limits

The operation limits depend on the specific operation the ship is to perform. For transit operations, the operation limits ensure that ship motions and accelerations do not adversely affect the ship structure, systems and equipment needed for the mission nor the task performance of the crew.

Operation limits for the hull are set to prevent structural damage caused by slamming or wetness (water on deck), and to prevent degradation of the ship operability due to propeller emergence.

1.1.3 Verification approach

It is a basic requirement that sea-keeping assessment is performed in order to verify the ability of the ship to transit as required during transit operations. This verification is treated in the current section.

Verification of a vessel's sea-keeping characteristics with respect to operational limits for other specific operations, such as flight and replenishment at sea operations, is covered by additional class notations and, as such, subject to the requirements in Pt E, Ch 9, Sec 3.

1.1.4 Transit operations (TRAN)

The TRAN mission models the situation where the ship is sailing from one place to another, with the crew performing routine shipboard activities for transit and patrol. In terms of a vessel's sea-keeping characteristics, this mission depends upon the ship's ability to transit as required across the seas.

Survivability in extreme seas is therefore a special subset of the TRAN mission. Two aspects of survivability are of major importance: the ultimate stability and the ultimate strength. As such, it is necessary to determine and take into account extreme values for wave induced bending moments.

By default, the wave induced bending moments are to be taken as described in Ch 5, Sec 2, [3]. As an alternative, the designer may perform direct computations in order to derive design values that may be used instead. In such a case, the principles and criteria to be adopted in a long term sea-keeping assessment used to derive these values are provided in Ch 3, App 6. The applicability of results of long term sea-keeping assessments as an alternative to the requirements in Ch 5, Sec 2, [3] are to be approved by the Society on a case-by-case basis.

Other requirements for the hull and equipment in the context of the TRAN mission are given in Article [2].

1.2 Assessment procedure

1.2.1 Parameters

The methods for calculating the parameters to be considered for the sea-keeping assessment are defined in Article [2].

1.2.2 Evaluation

The values of the ship sea-keeping parameters are to be assessed by means of computer calculations and/or small-scale model tests in a model basin.

The computer calculations are to be performed as described in Ch 3, App 6, and the following documentation is to be provided:

- justification of the validity of the used software
- parameters to be calculated
- computation input data
- computation results
- model test results that verify and/or replace calculated results.

Concerning model tests, the following documentation is to be provided:

- parameters to be measured
- detailed test program
- analysis procedure of measured data
- sea- and ship loading-condition during the tests
- test results and their analysis.

1.3 Environmental conditions

1.3.1 Sea state

Sea state is an expression used to categorise wave conditions and normally a sea state comprises a significant wave height Hs and a wave period.

Unless otherwise specified, the environmental conditions for sea-keeping analyses or model tests are to be selected and applied in accordance with NATO STANAG 4154 Ed.4. The wave spectrums to be considered are described in Ch 3, App 6. Further guidance is available in NI691 'Environmental Conditions, Loads and Induced Responses of Marine Units'.

Whenever computer calculations or model scale tests are used (i.e. when the environmental conditions are selectable), the sea states used for the verification of the criteria in [2.3] are to be defined as described in [1.3.2] and [1.3.3].

The limiting sea state defines the sea state up to and including which the sea-keeping criteria can be satisfied for the TRAN mission.

1.3.2 Wave height

Generally, the references to the wave height are to be taken as the significant wave height Hs, i.e. the average of the 1/3 largest wave heights in a sea state.

The description of sea states shown in Ch 3, App 6, Tab 2 defines the significant wave height as ranges, not absolute values. For this reason, sea states are to be referred to not only by their number, but also whether it is a low, mid or high sea state. For example, for the sea states defined as per STANAG 4154, a low sea state 6 has Hs = 4,0 m, mid sea state 6 has Hs = 5,0 m and high sea state 6 has Hs = 6,0 m.

The wave height to be considered for the verifications is to be the largest significant wave height relative to the specified sea state; for example, if a mid sea state 6 is specified, Hs is to be taken as 5,0 m, but if only sea state 6 is specified, Hs is to be taken equal to 6,0 m.

1.3.3 Wave period

Generally, references to the wave period are to be taken as the modal wave period, as per STANAG 4154.

For the TRAN mission, at least three periods are to be considered, the values of which are to be taken from STANAG 4154. For other cases, one period value will, in general, be sufficient.

1.4 Requirements to be complied with

1.4.1 The requirements of Article [2] are equivalent to the requirements in NATO STANAG 4154 Ed.4

2 Hull

2.1 General

2.1.1 Scope

The sea-keeping performance is to be evaluated in order to ensure that the ship motions do not become so severe that slamming, water on deck and propeller emergences can damage the hull structure or equipment, and verify that they do not prevent the ship from transiting in weather conditions where the ship is expected to carry out its mission.

2.1.2 Requirements

It is to be ensured that the ship is able to perform the TRAN mission by verifying that the parameters evaluated do not exceed the criteria defined in [2.3].

Unless otherwise specified, the parameters evaluated are to comply with the criteria for a limiting sea state not less than mid sea state 5 as defined in STANAG 4154.

2.2 Parameters

2.2.1 Wetness index

The wetness index is defined as the number of occurrences of water on deck in an hour. This index is to be based on the variance ($m_{0,M}$) of the relative vertical motion at the bow combined with the distance between the deepest subdivision load line and the weather deck at the same location:

$WI = N_Z\ F(D_F)$

where:

$$F(D_F) = \exp\left(-\left(\frac{D_F}{\sqrt{2\,m_{0,M}}}\right)^2\right)$$

$$N_Z = \frac{3600}{2\pi}\sqrt{\frac{m_{2,M}}{m_{0,M}}}$$

$m_{0,M}$: Zero order spectral moment of relative vertical motion response

$m_{2,M}$: Second order spectral moment of relative vertical motion response.

2.2.2 Slamming index

The slamming index is defined as the number of times in an hour a keel emergence is followed by a re-entry in water that exceeds a certain threshold velocity:

$SI = N_Z \; F(V_{TH}) \; F(T_{SL})$

where:

$F(V_{TH})$: Probability of exceeding the threshold velocity:

$$F(V_{TH}) = \exp\left(-\left(\frac{V_{TH}}{\sqrt{2\,m_{0,V}}}\right)^2\right)$$

$F(T_{SL})$: Probability of keel emergence:

$$F(T_{SL}) = \exp\left(-\left(\frac{T_{SL}}{\sqrt{2\,m_{0,M}}}\right)^2\right)$$

$$N_Z = \frac{3600}{2\pi}\sqrt{\frac{m_{2,M}}{m_{0,M}}}$$

$m_{0,V}$: Zero order spectral moment of relative vertical velocity response

$m_{0,M}$: Zero order spectral moment of relative vertical motion response

$m_{2,M}$: Second order spectral moment of relative vertical motion response.

The location of the slamming assessment is to be at the keel at 3/20 L behind the fore perpendicular.

The vertical threshold velocity is based on the ship length, and defined, in m/s, as:

$$V_{TH} = 3,66\sqrt{\frac{L}{158,5}}$$

2.2.3 Propeller emergence

Propeller emergence is defined as the number of times the highest quarter part of the propeller diameter (D_{PROP}) emerges from the sea surface in an hour. This index is to be based on the variance ($m_{0,M}$) of the relative vertical motion at the propeller location combined with the distance from the propeller axis to the calm water sea surface (Z_{PROP}).

According to the above definitions and the dimensions shown in Fig 1, propeller emergence occurs when the relative motion exceeds Z_{PE} defined as:

$$Z_{PE} = Z_{PROP} - \frac{1}{4}D_{PROP}$$

The number of propeller emergences in an hour can now be determined as:

$PE = N_Z \; F(Z_{PE})$

where:

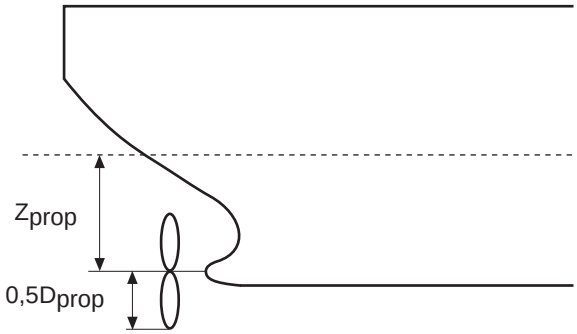
$$F(Z_{PE}) = \exp\left(-\left(\frac{Z_{PE}}{\sqrt{2\,m_{0,M}}}\right)^2\right)$$

$$N_Z = \frac{3600}{2\pi}\sqrt{\frac{m_{2,M}}{m_{0,M}}}$$

$m_{0,M}$: Zero order spectral moment of relative vertical motion response

$m_{2,M}$: Second order spectral moment of relative vertical motion response.

Figure 1 : Dimensions for calculation of relative motion Z_{PE}



2.3 Criteria

2.3.1 The criteria that ensure that wetness, slamming and propeller emergence events do not become excessive are given in Tab 1 for all monohull ships.

Ships with sponsons are also to comply with the additional criteria given in Tab 2.

Table 1 : Hull criteria limits

MONOHULL		
Parameter	Limit	Location
Wetness index (WI)	30/hr	Forward perpendicular
Slamming index (SI)	20/hr	Keel, 3/20 L aft of FP
Propeller emergence (PE)	90/hr	1/4 propeller diameter above shaft center / Top of water jet inlet

Table 2 : Additional hull criteria limits for ships with sponsons

Parameter	Limit	Location
Slamming index (SI)	20/hr	Sponson

Appendix 1 Inclining Test and Lightweight Check

1 Inclining test and lightweight check

1.1 General

1.1.1 General conditions of the ship

Prior to the test, the Society's Surveyor is to be satisfied of the following:

- the weather conditions are to be favourable
- the ship is to be moored in a quiet, sheltered area free from extraneous forces, such as to allow unrestricted heeling. The ship is to be positioned in order to minimise the effects of possible wind, stream and tide
- the ship is to be transversely upright and the trim is to be taken not more than 1% of the length between perpendiculars. Otherwise, hydrostatic data and sounding tables are to be available for the actual trim
- cranes, derrick, lifeboats and liferafts capable of inducing oscillations are to be secured
- main and auxiliary boilers, pipes and any other system containing liquids are to be filled
- the bilge and the decks are to be thoroughly dried
- preferably, all tanks are to be empty and clean, or completely full. The number of tanks containing liquids is to be reduced to a minimum taking into account the above-mentioned trim. In particular the filling of slack tanks is to be less than 80% to avoid any influence of structural elements. The shape of the tank is to be such that the free surface effect can be accurately determined and remain almost constant during the test. All cross connections are to be closed
- the weights necessary for the inclination are to be already on board, located in the correct place
- all work on board is to be suspended and crew or personnel not directly involved in the inclining test is to leave the ship
- the ship is to be as complete as possible at the time of the test. The number of weights to be removed, added or shifted is to be limited to a minimum. Temporary material, tool boxes, staging, sand, debris, etc., on board is to be reduced to an absolute minimum.

1.1.2 Inclining weights

The total weight used is preferably to be sufficient to provide a minimum inclination of one degree and a maximum of four degrees of heel to each side. The Society may, however, accept a smaller inclination angle for large ships provided that the requirement on pendulum deflection or U-tube difference in height specified in [1.1.4] is complied with. Test weights are to be compact and of such a configuration that the VCG (vertical centre of gravity) of the weights can be accurately determined. Each weight is to be marked with an identification number and its weight. Re-certification of the test weights is to be carried out prior to the incline. A crane of sufficient capacity and reach, or some other means, is to be available during the inclining test to shift weights on the deck in an expeditious and safe manner. Water ballast is generally not acceptable as inclining weight.

1.1.3 Water ballast as inclining weight

Where the use of solid weights to produce the inclining moment is demonstrated to be impracticable, the movement of ballast water may be permitted as an alternative method. This acceptance would be granted for a specific test only, and approval of the test procedure by the Society is required. As a minimal prerequisite for acceptability, the following conditions are to be required:

- inclining tanks are to be wall-sided and free of large stringers or other internal members that create air pockets
- tanks are to be directly opposite to maintain ship's trim
- specific gravity of ballast water is to be measured and recorded
- pipelines to inclining tanks are to be full. If the ship's piping layout is unsuitable for internal transfer, portable pumps and pipes/hoses may be used
- blanks must be inserted in transverse manifolds to prevent the possibility of liquids being "leaked" during transfer. Continuous valve control is to be maintained during the test
- all inclining tanks are to be manually sounded before and after each shift
- vertical, longitudinal and transverse centres are to be calculated for each movement
- accurate sounding/ullage tables are to be provided. The ship's initial heel angle is to be established prior to the incline in order to produce accurate values for volumes and transverse and vertical centres of gravity for the inclining tanks at every angle of heel. The draught marks amidships (port and starboard) are to be used when establishing the initial heel angle
- verification of the quantity shifted may be achieved by a flowmeter or similar device
- the time to conduct the inclining is to be evaluated. If time requirements for transfer of liquids are considered too long, water may be unacceptable because of the possibility of wind shifts over long periods of time.

1.1.4 Pendulums

The use of three pendulums is recommended but a minimum of two are to be used to allow identification of bad readings at any one pendulum station. However, for ships of a length equal to or less than 30 m, only one pendulum can be accepted. They are

each to be located in an area protected from the wind. The pendulums are to be long enough to give a measured deflection, to each side of upright, of at least 10 cm. To ensure recordings from individual instruments are kept separate, it is suggested that the pendulums be physically located as far apart as practical.

The use of an inclinometer or U-tube is to be considered in each separate case. It is recommended that inclinometers or other measuring devices only be used in conjunction with at least one pendulum.

1.1.5 Means of communications

Efficient two-way communications are to be provided between central control and the weight handlers, and between central control and each pendulum station. One person at a central control station is to have complete control over all personnel involved in the test. The internal means of communication inside the ship may be used for this purpose.

1.1.6 Documentation

The person in charge of the inclining test is to have available a copy of the following plans at the time of the test:

- hydrostatic curves or hydrostatic data
- general arrangement plan of decks, holds, inner bottoms, etc
- capacity plan showing capacities and vertical and longitudinal centres of gravity of cargo spaces, tanks, etc. When water ballast is used as inclining weights, the transverse and vertical centres of gravity for the applicable tanks, for each angle of inclination, are to be available
- tank sounding tables
- draught mark locations
- docking drawing with keel profile and draught mark corrections (if available).

1.1.7 Determination of the displacement

The Society's Surveyor is to carry out all the operations necessary for the accurate evaluation of the displacement of the ship at the time of the inclining test, as listed below:

- draught mark readings are to be taken at aft, midship and forward, at starboard and port sides
- the mean draught (average of port and starboard readings) is to be calculated for each of the locations where draught readings are taken and plotted on the ship's lines drawing or outboard profile to ensure that all readings are consistent and together define the correct waterline. The resulting plot is to yield either a straight line or a waterline which is either hogged or sagged. If inconsistent readings are obtained, the freeboards/ draughts are to be retaken
- the specific gravity of the sea water is to be determined. Samples are to be taken from a sufficient depth of the water to ensure a true representation of the sea water and not merely surface water, which could contain fresh water from run off of rain. A hydrometer is to be placed in a water sample and the specific gravity read and recorded. For large ships, it is recommended that samples of the sea water be taken forward, midship and aft, and the readings averaged. For small ships, one sample taken from midship is sufficient. The temperature of the water is to be taken and the measured specific gravity corrected for deviation from the standard, if necessary. A correction to water specific gravity is not necessary if the specific gravity is determined at the inclining experiment site. Correction is necessary if specific gravity is measured when the sample temperature differs from the temperature at the time of the inclining (e.g., if the check of specific gravity is performed at the office). Where the value of the average calculated specific gravity is different from that reported in the hydrostatic curves, adequate corrections are to be made to the displacement curve
- all double bottoms, as well as all tanks and compartments which can contain liquids, are to be checked, paying particular attention to air pockets which may accumulate due to the ship's trim and the position of air pipes, and also taking into account the provisions of [1.1.1]
- it is to be checked that the bilge is dry, and an evaluation of the liquids which cannot be pumped, remaining in the pipes, boilers, condenser, etc., is to be carried out
- the entire ship is to be surveyed in order to identify all items which need to be added, removed or shifted to bring the ship to the lightship condition. Each item is to be clearly identified by its weight and the location of its centre of gravity
- the possible solid permanent ballast is to be clearly identified and listed in the report.

1.1.8 The incline

The standard test generally employs eight distinct weight movements as shown in Fig 1.

The weights are to be transversely shifted, so as not to modify the ship's trim and the vertical position of the centre of gravity.

After each weight shifting, the new position of the transverse centre of gravity of the weights is to be accurately determined.

After each weight movement, the distance the weight was moved (centre to centre) is to be measured and the heeling moment calculated, multiplying the distance by the amount of weight moved. The tangent is calculated for each pendulum, dividing the deflection by the length of the pendulum. The resultant tangents are plotted on the graph as shown in Fig 2.

The pendulum deflection is to be read when the ship has reached a final position after each weight shifting.

During the reading, no movement of personnel is allowed.

For ships with a length equal to or less than 30 m, six distinct weight movements may be accepted.

Figure 1 : Weight shift procedure

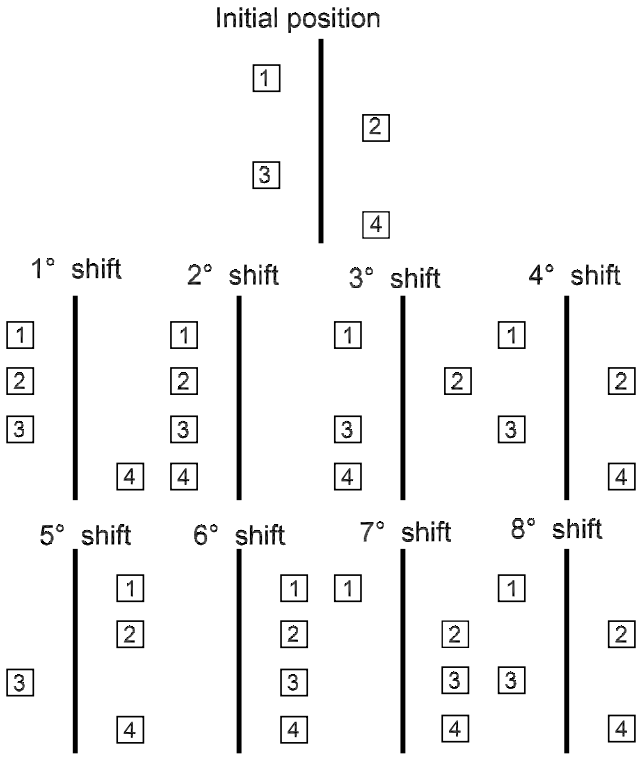
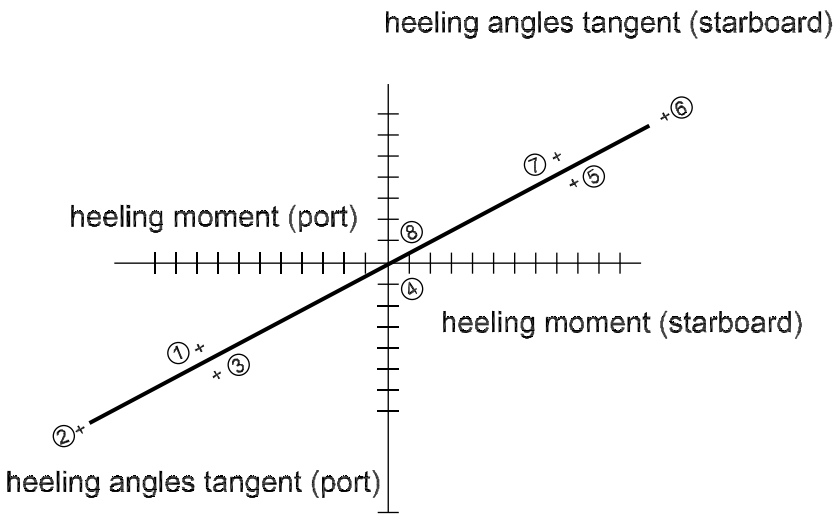


Figure 2 : Graph of resultant tangents



Appendix 2 Trim and Stability Booklet

1 Trim and stability booklet

1.1 Information to be included in the trim and stability booklet

1.1.1 General

A trim and stability booklet is a stability manual, to be approved by the Society, which is to contain sufficient information to enable the Captain to operate the ship in compliance with the applicable requirements contained in the Rules.

The format of the stability booklet and the information included vary depending on the ship type and operation.

1.1.2 List of information

The following information is to be included in the trim and stability booklet:

- a general description of the ship, including:
  - the ship's name and the Society classification number
  - the ship type and service notation
  - the class notations
  - the yard, the hull number and the year of delivery
  - the moulded dimensions
  - the draught corresponding to the minimum operational loaded ship (defined in Ch 1, Sec 2, [5.4]), the draught corresponding to the assigned full loaded ship (defined in Ch 1, Sec 2, [5.2])
  - the displacement corresponding to the above-mentioned draughts
- clear instructions on the use of the booklet
- general arrangement and capacity plans indicating the assigned use of compartments and spaces (cargo, stores, accommodation, etc.)
- a sketch indicating the position of the draught marks referred to the ship's perpendiculars
- hydrostatic curves or tables corresponding to the design trim, and, if significant trim angles are foreseen during the normal operation of the ship, curves or tables corresponding to such range of trim are to be introduced. A clear reference relevant to the sea density, in t/m^3, is to be included as well as the draught measure (from keel or underkeel)
- cross curves (or tables) of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves
- tank sounding tables or curves showing capacities, centres of gravity, and free surface data for each tank
- lightship data from the inclining test, as indicated in Ch 3, Sec 1, [3.2], including lightship displacement, centre of gravity co-ordinates, place and date of the inclining test, as well as the Society approval details specified in the inclining test report. It is suggested that a copy of the approved test report be included.

  Where the above-mentioned information is derived from a sister ship, the reference to this sister ship is to be clearly indicated, and a copy of the approved inclining test report relevant to this sister ship is to be included
- standard loading conditions and examples for developing other acceptable loading conditions using the information contained in the booklet
- intact stability results (total displacement and its centre of gravity co-ordinates, draughts at perpendiculars, GM, GM corrected for free surfaces effect, GZ values and curve, criteria as indicated in Ch 3, Sec 2 as well as possible additional criteria specified in Part D when applicable, reporting a comparison between the actual and the required values) are to be available for each of the above-mentioned operating conditions. The method and assumptions to be followed in the stability curve calculation are specified in [1.2]
- damage stability results (total displacement and its maximum permissible centre of gravity height, draughts at perpendiculars, GM, GM corrected for free surfaces effect, GZ values and curve, criteria as indicated in Ch 3, Sec 3 as well as possible additional criteria specified in Part D when applicable, reporting a comparison between the actual and the required values)

are to be available for each of the above-mentioned operating conditions. The method and assumptions to be followed in the stability curve calculation are specified in [1.2]

- information on loading restrictions (maximum allowable load on double bottom, maximum KG or minimum GM curve or table which can be used to determine compliance with the applicable intact and damage stability criteria) when applicable
- information about openings (location, tightness, means of closure), pipes or other progressive flooding sources. the opening used for the calculation of the down flooding angle has to be clearly identified
- information concerning the use of any special cross-flooding fittings with descriptions of damage conditions which may require cross-flooding, when applicable
- any other necessary guidance for the safe operation of the ship
- a table of contents and index for each booklet.

1.2 Stability curve calculation

1.2.1 General

Hydrostatic and stability curves are normally prepared on a designed trim basis. However, where the operating trim or the form and arrangement of the ship are such that change in trim has an appreciable effect on righting arms, such change in trim is to be taken into account.

1.2.2 Superstructures, deckhouses, etc. which may be taken into account

Enclosed superstructures complying with Ch 1, Sec 2 may be taken into account.

The second tier of similarly enclosed superstructures may also be taken into account.

Deckhouses on the main deck may be taken into account, provided that they comply with the conditions for enclosed superstructures laid down in Ch 1, Sec 2.

Where deckhouses comply with the above conditions, except that no additional exit is provided to a deck above, such deckhouses are not to be taken into account; however, any deck openings inside such deckhouses are to be considered as closed even where no means of closure are provided.

Deckhouses, the doors of which do not comply with the requirements of Ch 8, Sec 4, [1.5.4], are not to be taken into account; however, any deck openings inside the deckhouse are regarded as closed where their means of closure comply with the requirements of Ch 8, Sec 8, [8.3] or Ch 8, Sec 8, [9.2], as relevant.

Deckhouses on decks above the main deck are not to be taken into account, but openings within them may be regarded as closed.

Superstructures and deckhouses not regarded as enclosed may, however, be taken into account in stability calculations up to the angle at which their openings are flooded (at this angle, the static stability curve is to show one or more steps, and in subsequent computations the flooded spaces are to be considered non-existent).

Trunks may be taken into account. Hatchways may also be taken into account having regard to the effectiveness of their closures.

1.2.3 Angle of flooding

In cases where the ship would sink due to flooding through any openings, the stability curve is to be cut short at the corresponding angle of flooding and the ship is to be considered to have entirely lost its stability.

Small openings such as those for passing wires or chains, tackle and anchors, and also holes of scuppers, discharge and sanitary pipes are not to be considered as open if they submerge at an angle of inclination more than 30°. If they submerge at an angle of 30° or less, these openings are to be assumed open if the Society considers this to be a source of significant progressive flooding; therefore such openings are to be considered on a case by case basis.

Appendix 3 Calculation Method for Cross-Flooding Arrangements

1 Calculation method for cross-flooding arrangements

1.1 Cross-flooding area

1.1.1 Cross-flooding area calculation

The cross-flooding area S, in m^2, can be calculated from the following formula:

$$S = \frac{2W}{tF(\sqrt{2gH_o} + \sqrt{2gH_F})}$$

where:

W : Volume, in m^3, of water entering the equalising compartments during the period considered

t : Time, in s, necessary to complete the equalisation

F : Factor, to be taken equal to:

$$F = \frac{1}{\sqrt{1 + \sum k}}$$

In general, a value of F equal to 0,65 may be used. Anyway, for particular shape of pipes, appropriate values of k are to be used in the above formula

k : Dimensionless factor of reduction of speed through the duct, being a function of bends, valves, etc., in the cross-flooding system, to be obtained from [1.1.2], as the case may be

g : Gravity acceleration, in m/s^2:

$g = 9,81\ m/s^2$

H_o : Initial head of water, in m

H_F : Final head of water after cross-flooding, in m.

1.1.2 Factor of reduction k

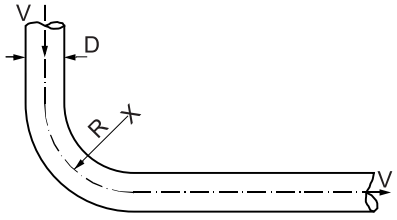
The factor of reduction is to be calculated depending on the following cases:

- Case 1: 90° circular bend (see Tab 1)
- Case 2: Radius bend R/D = 2 (see Tab 2)
- Case 3: Mitre bend (see Tab 3)
- Case 4: 90° double mitre bend (see Tab 4)
- Case 5: Pipe inlet (see Tab 5)
- Case 6: Pipe outlet (see Tab 6)
- Case 7: Non-return valve (see Tab 7
- Case 8: Pipe friction losses (see Tab 8)
- Case 9: Gate valve (see Tab 9)
- Case 10: Butterfly valve (see Tab 10)
- Case 11: Disc valve (see Tab 11).

1.1.3 Overflows

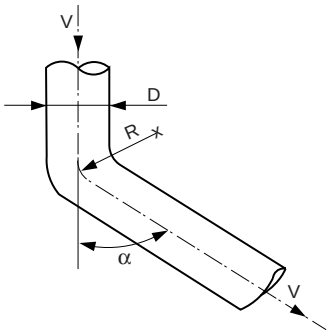
In general, the area of overflows relevant to the connected compartments is to be not less than S/10, where S is defined in [1.1.1].

Table 1 : Case 1 - 90° circular bend - Values of factor k



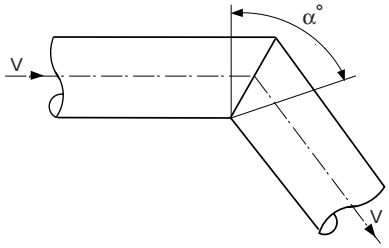
R/D	2	3	4	5	6	7
k	0,30	0,26	0,23	0,20	0,18	0,17

Table 2 : Case 2 - Radius bend R/D = 2 - Values of factor k



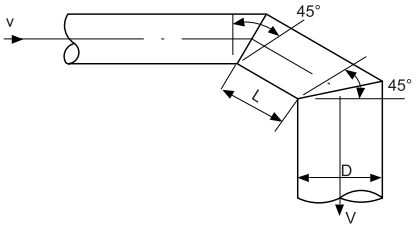
α°	15	30	45	60	75	90
k	0,06	0,12	0,18	0,24	0,27	0,30

Table 3 : Case 3 - Mitre Bend - Values of factor k



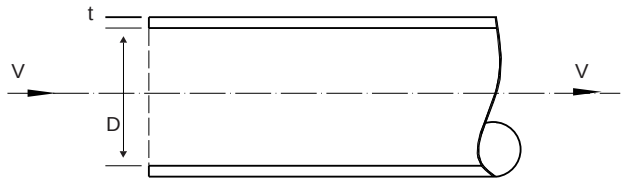
α°	5	15	30	45	60	90
k	0,02	0,06	0,17	0,32	0,68	1,26

Table 4 : Case 4 - Double Mitre Bend - Values of factor k



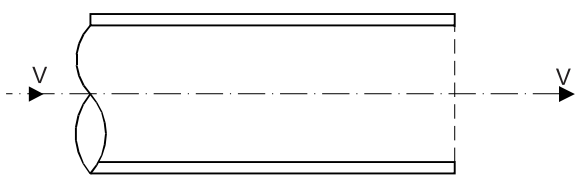
L/D	1	2	3	4	5	6
k	0,41	0,40	0,43	0,46	0,46	0,44

Table 5 : Case 5 - Pipe Inlet - Values of factor k



t/D	0,01	0,02	0,03	0,04	0,05	> 0,05
k	0,83	0,68	0,53	0,46	0,44	0,43

Table 6 : Case 6 - Pipe Outlet - Values of factor k



k = 1,0

Table 7 : Case 7 - Non-return valve - Values of factor k

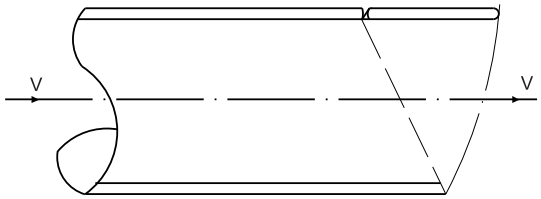
	k = 0,5 The value of k actually increases with decrease in Froude number, particularly below speeds of 2m/sec

Table 8 : Case 8 - Pipe Friction Losses - Values of factor k

k = 0,02/D per unit length
The coefficient above is a mean value and does in fact vary as Reynold's number (i.e. varies with V for constant D and ν) as well as with relative roughness.

Table 9 : Case 9 - Gate Valve - Values of factor k

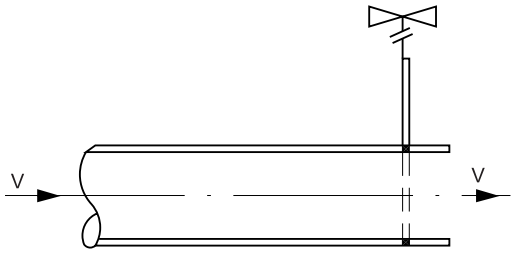
	k = 0,3

Table 10 : Case 10 - Butterfly Valve - Values of factor k

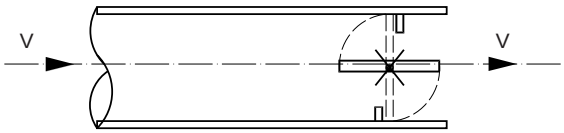
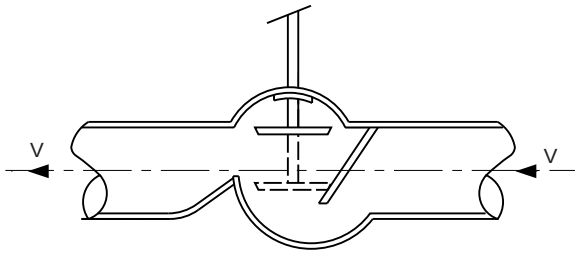
	k = 0,8

Table 11 : Case 11 - Disc Valve - Values of factor k

	k = 6,0

Appendix 4 Buoyancy Reserve - “V” Line Method

1 Buoyancy reserve

1.1 Purpose

1.1.1 This method allows to define the zones of flooding interested in damage cases.

The buoyancy check assures that the water couldn't exceed the margin line after the ship reaches the equilibrium at the end of the flooding.

It is necessary to take into account the dynamic effect of the rolling, which may cause a progressive flooding with considerable reduction of the stability characteristics of the ship.

The purpose of the “V” Line calculation is to determine, at the design stage, the areas which may be flooded after damage. If the waterline at the equilibrium after damage cannot be located above the margin line, the dynamic effects, such as rolling of the ship, waves, may cause water to be above the margin line. In this respect, progressive flooding may occur to spaces not previously flooded. Consequently it is necessary to define watertight boundaries in order to keep sufficient buoyancy and stability to the ship.

1.1.2 Method

The longitudinal envelope of the waterlines at the end of each symmetrical flooding for all examined loading conditions is to be taken into account.

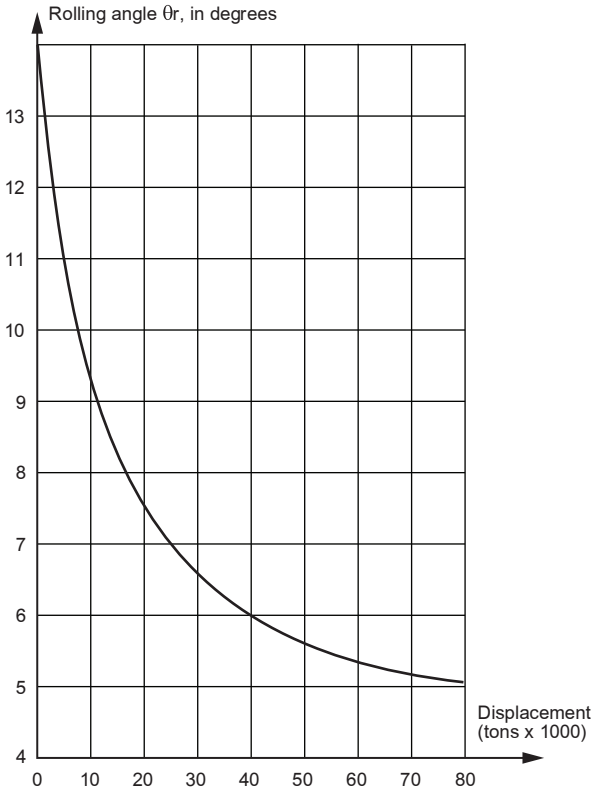
In each transversal section interested by such envelope, proceed as follows (see Fig 2):

a) an heeling angle equal to 15° is to be considered (safety target). This angle may be reduced when obtained from direct damage stability calculations

b) a further rolling angle is applied as shown in Fig 1

c) an elevation of the consequent level of 1,25 m is added to the waterline to consider the movement of the water inside the ship.

Figure 1 : Rolling angles to be taken into account in damage stability calculations, valid also in “V” Line tracing



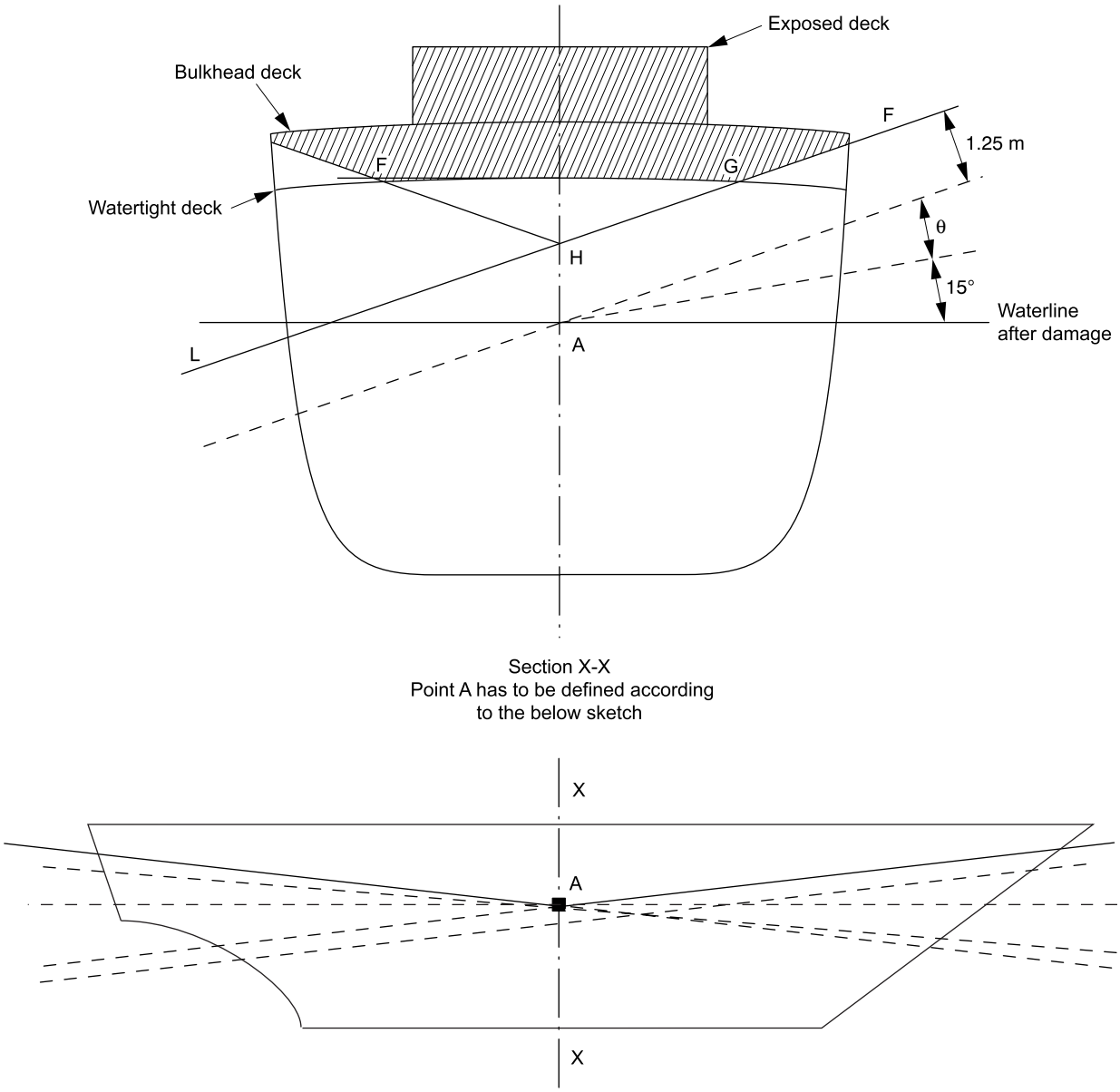
1.1.3 Interpretation of the obtained “V” Line

The “V” Line identifies, in each transversal section, two different zones above the watertight deck:

a) **zone inside “V” Line**, where it is possible to cross the auxiliary transversal bulkheads and the bulkhead deck without particular requirements relevant to the restoring of watertight integrity

b) **zone outside “V” Line**, where each crossing and/or opening is to be provided with a system of watertight closure as described in Ch 2, Sec 3.

Figure 2 : “V” Line example



Appendix 5 Evaluation of the Heeling Moment due to Athwart Wind (Intact Vessel)

1 Evaluation of the heeling moment due to athwart wind (intact vessel)

1.1 Intact stability

1.1.1 The inclining moment, IM, in t·m, caused by the wind is carried out with the following formula:

$$IM = \frac{0,0195 V^2 A h \cos^2 \theta}{1000}$$

where (see Fig 2):

V : Wind speed, in knots

h : Vertical distance, in m, between the windage centre surface and the driftage centre surface which may be considered at middle of draught

A : Area of windage surface, in m^2, above the waterline

θ : Transverse heeling angle, in degrees.

1.1.2 To obtain the value of the inclining arm, the value obtained from [1.1.1] is to be divided by the displacement of the vessel at the loading condition in question.

1.1.3 To define the heeling moment curve caused by the wind together with the result of the formula in [1.1.1], Fig 1 is to be used. In that Figure, the changing of the wind speed is represented as a function of the height above the waterline for a theoretical speed of 100 knots at 10 m. The value of the wind on the windage area is to be corrected by the ratio with such a curve.

1.1.4 For the purpose of facilitating the task, the values reported in Tab 1 may be used; they give, calculated from the formula in [1.1.1], the values of the inclining moment, taking account of the gradient of the wind speed as a function of the height above the waterline.

Figure 1 : Speed of the wind as a function of the height above the waterline

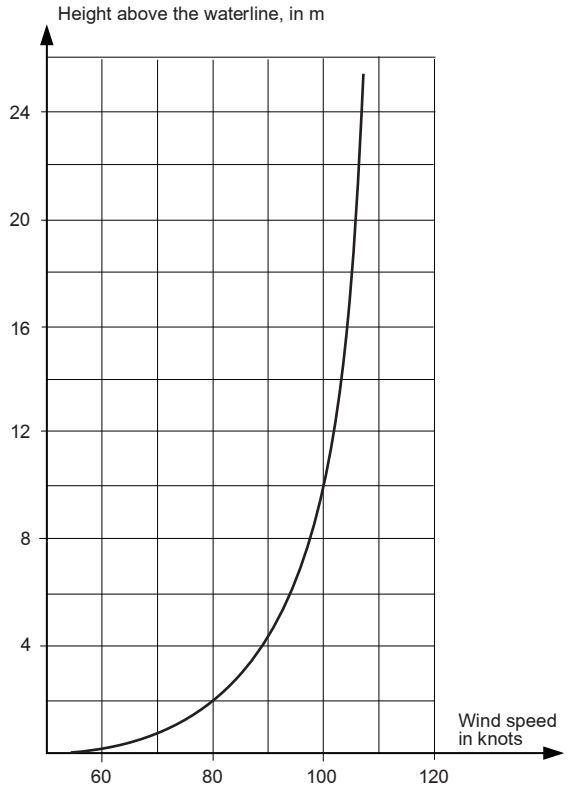


Figure 2 : Example showing the elements used in carrying out the heeling arms caused by the wind

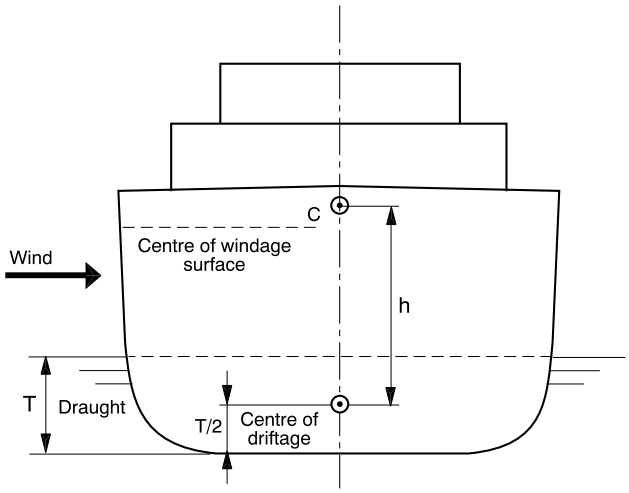


Table 1 : Inclining moment (t·m) per m² for a theoretical wind speed of 100 knots

Height above waterline (in m)	Ship centre of lateral resistance below waterline (in m)											
	0,25	0,50	0,75	1,00	1,25	1,50	1,75	2,00	2,25	2,50	2,75	3,00
0-2	0,13	0,16	0,19	0,21	0,24	0,27	0,29	0,32	0,35	0,37	0,40	0,43
2-4	0,45	0,49	0,52	0,56	0,59	0,63	0,66	0,70	0,73	0,77	0,80	0,84
4-6	0,87	0,91	0,95	0,99	1,03	1,08	1,12	1,16	1,20	1,24	1,28	1,32
6-8	1,31	1,36	1,40	1,45	1,49	1,54	1,58	1,63	1,67	1,72	1,76	1,81
8-10	1,76	1,81	1,86	1,90	1,95	2,00	2,05	2,09	2,14	2,19	2,24	2,28
10-12	2,23	2,28	2,33	2,38	2,43	2,48	2,53	2,58	2,63	2,67	2,72	2,77
12-14	2,72	2,77	2,82	2,87	2,93	2,98	3,03	3,08	3,13	3,18	3,23	3,28
14-16	3,22	3,27	3,32	3,37	3,43	3,48	3,53	3,59	3,64	3,69	3,74	3,80
16-18	3,73	3,78	3,84	3,89	3,95	4,00	4,05	4,11	4,16	4,22	4,27	4,32
18-20	4,23	4,29	4,34	4,40	4,45	4,51	4,56	4,62	4,67	4,73	4,78	4,84
20-22	4,77	4,83	4,88	4,94	5,00	5,05	5,11	5,16	5,22	5,28	5,33	5,39
22-24	5,30	5,35	5,41	5,47	5,53	5,58	5,64	5,70	5,75	5,81	5,87	5,92
24-26	5,78	5,83	5,89	5,95	6,00	6,06	6,12	6,18	6,23	6,29	6,35	6,40
26-28	6,23	6,29	6,35	6,40	6,46	6,52	6,58	6,63	6,69	6,75	6,80	6,86
28-30	6,69	6,75	6,80	6,86	6,92	6,98	7,03	7,09	7,15	7,20	7,26	7,32
Height above waterline (in m)	Ship centre of lateral resistance below waterline (in m)											
	3,25	3,50	3,75	4,00	4,25	4,50	4,75	5,00	5,25	5,50	5,75	6,00
0-2	0,46	0,48	0,51	0,54	0,56	0,59	0,62	0,64	0,67	0,70	0,72	0,75
2-4	0,87	0,91	0,94	0,98	1,01	1,05	1,08	1,12	1,15	1,19	1,22	1,26
4-6	1,36	1,41	1,45	1,49	1,53	1,57	1,61	1,65	1,70	1,74	1,78	1,82
6-8	1,85	1,90	1,94	1,99	2,03	2,08	2,12	2,17	2,22	2,26	2,31	2,35
8-10	2,33	2,38	2,43	2,47	2,52	2,57	2,62	2,66	2,71	2,76	2,81	2,86
10-12	2,82	2,87	2,92	2,97	3,02	3,07	3,12	3,17	3,22	3,27	3,32	3,37
12-14	3,34	3,39	3,44	3,49	3,54	3,59	3,64	3,69	3,75	3,80	3,85	3,90
14-16	3,85	3,90	3,95	4,01	4,06	4,11	4,17	4,22	4,27	4,32	4,38	4,43
16-18	4,38	4,43	4,49	4,54	4,59	4,65	4,70	4,76	4,81	4,86	4,92	4,97
18-20	4,89	4,95	5,00	5,06	5,11	5,17	5,22	5,28	5,33	5,39	5,44	5,50
20-22	5,44	5,50	5,56	5,61	5,67	5,72	5,78	5,84	5,89	5,95	6,01	6,06
22-24	5,98	6,04	6,10	6,15	6,21	6,27	6,32	6,38	6,44	6,49	6,55	6,61
24-26	6,46	6,52	6,58	6,63	6,69	6,75	6,80	6,86	6,92	6,98	7,03	7,09
26-28	6,92	6,98	7,03	7,09	7,15	7,20	7,26	7,32	7,38	7,43	7,49	7,55
28-30	7,38	7,43	7,49	7,55	7,60	7,66	7,72	7,78	7,83	7,89	7,95	8,00

1.1.5 Calculation procedure

a) The windage area is to be divided into strips 2 m in height starting from the considered waterline

b) The surface of each strip is to be calculated, in m^2

c) The vertical position of the centre of driftage area is to be evaluated (corresponding approximately to the half draught) and each strip is to be assigned a moment value as indicated in Tab 1

d) Each surface calculated in item b) is to be multiplied by its assigned moment value obtained in item c)

e) All the moments so obtained are to be added in order to have a moment corresponding to a theoretical wind speed of 100 knots

f) For a wind speed different from 100 knots, the value obtained in item e) is to be multiplied by the following value:

$$\left(\frac{V}{100}\right)^2$$

1.2 Damage stability

1.2.1 The same approach as in [1.1.1] is to be followed, taking account of:

h : Vertical distance, in m, between the windage centre surface and the driftage centre surface (which may be considered at middle of draught) in the final equilibrium after damage.

Appendix 6 Sea-Keeping Calculations

1 Introduction

1.1 General

1.1.1 This Appendix applies to ships with typical hull shape. Ships of unusual type or design are to be considered by the Society on a case by case basis.

The requirements are based on the assumption that a frequency domain strip theory sea-keeping code is being used for the calculations. The software to be used is to be documented and supported by validation documents.

1.2 Scope

1.2.1 The scope of the present Appendix is to supply details on how the sea-keeping calculations are to be performed. Requirements are given primarily on how to perform the short term assessments, but some recommendations concerning long term assessments are also given.

The short term assessments comprise all analyses of the ship behaviour in a single sea state, and thus short term assessments yield all necessary information for the determination of:

- wetness index
- slamming index
- propeller emergence
- Motion Induced Interruption
- RMS values of all ship motions and accelerations.

Long term assessments of the sea-keeping yield estimates of, for example, the long term distribution of the vertical bending moment.

2 Short term assessment

2.1 General

2.1.1 Short term assessments serve to analyse a ship sea-keeping behaviour in a given sea state. The sea states to be considered for the required rule checks are defined in Ch 3, Sec 4.

2.2 Loading conditions

2.2.1 The sea-keeping verifications are to be carried out for the following loading conditions:

- auxiliary ships: full load and operational load
- front and second line ships: operational load.

Refer to Ch 1, Sec 2, [5.2] and Ch 1, Sec 2, [5.3] for definitions of full load condition and operational load condition respectively. The verifications are to consider the loading conditions both “at delivery” and at “end of life.”

2.3 Ship speed

2.3.1 Unless otherwise specified, a discrete set of ship speeds to be agreed with the Society is to be considered for the short term sea-keeping calculations.

2.4 Wave spectrum

2.4.1 General

The wave spectrum to be applied in the short term sea-keeping calculations is based on the characteristics of the sea area where the ship is going to operate:

- open ocean conditions: Bretschneider spectrum with both short and long crested seas
- limited fetch sea areas (e.g. North Sea): JONSWAP spectrum with short crested sea.

2.4.2 Bretschneider spectrum

The Bretschneider spectrum, or two parameter Pierson-Moskowitz spectrum, is defined as:

$$S(\omega) = \frac{H_S^2}{4\pi}\left(\frac{2\pi}{T_Z}\right)^4 \omega^{-5} \exp\left(-\frac{1}{\pi}\left(\frac{2\pi}{T_Z}\right)^4 \omega^{-4}\right)$$

where:

H_S : Significant wave height, in m

ω : Angular wave frequency, in rad/s

T_Z : Zero up-crossing period, in s.

2.4.3 JONSWAP spectrum

The JONSWAP spectrum is defined as:

$$S(\omega)=173\frac{H_S^2 T_S (T_S\omega)^{-5}}{F_1 F_2^4}\exp(-692(F_2 T_S\omega)^{-4})\gamma^{\exp[-(0,206F_2T_S\omega-1)^2/2\sigma^2]}$$

where:

H_S : Significant wave height, in m

ω : Angular wave frequency, in rad/s

T_S : Mean wave period, in s

γ : JONSWAP peakedness parameter

$$\sigma = \begin{cases} 0,07 \text{ for } \omega \le (0,206F_2T_S)^{-1} \\ 0,09 \text{ for } \omega > (0,206F_2T_S)^{-1} \end{cases}$$

The values of F_1 and F_2 are given in Tab 1.

Unless otherwise agreed with the Society, the peakedness parameter γ is to be taken equal to 3,3, corresponding to the mean JONSWAP spectrum.

Table 1 : F_1 and F_2 values as a function of γ

γ	F_1	F_2
1	1,00	1,00
2	1,24	0,95
3	1,46	0,93
3,3 **(1)**	1,52	0,92
4	1,66	0,91
5	1,86	0,90
6	2,04	0,89
(1) Mean JONSWAP spectrum		

2.4.4 Wave spreading

In case of short crested sea a spreading function is to be applied to the wave spectrum when calculating the spectral moments of the response processes. The spreading function is defined as:

$$D(\psi) = \frac{2}{\pi}\cos^2(\bar{\psi}-\psi)$$

where:

ψ : Heading angle

ψ : Angle ranging from $(\psi - \pi/2)$ to $(\psi + \pi/2)$.

2.5 Hydrodynamic model

2.5.1 Short term assessment of the sea-keeping behaviour is to imply that RAO's (Response Amplitude Operators) are to be calculated for:

- A suitable range of wave frequencies to cover the range of the sea spectrum (typically 0,2-2,0 rad/s, with not less than 20 frequencies). Most frequencies are to be placed in the range where most wave energy is present, and the calculation of RAO's at irregular frequencies, or for wave frequencies where the encounter frequency approaches zero, is to be avoided.
- At least 12 evenly distributed heading angles: 0°, 30°, 60°, … , 330° (with 0° being the following sea).

2.6 Spectral moments

2.6.1 The n'th order response spectral moments are to be determined as follows:

- Short crested sea:

$$m_n = \int_0^{\infty} \int_{\bar{\psi}-\frac{\pi}{2}}^{\psi+\frac{\pi}{2}} \left| \omega - \frac{\omega^2 V}{g} \cos\psi \right|^n |\phi(\omega)|^2 S(\omega) D(\psi) d\psi d\omega$$

- Long crested sea:

$$m_n = \int_0^{\infty} \left| \omega - \frac{\omega^2 V}{g} \cos\psi \right|^n |\phi(\omega)|^2 S(\omega) d\omega$$

where:

V : Ship speed, in m/s

g : Gravity acceleration (g = 9,81 m/s^2)

ψ : Heading angle

$D(\psi)$: Spreading function

$\phi(\omega)$: RAO

$S(\omega)$: Wave spectrum

ω : Wave frequency, in rad/s.

2.7 RMS values

2.7.1 The Root Mean Square (RMS) value of a response is defined as:

$$RMS = \sqrt{m_0}$$

where m_0 is the zero'th order spectral moment of the response.

3 Long term assessment

3.1 General

3.1.1 Long term assessments serve to estimate long term distributions of the various ship responses, typically the wave induced amidships vertical bending moment.

Such a long term distribution can thus be used to obtain estimates of the extreme responses, for example, the most probable largest response in 10^8 wave cycles.

3.2 Hydrodynamic model

3.2.1 Unless otherwise agreed with the Society, the long term assessments are to be carried out with the following hydrodynamic model:

- zero forward speed
- Bretschneider wave spectrum
- short crested sea
- a suitable range of wave frequencies to cover the range of the sea spectrum (typically 0,2-2,0 rad/s with not less than 20 frequencies). Most frequencies are to be placed in the range where most wave energy is present, and the calculation of RAO's at irregular frequencies is to be avoided
- at least 12 evenly distributed heading angles
- uniform distribution of heading angles, meaning that the same probability (e.g. 1/12 if 12 heading angles are considered) is assigned to each considered heading
- extreme responses are to be determined at 10^{-8} probability of exceedance.

3.3 Sea state scatter diagram

3.3.1 The scatter diagram to be applied in the spectral approach relates the probability of occurrence to a wide range of sea states, characterised by their significant wave height and zero up-crossing period.

When considering unrestricted service the scatter diagram shown in Tab 2 is to be applied. However, in case of ship with a restricted navigation notation, different scatter diagrams may be applied when agreed on with the Society.

Table 2 : Recommended sea state scatter diagram for unrestricted service

H_S	T_Z																		
	1,5	2,5	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5	11,5	12,5	13,5	14,5	15,5	16,5	17,5	18,5	SUM
0,5	0	0	1,3	133,7	865,6	1186	634,2	186,3	36,9	5,6	0,7	0,1	0	0	0	0	0	0	3050
1,5	0	0	0	29,3	986	4976	7738	5569,7	2375,7	703,5	160,7	30,5	5,1	0,8	0,1	0	0	0	22575
2,5	0	0	0	2,2	197,5	2158,8	6230	7449,5	4860,4	2066	644,5	160,2	33,7	6,3	1,1	0,2	0	0	23810
3,5	0	0	0	0,2	34,9	695,5	3226,5	5675	5099,1	2838	1114,1	337,7	84,3	18,2	3,5	0,6	0,1	0	19128
4,5	0	0	0	0	6	196,1	1354,3	3288,5	3857,5	2685,5	1275,2	455,1	130,9	31,9	6,9	1,3	0,2	0	13289
5,5	0	0	0	0	1	51	498,4	1602,9	2372,7	2008,3	1126	463,6	150,9	41	9,7	2,1	0,4	0,1	8328
6,5	0	0	0	0	0,2	12,6	167	690,3	1257,9	1268,6	825,9	386,8	140,8	42,2	10,9	2,5	0,5	0,1	4806
7,5	0	0	0	0	0	3	52,1	270,1	594,4	703,2	524,9	276,7	111,7	36,7	10,2	2,5	0,6	0	2586
8,5	0	0	0	0	0	0,7	15,4	97,9	255,9	350,6	296,9	174,6	77,6	27,7	8,4	2,2	0,5	0,1	1309
9,5	0	0	0	0	0	0,2	4,3	33,2	101,9	159,9	152,2	99,2	48,3	18,7	6,1	1,7	0,4	0,1	626
10,5	0	0	0	0	0	0	1,2	10,7	37,9	67,5	71,7	51,5	27,3	11,4	4	1,2	0,3	0,1	285
11,5	0	0	0	0	0	0	0,3	3,3	13,3	26,6	31,4	24,7	14,2	6,4	2,4	0,7	0,2	0,1	124
12,5	0	0	0	0	0	0	0,1	1	4,4	9,9	12,8	11	6,8	3,3	1,3	0,4	0,1	0	51
13,5	0	0	0	0	0	0	0	0,3	1,4	3,5	5	4,6	3,1	1,6	0,7	0,2	0,1	0	21
14,5	0	0	0	0	0	0	0	0,1	0,4	1,2	1,8	1,8	1,3	0,7	0,3	0,1	0	0	8
15,5	0	0	0	0	0	0	0	0	0,1	0,4	0,6	0,7	0,5	0,3	0,1	0,1	0	0	3
16,5	0	0	0	0	0	0	0	0	0	0,1	0,2	0,2	0,2	0,1	0,1	0	0	0	1
SUM	0	0	1	165	2091	9280	19922	24879	20870	12898	6245	2479	837	247	66	16	3	1	100.0000

Note 1: H_S is the significant wave height and T_Z is the zero up-crossing period of the short term sea states. The probability of a sea state is given as fractions of 100.000.

CHAPTER 4
STRUCTURE DESIGN PRINCIPLES

Section 1 Materials
Section 2 Net Scantling Approach
Section 3 Strength Principles
Section 4 Bottom Structure
Section 5 Side Structure
Section 6 Deck Structure
Section 7 Bulkhead Structure

Section 1 Materials

1 General

1.1 Characteristics of materials

1.1.1 Materials used during construction of ships are to comply with the applicable requirements of NR216 Materials and Welding.

1.1.2 Materials other than those covered in [1.1.1] may be accepted, provided that their specification (e.g. manufacture, chemical composition, mechanical properties, welding, etc.) is submitted to the Society for approval.

1.2 Testing of materials

1.2.1 Materials are to be tested in compliance with the applicable requirements of NR216 Materials and Welding.

1.3 Manufacturing processes

1.3.1 The requirements of this Section presume that welding and other cold or hot manufacturing processes are carried out in compliance with current sound working practice and the applicable requirements of NR216 Materials and Welding.

In particular:

- parent material and welding processes are to be approved within the limits stated for the specified type of material for which they are intended
- specific preheating may be required before welding
- welding or other cold or hot manufacturing processes may need to be followed by an adequate heat treatment.

2 Steels for hull structure

2.1 Application

2.1.1 Steel having a specified minimum yield stress equal to 235 N/mm² is regarded as normal strength steel and is denoted "NSS". Steel having a higher specified minimum yield stress is regarded as higher strength steel and is denoted "HSS".

Steel grades are referred to as follows:

- A, B, D and E denote normal strength steel grades
- AH, DH and EH denote higher strength steel grades.

Tab 1 gives the mechanical characteristics of steels generally used in the construction of ships.

Higher strength steels other than those indicated in Tab 1 are considered by the Society on a case-by-case basis.

2.1.2 When steels with a minimum guaranteed yield stress R_{eH} other than 235 N/mm² are used on a ship, hull scantlings are to be determined, taking into account the material factor k defined in [2.3].

2.1.3 Characteristics of steels with specified through thickness properties are given in NR216, Ch 3, Sec 1, [12].

Table 1 : Mechanical properties of hull steels for plates with thickness t ≤ 100 mm

Steel grades	R_{eH}, in N/mm²	R_m, in N/mm²
A-B-D-E	235	400 - 520
AH32-DH32-EH32-FH32	315	440 - 570
AH36-DH36-EH36-FH36	355	490 - 630
AH40-DH40-EH40 FH40	390	510 - 660
Note 1: Refer to NR216 Materials and Welding, Ch 2, Sec 1, [2]. R_{eH} : Minimum yield stress R_m : Ultimate minimum tensile strength.		

2.2 Information to be kept on board

2.2.1 A plan indicating the steel types and grades adopted for the hull structures is to be kept on board. Where steels other than those indicated in Tab 1 are used, their mechanical and chemical properties, as well as any workmanship requirements or recommendations, are to be available on board together with the above plan. When materials with sensitive know-how are used, it may be accepted that they are only documented on case by case for repair in service.

2.3 Material factor k

2.3.1 Unless otherwise specified, the material factor k has the values defined in Tab 2, as a function of the minimum guaranteed yield stress R_{eH}.

For intermediate values of R_{eH}, k may be obtained by linear interpolation.

Table 2 : Material factor k

R_{eH}, in N/mm^2	k
235	1,00
315	0,78
355	0,72
390	0,68

2.3.2 Steels with a yield stress lower than 235 N/mm^2 or greater than 390 N/mm^2 are considered by the Society on a case-by-case basis.

When steels with a yield stress greater than 390 N/mm^2 are used, the material factor k is limited to 0,68 for scantlings calculations under Rules loads.

2.3.3 For strength checks as detailed in Part B, Chapter 7 and Part B, Chapter 8 under local loads whose frequency of appearance is not liable to create fatigue damage (e.g. helicopter landing), the minimum yield stress of the material R_y may be considered equal to R_{eH}, subject to the special agreement of the Society on a case-by-case basis.

2.4 Grades of steel

2.4.1 For the purpose of the selection of steel grades to be used for the various structural members, the latter are divided into categories (SECONDARY, PRIMARY and SPECIAL), as indicated in Tab 3.

Tab 3 also specifies the classes (I, II and III) of the materials to be used for the various categories of structural members.

2.4.2 Materials are to be of a grade not lower than that indicated in Tab 3 or in Tab 4 for front line or second line ships, depending on the material class and structural member gross thickness (see [2.4.5]).

2.4.3 For strength members not mentioned in Tab 3, grade A/AH may generally be used.

2.4.4 Single strakes required to be of class III or of grade E/EH are to have a breadth within 0,4L amidships not less than (800 + 5 L) mm, but not necessarily greater than 1800 mm.

2.4.5 The steel grade is to correspond to the as-fitted gross thickness when this one is greater than the gross thickness obtained from the net thickness required by the Rules, according to Ch 4, Sec 2, [1].

2.4.6 Steel grades of plates or sections of gross thickness greater than the limiting thicknesses in Tab 4 are considered by the Society on a case-by-case basis.

2.4.7 In specific cases, such as in [2.4.8], with regard to stress distribution along the hull girder, the classes required within 0,4 L amidships may be extended beyond that zone, on a case-by-case basis.

2.4.8 The material classes required for the strength deck plating, the sheerstrake and the upper strake of longitudinal bulkheads within 0,4 L amidships are to be maintained over an adequate length across the poop front and at the ends of the bridge, where fitted.

2.4.9 Rolled products used for welded attachments on hull plating, such as gutter bars and bilge keels, are to be of the same grade (or equivalent) as the one used for the hull plating in way.

Where it is necessary to weld attachments to the sheerstrake or stringer plate, attention is to be given to the appropriate choice of material and design, the workmanship and welding and the absence of prejudicial undercuts and notches, with particular regard to any free edges of the material.

2.4.10 In the case of full penetration welded joints located in positions where high local stresses may occur perpendicular to the continuous plating, the Society may, on a case-by-case basis, require the use of rolled products having adequate ductility properties in the through thickness direction, such as to prevent the risk of lamellar tearing (Z type steel, see NR216 Materials and Welding). For such situation involving small weight of plates, a case-by-case consideration is to be given.

2.4.11 In highly stressed areas other than Class III according to Tab 3, the Society may require that plates of gross thickness greater than 20 mm are of grade D/DH or E/EH.

Table 3 : Application of material classes and grades

Structural member category	Material class or grade	
	Within 0,4 L amidships	Outside 0,4 L amidships
SECONDARY: Lower strake in longitudinal bulkhead Deck plating exposed to weather (in general) Side plating	I	A / AH**(6)**
PRIMARY: Bottom plating (including keel plate) Strength deck plating **(1)** Continuous longitudinal members above strength deck (excluding continuous longitudinal hatch coamings of ships equal to or greater than 90 m in length) Upper strake in longitudinal bulkhead Vertical strake (hatch side girder) and upper sloped strake in topside tank	II	A / AH **(7)**
SPECIAL: Sheerstrake at strength deck **(2)** Stringer plate in strength deck**(2)** Deck strake at longitudinal bulkhead Bilge strake **(3) (4)** Continuous longitudinal hatch coamings of ships equal to or greater than 90 m in length **(6)**	III	II **(8)** (I outside 0,6 L amidships)

(1) Plating at corners of large hatch openings to be considered on a case-by-case basis. Class III or grade E/EH to be applied in positions where high local stresses may occur

(2) To be not less than grade E/EH within 0,4L amidships in ships greater than 250 m in length

(3) May be of class II in ships less than 150 m in length and having a double bottom over the full breadth

(4) To be not less than grade D/DH in ships greater than 250 m in length

(5) To be not less than grade D/DH

(6) To be of class I for front line or second line ships

(7) To be of class II for front line and second line ships

(8) To be of class III for front line and second line ships.

Note 1: Plating materials for sternframes, rudders, rudder horns and shaft brackets are generally to be of grades not lower than those corresponding to class II.

For rudder and rudder blade plates subjected to stress concentrations (e.g. in way of lower support of semi-spade rudders or at upper part of spade rudders), class III is to be applied.

Note 2: Bedplates of seats for propulsion and auxiliary engines inserted in the inner bottom are to be of class I. In other cases, the steel may be generally of grade A. Different grades may be required by the Society on a case-by-case basis.

Note 3: Plating at corners of large hatch openings on decks located below the strength deck, in the case of hatches of holds for refrigerated cargoes, and insert plates at corners of large openings on side shell plating are generally to be of class III.

Table 4 : Material grade requirements for classes I, II and III

Class	I		II		III	
Gross thickness, in mm	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 15	A	AH	A	AH	A	AH
15 < t ≤ 20	A	AH	A	AH	B	AH
20 < t ≤ 25	A	AH	B	AH	D	DH
25 < t ≤ 30	A	AH	D	DH	D	DH
30 < t ≤ 35	B	AH	D	DH	E	EH
35 < t ≤ 40	B	AH	D	DH	E	EH
40 < t ≤ 50	D	DH	E	EH	E	EH

Note 1: see [2.1.1] for definitions of NSS and HSS.

2.5 Grades of steel for structures exposed to low air temperatures

2.5.1 For ships intended to operate in areas with low air temperatures (–20°C or below), e.g. regular service during winter seasons to Arctic or Antarctic waters, the materials in exposed structures are to be selected based on the design temperature t_D, to be taken as defined in [2.5.2].

2.5.2 The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation, where:

Mean : Statistical mean over observation period (at least 20 years)

Average : Average during one day and night

Lowest : Lowest during one year.

Fig 1 illustrates the temperature definition.

For seasonally restricted service, the lowest value within the period of operation applies.

2.5.3 For the purpose of the selection of steel grades to be used for the structural members above the lowest ballast waterline and exposed to air, the latter are divided into categories (SECONDARY, PRIMARY and SPECIAL), as indicated in Tab 5.

Tab 5 also specifies the classes (I, II and III) of the materials to be used for the various categories of structural members.

For non-exposed structures and structures below the lowest ballast waterline, see [2.4].

2.5.4 Materials may not be of a lower grade than that indicated in Tab 6 to Tab 8 depending on the material class, the structural member gross thickness and design temperature t_D.

For design temperatures $t_D < -55$°C, materials are to be specially considered by the Society on a case-by-case basis.

2.5.5 Single strakes required to be of class III or of grade E/EH or FH are to have breadths not less than (800+5L) mm, but not necessarily greater than 1800 mm.

Figure 1 : Commonly used definitions of temperatures

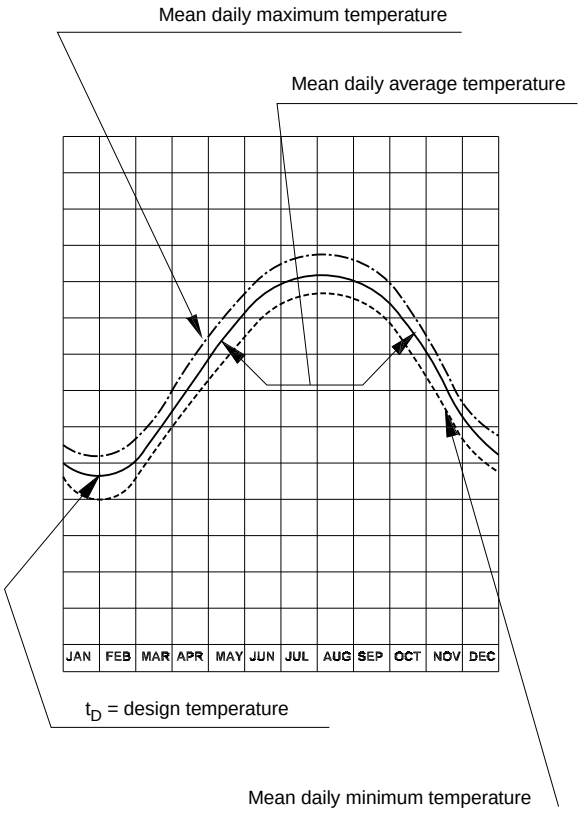


Table 5 : Application of material classes and grades - Structures exposed to low air temperatures

Structural member category	Material class	
	Within 0,4 L amidships	Outside 0,4 L amidships
SECONDARY: Deck plating exposed to weather (in general) Side plating above T_B **(1)** Transverse bulkheads above T_B **(1)**	I	I
PRIMARY: Strength deck plating **(2)** Continuous longitudinal members above strength deck (excluding longitudinal hatch coamings of ships equal to or greater than 90 m in length) Longitudinal bulkhead above T_B **(1)** Topside tank bulkhead above T_B **(1)**	II	I
SPECIAL: Sheerstrake at strength deck **(3)** Stringer plate in strength deck **(3)** Deck strake at longitudinal bulkhead Continuous longitudinal hatch coamings of ships equal to or greater than 90 m in length **(4)**	III	II

(1) T_B is the draught in light ballast condition, defined in Ch 5, Sec 1, [2.4.3]

(2) Plating at corners of large hatch openings to be considered on a case-by-case basis. Class III or grade E/EH to be applied in positions where high local stresses may occur

(3) To be not less than grade E/EH within 0,4 L amidships in ships greater than 250 m in length

(4) To be not less than grade D/DH.

Note 1: Plating materials for sternframes, rudder horns, rudders and shaft brackets are to be of grades not lower than those corresponding to the material classes in [2.4].

Table 6 : Material grade requirements for class I at low temperatures

Gross thickness, in mm	–20°C / –25°C		–26°C / –35°C		–36°C / –45°C		–46°C / –55°C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	A	AH	B	AH	D	DH	D	DH
10 < t ≤ 15	B	AH	D	DH	D	DH	D	DH
15 < t ≤ 20	B	AH	D	DH	D	DH	E	EH
20 < t ≤ 25	D	DH	D	DH	D	DH	E	EH
25 < t ≤ 30	D	DH	D	DH	E	EH	E	EH
30 < t ≤ 35	D	DH	D	DH	E	EH	E	EH
35 < t ≤ 45	D	DH	E	EH	E	EH	N.A.	FH
45 < t ≤ 50	E	EH	E	EH	N.A.	FH	N.A.	FH

Note 1: see [2.1.1] for definitions of NSS and HSS.

Note 2: N.A. = Not applicable.

Table 7 : Material grade requirements for class II at low temperatures

Gross thickness, in mm	–20°C / –25°C		–26°C / –35°C		–36°C / –45°C		–46°C / –55°C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	B	AH	D	DH	D	DH	E	EH
10 < t ≤ 20	D	DH	D	DH	E	EH	E	EH
20 < t ≤ 30	D	DH	E	EH	E	EH	N.A.	FH
30 < t ≤ 40	E	EH	E	EH	N.A.	FH	N.A.	FH
40 < t ≤ 45	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
45 < t ≤ 50	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.

Note 1: see [2.1.1] for definitions of NSS and HSS.

Note 2: N.A. = Not applicable.

Table 8 : Material grade requirements for class III at low temperatures

Gross thickness, in mm	–20°C / –25°C		–26°C / –35°C		–36°C / –45°C		–46°C / –55°C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	D	DH	D	DH	E	EH	E	EH
10 < t ≤ 20	D	DH	E	EH	E	EH	N.A.	FH
20 < t ≤ 25	E	EH	E	EH	N.A.	FH	N.A.	FH
25 < t ≤ 30	E	EH	E	EH	N.A.	FH	N.A.	FH
30 < t ≤ 35	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
35 < t ≤ 40	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
40 < t ≤ 50	N.A.	FH	N.A.	FH	N.A.	N.A.	N.A.	N.A.

Note 1: see [2.1.1] for definitions of NSS and HSS.
Note 2: N.A. = Not applicable.

2.6 Grades of steel within refrigerated spaces

2.6.1 For structural members within or adjacent to refrigerated spaces, when the design temperature is below 0°C, the materials are to be of grade not lower than those indicated in Tab 9, depending on the design temperature, the structural member gross thickness and its category (as defined in Tab 3).

2.6.2 Unless a temperature gradient calculation is carried out to assess the design temperature and the steel grade in the structural members of the refrigerated spaces, the temperatures to be assumed are specified below:

- temperature of the space on the uninsulated side, for plating insulated on one side only, either with uninsulated stiffening members (i.e. fitted on the uninsulated side of plating) or with insulated stiffening members (i.e. fitted on the insulated side of plating)
- mean value of temperatures in the adjacent spaces, for plating insulated on both sides, with insulated stiffening members, when the temperature difference between the adjacent spaces is generally not greater than 10°C (when the temperature difference between the adjacent spaces is greater than 10°C, the temperature value is established by the Society on a case-by-case basis)
- in the case of non-refrigerated spaces adjacent to refrigerated spaces, the temperature in the non-refrigerated spaces is to be conventionally taken equal to 0°C.

2.6.3 Situations other than those mentioned in [2.6.1] and [2.6.2] or special arrangements are to be considered by the Society on a case-by-case basis.

2.6.4 Irrespective of the provisions of [2.6.1], [2.6.2] and Tab 9, steel having grades lower than those required in [2.4], Tab 3 and Tab 4 and in relation to the class and the gross thickness of the structural member considered may not be used.

Table 9 : Material grade requirements for members within or adjacent to refrigerated spaces

Design temperature, in °C	Gross thickness, in mm	Structural member category	
		Secondary	Primary or Special
$-10 \le t_D < 0$	t ≤ 20	B / AH	B / AH
	20 < t ≤ 25	B / AH	D / DH
	t > 25	D / DH	E / EH
$-25 \le t_D < -10$	t ≤ 15	B / AH	D / DH
	15 < t ≤ 25	D / DH	E / EH
	t > 25	E / EH	E / EH
$-40 \le t_D < -25$	t ≤ 25	D / DH	E / EH
	t > 25	E / EH	E / EH

3 Steels for forging and casting

3.1 General

3.1.1 Mechanical and chemical properties of steels for forging and casting to be used for structural members are to comply with the applicable requirements of NR216 Materials and Welding.

3.1.2 Steels of structural members intended to be welded are to have mechanical and chemical properties deemed appropriate for this purpose by the Society on a case-by-case basis.

3.1.3 The steels used are to be tested in accordance with the applicable requirements of NR216 Materials and Welding.

3.2 Steels for forging

3.2.1 Rolled bars may be accepted in lieu of forged products, after consideration by the Society on a case-by-case basis.

In such case, compliance with the requirements of NR216 Materials and Welding, Ch 2, Sec 1, relevant to the quality and testing of rolled parts accepted in lieu of forged parts, may be required.

3.3 Steels for casting

3.3.1 Cast parts intended for stems, sternframes, rudders, parts of steering gear and deck machinery in general may be made of C and C-Mn weldable steels of quality 1, having tensile strength R_m equal to 400 N/mm^2 or 440 N/mm^2, in accordance with the applicable requirements of NR216 Materials and Welding, Ch 2, Sec 4.

Items which may be subjected to high stresses may be required to be of quality 2 steels of the above types.

3.3.2 The welding of cast parts to main plating contributing to hull strength members is considered by the Society on a case-by-case basis.

The Society may require additional properties and tests for such casting, in particular impact properties which are appropriate to those of the steel plating on which the cast parts are to be welded and non-destructive examinations.

3.3.3 Heavily stressed cast parts of steering gear, particularly those intended to form a welded assembly and tillers or rotors mounted without key, are to be subjected to non-destructive examination to check their internal structure.

4 Aluminium alloy structures

4.1 General

4.1.1 The characteristics of aluminium alloys are to comply with the requirements of NR216 Materials and Welding, Ch 3, Sec 2.

Series 5000 aluminium-magnesium alloys or series 6000 aluminium-magnesium-silicon alloys are generally to be used (see NR216 Materials and Welding, Ch 3, Sec 2, [2]).

4.1.2 In the case of structures subjected to low service temperatures or intended for other specific applications, the alloys to be employed are defined in each case by the Society, which states the acceptability requirements and conditions.

4.2 Extruded plating

4.2.1 Extrusions with built-in plating and stiffeners, referred to as extruded plating, may be used.

4.2.2 In general, the application is limited to decks, bulkheads, superstructures and deckhouses and any other element not contributing to the hull girder strength. Other uses may be permitted by the Society on a case-by-case basis.

4.2.3 Extruded plating is preferably to be oriented so that the stiffeners are parallel to the direction of main stresses.

4.2.4 Connections between extruded plating and primary members are to be given special attention.

4.3 Influence of welding on mechanical characteristics

4.3.1 Welding heat input lowers locally the mechanical strength of aluminium alloys hardened by work hardening (series 5000 other than condition 0 or H111) or by heat treatment (series 6000).

4.3.2 Consequently, where necessary, a drop in the mechanical characteristics of welded structures with respect to those of the parent material is to be considered in the heat-affected zone.

The heat-affected zone may be taken to extend 25 mm on each side of the weld axis.

4.3.3 Aluminium alloys of series 5000 in 0 condition (annealed) or in H111 condition (annealed flattened) are not subject to a drop in mechanical strength in the welded areas.

4.3.4 Aluminium alloys of series 5000 other than condition 0 or H111 are subject to a drop in mechanical strength in the welded areas.

The mechanical characteristics to consider are normally those of condition 0 or H111.

Higher mechanical characteristics may be taken into account, provided they are duly justified.

4.3.5 Aluminium alloys of series 6000 are subject to a drop in mechanical strength in the vicinity of the welded areas.

The mechanical characteristics to be considered are normally indicated by the supplier.

4.4 Material factor k

4.4.1 The material factor k for aluminium alloys is to be obtained from the following formula:

$$k = \frac{235}{R'_{lim}}$$

where:

R'_{lim} : Minimum guaranteed yield stress of the parent metal in welded condition $R'_{p0,2}$, in N/mm^2, but not to be taken greater than 70% of the minimum guaranteed tensile strength of the parent metal in welded condition R'_m, in N/mm^2

$R'_{p0,2} = \eta_1 R_{p0,2}$

$R'_m = \eta_2 R_m$

$R_{p0,2}$: Minimum guaranteed yield stress, in N/mm^2, of the parent metal in delivery condition

R_m : Minimum guaranteed tensile stress, in N/mm^2, of the parent metal in delivery condition.

η_1 and η_2 are given in Tab 10.

4.4.2 In the case of welding of two different aluminium alloys, the material factor k to be considered for the scantlings is the greater material factor of the aluminium alloys of the assembly.

4.4.3 For welded constructions in hardened aluminium alloys (series 5000 other than condition 0 or H111 and series 6000), greater characteristics than those in welded condition may be considered, provided that welded connections are located in areas where stress levels are acceptable for the alloy considered in annealed or welded condition.

Table 10 : Aluminium alloys for welded construction

Aluminium alloy	η_1	η_2
Alloys without work-hardening treatment (series 5000 in annealed condition 0 or annealed flattened condition H111)	1	1
Alloys hardened by work hardening (series 5000 other than condition 0 or H111)	$R'_{p0,2}/R_{p0,2}$	R'_m / R_m
Alloys hardened by heat treatment (series 6000) **(1)**	$R'_{p0,2}/R_{p0,2}$	0,6
(1) When no information is available, coefficient η is to be taken equal to the metallurgical efficiency coefficient β defined in Tab 11. **Note 1:** $R'_{p0,2}$: Minimum guaranteed yield stress, in N/mm^2, of material in welded condition (see [4.3]). R'_m : Minimum guaranteed tensile stress, in N/mm^2, of material in welded condition (see [4.3]).		

Table 11 : Aluminium alloys Metallurgical efficiency coefficient β

Aluminium alloy	Temper condition	Gross thickness	β
6005 A (Open sections)	T5 or T6	t ≤ 6 mm	0,45
		t > 6 mm	0,40
6005 A (Closed sections)	T5 or T6	all	0,50
6061 (Sections)	T6	all	0,53
6082 (Sections)	T6	all	0,45

5 Other materials and products

5.1 General

5.1.1 Other materials and products such as parts made of iron castings, where allowed, products made of copper and copper alloys, rivets, anchors, chain cables, cranes, masts, derrick posts, derricks, accessories and wire ropes are generally to comply with the applicable requirements of NR216 Materials and Welding.

5.1.2 The use of plastics or other special materials not covered by these Rules is to be considered by the Society on a case-by-case basis. In such cases, the Society states the requirements for the acceptance of the materials concerned.

5.1.3 Materials used in welding processes are to comply with the applicable requirements of NR216 Materials and Welding.

5.2 Iron cast parts

5.2.1 As a rule, the use of grey iron, malleable iron or spheroidal graphite iron cast parts with combined ferritic/perlitic structure is allowed only to manufacture low stressed elements of secondary importance.

5.2.2 Ordinary iron cast parts may not be used for windows or sidescuttles; the use of high grade iron cast parts of a suitable type is to be considered by the Society on a case-by-case basis.

Section 2 Net Scantling Approach

Symbols

t_C : Rule corrosion addition, in mm, see Article [3]

w_N : Net section modulus, in cm^3, of ordinary stiffeners

w_G : Gross section modulus, in cm^3, of ordinary stiffeners.

1 Application criteria

1.1 General

1.1.1 The scantlings obtained by applying the criteria specified in Part B are net scantlings, i.e. those which provide the strength characteristics required to sustain the loads, excluding any addition for corrosion. Exceptions are the scantlings of:

- bow and inner doors in Ch 8, Sec 5
- side doors and stern doors in Ch 8, Sec 6
- rudder structures and hull appendages in Part B, Chapter 9
- massive pieces made of steel forgings, steel castings or iron castings,

which are gross scantlings, i.e. they include additions for corrosion.

1.1.2 The required strength characteristics are:

- thickness, for plating including that which constitutes primary supporting members
- section modulus, shear area, moments of inertia and local thickness, for ordinary stiffeners and, as the case may be, primary supporting members
- section modulus, moments of inertia and single moment for the hull girder.

1.1.3 The ship is to be built at least with the gross scantlings obtained by adding the corrosion additions, specified in Tab 2, to the net scantlings.

2 Net strength characteristic calculation

2.1 Designer's proposal based on gross scantlings

2.1.1 General criteria

If the Designer provides the gross scantlings of each structural element without providing the corrosion additions, the structural checks are to be carried out on the basis of the net strength characteristics, derived as specified in [2.1.2] to [2.1.6].

2.1.2 Plating

The net thickness is to be obtained by deducting t_c from the gross thickness.

2.1.3 Ordinary stiffeners

The net transverse section is to be obtained by deducting t_C from the gross thickness of the elements which constitute the stiffener profile. For bulb profiles, an equivalent angle profile, as specified in Ch 4, Sec 3, [3.1.2], may be considered.

The net strength characteristics are to be calculated for the net transverse section. As an alternative, the net section modulus may be obtained from the following formula:

$$w_N = w_G(1 - \alpha t_C) - \beta t_C$$

where α and β are the coefficients defined in Tab 1.

Table 1 : Coefficients α and β

Type of ordinary stiffeners	α	β
Flat bars	0,035	2,8
Flanged profiles	0,060	14,0
Bulb profiles:		
$w_G \leq 200$ cm^3	0,070	0,4
$w_G > 200$ cm^3	0,035	7,4

2.1.4 Primary supporting members analysed through an isolated beam structural model

The net transverse section is to be obtained by deducting t_C from the gross thickness of the elements which constitute the primary supporting members.

The net strength characteristics are to be calculated for the net transverse section.

2.1.5 Primary supporting members analysed through a three dimensional model or a complete ship model

The net thickness of plating which constitutes primary supporting members is to be obtained by deducting 0,5 t_c from the gross thickness.

2.1.6 Hull girder net strength characteristics

For the hull girder, the net hull transverse sections are to be considered as being constituted by plating and stiffeners having net scantlings calculated on the basis of the corrosion additions t_C, according to [2.1.2] to [2.1.4].

2.2 Designer's proposal based on net scantlings

2.2.1 Net strength characteristics and corrosion additions

If the Designer provides the net scantlings of each structural element, the structural checks are to be carried out on the basis of the proposed net strength characteristics.

The Designer is also to provide the corrosion additions or the gross scantlings of each structural element. The proposed corrosion additions are to be not less than the values specified in [3].

2.2.2 Hull girder net strength characteristic

For the hull girder, the net hull transverse sections are to be considered as being constituted by plating and stiffeners having the net scantlings proposed by the Designer.

It is to be checked whether:

$Z_{NAD} \geq 0,9\ Z_{GD}$

where:

Z_{NAD} : Net midship section modulus, in m^3, calculated on the basis of the net scantlings proposed by the Designer

Z_{GD} : Gross midship section modulus, in m^3, calculated on the basis of the gross scantlings proposed by the Designer.

Where the above condition is not satisfied, the hull girder normal and shear stresses, to be used for the checks of plating, ordinary stiffeners and primary supporting members analysed through an isolated beam structural model, are to be obtained by dividing by 0,9 those obtained by considering the hull girder transverse sections with their gross scantlings.

3 Corrosion additions

3.1 Values of corrosion additions

3.1.1 General

The values of the corrosion additions specified in this Article are to be applied in relation to the relevant protective coatings required by the Rules.

The Designer may define values of corrosion additions greater than those specified in [3.1.2].

The values of corrosion additions as given in Tab 2 apply to structure scantlings resulting from loads under normal operation at sea in peace time.

3.1.2 Corrosion additions for steel other than stainless steel

In general, the corrosion addition to be considered for plating forming the boundary between two compartments of different types is the sum of the values specified in Tab 2 for one side exposure to each compartment.

For an internal member within a given compartment, or for plating forming the boundary between two compartments of the same type, the corrosion addition to be considered is twice the value specified in Tab 2 for one side exposure to that compartment.

When, according to Tab 2, a structural element is affected by more than one value of corrosion additions (e.g. a side frame in a dry bulk cargo hold extending above the lower zone), the scantling criteria are generally to be applied considering the value of corrosion addition applicable at the lowest point of the element.

3.1.3 Corrosion additions for stainless steel

For structural members made of stainless steel, the corrosion addition t_c is to be taken equal to 0.

3.1.4 Corrosion additions for non-alloyed steel clad with stainless steel

For plates made of non-alloyed steel clad with stainless steel, the corrosion addition t_c is to be taken equal to 0 only for the plate side clad with stainless steel.

3.1.5 Corrosion additions for aluminium alloys

For structural members made of aluminium alloys, the corrosion addition t_c is to be taken equal to 0.

Table 2 : Corrosion additions t_c, in mm, for each exposed side

Compartment type		General **(1)**	Special cases
Ballast tank		1,00	1,25 in upper zone **(2)**
Fuel oil tank	Plating of horizontal surfaces	0,75	1,00 in upper zone **(2)**
	Plating of non-horizontal surfaces	0,50	1,00 in upper zone **(2)**
	Ordinary stiffeners and primary supporting members	0,75	1,00 in upper zone **(2)**
Accommodation space		0,00	
Compartments other than those mentioned above Outside sea and air		0,50	

(1) General: corrosion additions t_c are applicable to all members of the considered item with possible exceptions given for upper and lower zones.

(2) Upper zone: area within 1,5 m below the top of the tank. This is to be applied only to tanks with weather deck as the tank top.

Section 3 Strength Principles

Symbols

E : Young's modulus, in N/mm^2,to be taken equal to:
- for steels in general:
  E = 2,06·10^5 N/mm^2
- for stainless steels:
  E = 1,95·10^5 N/mm^2
- for aluminium alloys:
  E = 7,0·10^4 N/mm^2

s : Spacing, in m, of ordinary stiffeners or primary supporting members, as the case may be

ℓ : Span, in m, of an ordinary stiffener or a primary supporting member, as the case may be, measured between the supporting members (see Tab 1)

ℓ_b : Length, in m, of brackets (see Tab 1)

h_w : Web height, in mm, of an ordinary stiffener or a primary supporting member, as the case may be

t_w : Net web thickness, in mm, of an ordinary stiffener or a primary supporting member, as the case may be

b_f : Face plate width, in mm, of an ordinary stiffener or a primary supporting member, as the case may be

t_f : Net face plate thickness, in mm, of an ordinary stiffener or a primary supporting member, as the case may be

t_p : Net thickness, in mm, of the plating attached to an ordinary stiffener or a primary supporting member, as the case may be

w : Net section modulus, in cm^3, of an ordinary stiffener or a primary supporting member, as the case may be, with attached plating of width b_p

I : Net moment of inertia, in cm^4, of an ordinary stiffener or a primary supporting member, as the case may be, without attached plating, around its neutral axis parallel to the plating (see Tab 1)

I_B : Net moment of inertia, in cm^4, of an ordinary stiffener or a primary supporting member, as the case may be, with bracket and without attached plating, around its neutral axis parallel to the plating, calculated at mid-length of the bracket (see Tab 1).

1 General principles

1.1 Structural continuity

1.1.1 The variation in scantlings between the midship region and the fore and aft parts is to be gradual.

1.1.2 Attention is to be paid to the structural continuity:
- in way of changes in the framing system
- at the connections of primary supporting members or ordinary stiffeners
- in way of the ends of the fore and aft parts (see Ch 8, Sec 1 and Ch 8, Sec 2) and machinery space (see Ch 8, Sec 3)
- in way of ends of superstructures (see Ch 8, Sec 4).

1.1.3 Longitudinal members contributing to the hull girder longitudinal strength, according to Ch 6, Sec 1, [2], are to extend continuously over a sufficient distance towards the ends of the ship.

Ordinary stiffeners contributing to the hull girder longitudinal strength are generally to be continuous when crossing primary supporting members. Otherwise, the detail of connections is considered by the Society on a case-by-case basis.

Longitudinals of the bottom, bilge, sheerstrake, deck, upper and lower longitudinal bulkhead and inner side strakes, as well as the latter strakes themselves, the lower strake of the centreline bottom girder and the upper strake of the centreline deck girder, where fitted, are to be continuous through the transverse bulkheads. Alternative solutions may be examined by the Society on a case-by-case basis, provided they are equally effective.

1.1.4 Where stress concentrations may occur in way of structural discontinuities, adequate compensation and reinforcements are to be provided.

1.1.5 Openings are to be avoided, as far as practicable, in way of highly stressed areas.

Where necessary, the shape of openings is to be specially designed to reduce the stress concentration factors.

Openings are to be generally well rounded with smooth edges.

1.1.6 Primary supporting members are to be arranged in such a way that they ensure adequate continuity of strength. Abrupt changes in height or in cross-section are to be avoided.

1.2 Connections with higher strength steel

1.2.1 The vertical extent of higher strength steel is to comply with the requirements of Ch 6, Sec 2, [4.5].

1.2.2 When a higher strength steel is adopted at deck, members not contributing to the longitudinal strength and welded on the strength deck (e.g. hatch coamings, strengthening of deck openings) are also generally to be made of the same higher strength steel.

1.3 Connections between steel and aluminium

1.3.1 Any direct contact between steel and aluminium alloy is to be avoided (e.g. by means of zinc or cadmium plating of the steel parts and application of a suitable coating on the corresponding light alloy parts).

1.3.2 Any heterogeneous jointing system is considered by the Society on a case-by-case basis.

1.3.3 The use of transition joints made of aluminium/steel-clad plates or profiles is considered by the Society on a case-by-case basis (see NR216 Materials and Welding, Ch 3, Sec 2, [4]).

2 Plating

2.1 Insert plates and doublers

2.1.1 A local increase in plating thickness is generally to be achieved through insert plates. Local doublers, which are normally only allowed for temporary repair, may however be accepted by the Society on a case-by-case basis.

In any case, doublers and insert plates are to be made of materials of a quality at least equal to that of the plates on which they are welded.

2.1.2 Doublers having a width, in mm, greater than:

- 20 times their thickness, for thicknesses equal to or less than 15 mm
- 25 times their thickness, for thicknesses greater than 15 mm,

are to be fitted with slot welds, to be effected according to Ch 11, Sec 1, [2.6].

2.1.3 When doublers fitted on the outer shell and strength deck within 0,6 L amidships are accepted by the Society, their width and thickness are to be such that slot welds are not necessary according to the requirements in [2.1.2]. Outside this area, the possibility of fitting doublers requiring slot welds is to be considered by the Society on a case-by-case basis.

3 Ordinary stiffeners

3.1 General

3.1.1 Stiffener not perpendicular to the attached plating

Where the stiffener is not perpendicular to the attached plating, the actual net section modulus may be obtained, in cm^3, from the following formula:

$w = w_0 \sin \alpha$

where:

w_0 : Actual net section modulus, in cm^3, of the stiffener assumed to be perpendicular to the plating

α : Angle between the stiffener web and the attached plating.

3.1.2 Bulb section: equivalent angle profile

A bulb section may be taken as equivalent to an angle profile.

The dimensions of the equivalent angle profile are to be obtained, in mm, from the following formulae:

$$h_w = h'_w - \frac{h'_w}{9,2} + 2$$

$$t_w = t'_w$$

$$b_f = \alpha\left[t'_w + \frac{h'_w}{6,7} - 2\right]$$

$$t_f = \frac{h'_w}{9,2} - 2$$

where:

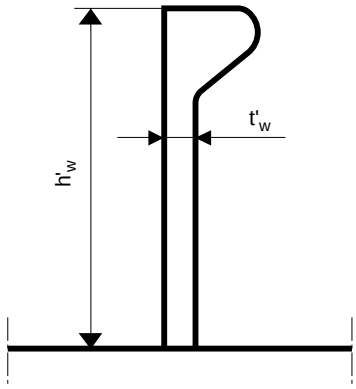
h'_w, t'_w : Height and net thickness of the bulb section, in mm, as shown in Fig 1

α : Coefficient equal to:

$$1,1 + \frac{(120 - h'_w)^2}{3000} \text{ for } h'_w \leq 120$$

$$1 \text{ for } h'_w > 120$$

Figure 1 : Dimensions of a bulb section

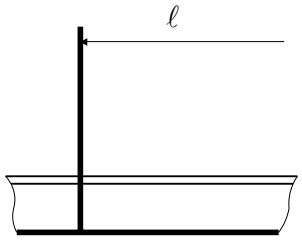
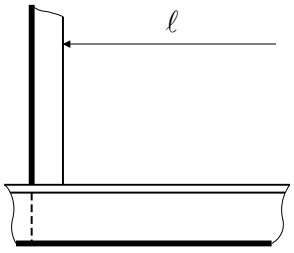
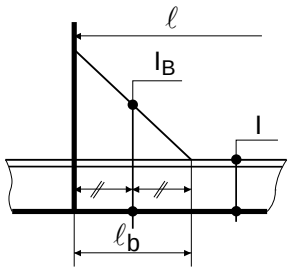
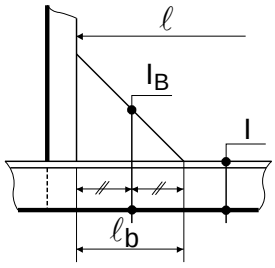


3.2 Span of ordinary stiffeners

3.2.1 General

The span ℓ of ordinary stiffeners is to be measured as shown in Tab 1

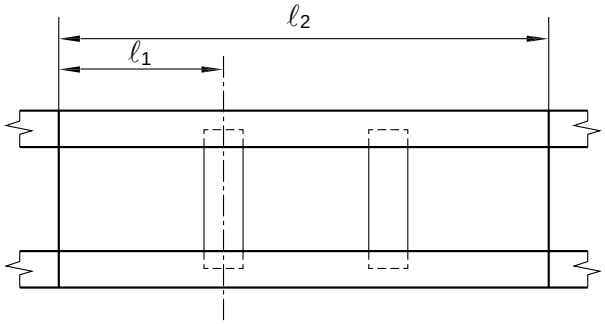
Table 1 : Span of ordinary stiffeners

Ordinary stiffener without brackets	Ordinary stiffener with a stiffener at one end	Ordinary stiffener with end bracket	Ordinary stiffener with a bracket and a stiffener at one end
			

3.2.2 Open floors

The span ℓ of transverse ordinary stiffeners connected by struts is to be taken as the greater of 1,4 ℓ_1 and 0,7 ℓ_2, where ℓ_1 and ℓ_2 are the spans defined in Fig 2.

Figure 2 : Span of ordinary stiffeners in the case of open floors



3.3 Width of attached plating

3.3.1 The width of the attached plating to be considered for the yielding check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where the plating extends on both sides of the ordinary stiffener:
  $b_P = s$
- where the plating extends on one side of the ordinary stiffener (i.e. ordinary stiffeners bounding openings):
  $b_P = 0,5\ s$

3.3.2 Buckling check and ultimate strength check

The attached plating to be considered for the buckling and ultimate strength check of ordinary stiffeners is defined in Ch 7, Sec 2, [4.1] and Ch 7, Sec 2, [5.2], respectively.

3.4 Geometric properties

3.4.1 Built section

The geometric properties of built sections as shown in Fig 3 may be calculated as indicated in the following formulae. These formulae are applicable provided that:

$$A_a \geq t_f b_f$$

$$\frac{h_w}{t_p} \geq 10$$

$$\frac{h_w}{t_f} \geq 10$$

where:

A_a : Net sectional area, in mm^2, of the attached plating.

The net shear sectional area of a built section with attached plating is to be obtained, in cm^2, from the following formula:

$$A_{sh} = \frac{h_w t_w}{100}$$

The net section modulus of a built section with attached plating is to be obtained, in cm^3, from the following formula:

$$w = \frac{h_w t_f b_f}{1000} + \frac{t_W h_W^2}{6000}\left(1 + \frac{A_a - t_f b_f}{A_a + \frac{t_W h_W}{2}}\right)$$

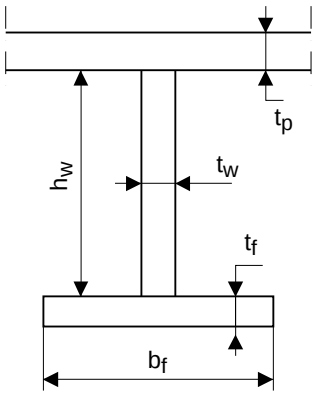
The distance from the face plate to the neutral axis is to be obtained, in cm, from the following formula:

$$v = \frac{h_W(A_a + 0,5 t_W h_W)}{10(A_a + t_f b_f + t_W h_W)}$$

The net moment of inertia of a built section with attached plating is to be obtained, in cm^4, from the following formula:

$I = w\ v$

Figure 3 : Dimensions of a built section



3.4.2 Corrugations

The net section modulus of a corrugation is to be obtained, in cm^3, from the following formula:

$$w = \frac{td}{6}(3b + c)10^{-3}$$

where:

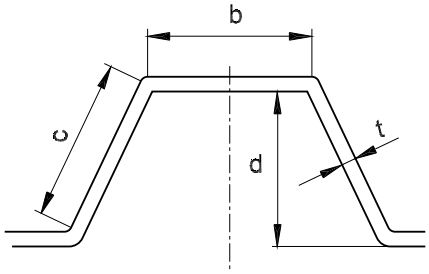
t : Net thickness of the plating of the corrugation, in mm

d, b, c : Dimensions of the corrugation, in mm, shown in Fig 4.

Where the web continuity is not ensured at ends of the bulkhead, the net section modulus of a corrugation is to be obtained, in cm^3, from the following formula:

$w = 0,5\ b\ t\ d\ 10^{-3}$

Figure 4 : Dimensions of a corrugation

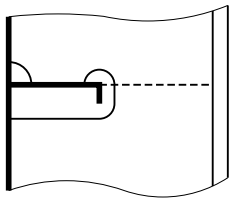
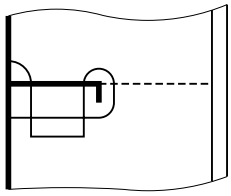
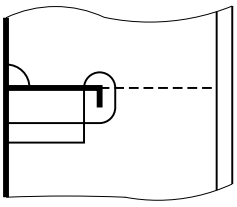
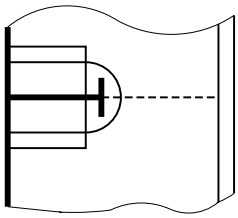


3.5 End connections

3.5.1 Where ordinary stiffeners are continuous through primary supporting members, they are to be connected to the web plating so as to ensure proper transmission of loads, e.g. by means of one of the connection details shown in Tab 2.

Connection details other than those shown in Tab 2 may be considered by the Society on a case-by-case basis. In some cases, the Society may require the details to be supported by direct calculations submitted for review.

Table 2 : End connection of ordinary stiffener

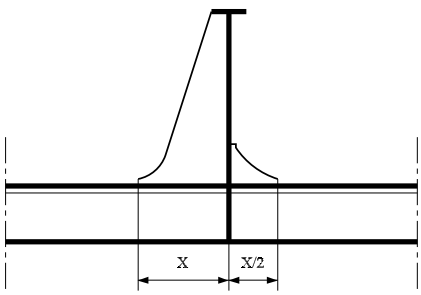
Without collar plate	Collar plate	One large collar plate	Two large collar plates
			

3.5.2 Where ordinary stiffeners are cut at primary supporting members, brackets are to be fitted to ensure the structural continuity. Their net section modulus and their net sectional area are to be not less than those of the ordinary stiffeners.

The net thickness of brackets is to be not less than that of ordinary stiffeners. Brackets with net thickness, in mm, less than $15\ L_b$, where L_b is the length, in m, of the free edge of the end bracket, are to be flanged or stiffened by a welded face plate. As a Rule, the net sectional area, in cm^2, of the flanged edge or face plate is to be at least equal to $10\ L_b$. Other dimensions of the net sectional area of the flanged edge or face plate may be accepted if deemed equivalent or validated by experience.

3.5.3 Where necessary, the Society may require backing brackets to be fitted, as shown in Fig 5, in order to improve the fatigue strength of the connection (see also [4.7.4]).

Figure 5 : End connection of ordinary stiffener - Backing bracket



4 Primary supporting members

4.1 Span of primary supporting members

4.1.1 The span of primary supporting members is to be determined in accordance with [3.2].

4.2 Width of attached plating

4.2.1 General

The width of the attached plating to be considered for the yielding check of primary supporting members analysed through beam structural models is to be obtained, in m, from the following formulae:

- where the plating extends on both sides of the primary supporting member:

  b_P = Min (s ; 0,2 ℓ)

- where the plating extends on one side of the primary supporting member (i.e. primary supporting members bounding openings):

  b_P = 0,5 Min (s ; 0,2 ℓ)

4.2.2 Corrugated bulkheads

The width of attached plating of corrugated bulkhead primary supporting members is to be determined as follows:

- when primary supporting members are parallel to the corrugations and are welded to the corrugation flanges, the width of the attached plating is to be calculated in accordance with [4.2.1] and is to be taken not greater than the corrugation flange width
- when primary supporting members are perpendicular to the corrugations, the width of the attached plating is to be taken equal to the width of the primary supporting member face plate.

4.3 Geometric properties

4.3.1 Standard roll sections

The geometric properties of primary supporting members made of standard roll sections may be determined in accordance with [3.4.1], reducing the web height h_w by the depth of the cut-out for the passage of ordinary stiffeners, if any (see [4.6.1]).

4.3.2 Built sections

The geometric properties of primary supporting members made of built sections (including primary supporting members of double skin structures, such as double bottom floors and girders) are generally determined in accordance with [3.4.1], reducing the web height h_w by the depth of the cut-out for the passage of ordinary stiffeners, if any (see [4.6.1]).

Additional requirements relevant to the net shear sectional area are provided in [4.3.3].

4.3.3 Net shear sectional area in the case of web large openings

Where large openings are fitted in the web of primary supporting members (e.g. where a pipe tunnel is fitted in the double bottom, see Fig 6), their influence is to be taken into account by assigning an equivalent net shear sectional area to the primary supporting member.

This equivalent net shear sectional area is to be obtained, in cm^2, from the following formula:

$$A_{Sh} = \frac{A_{Sh1}}{1 + \frac{0{,}0032\,\ell^2 A_{Sh1}}{I_1}} + \frac{A_{Sh2}}{1 + \frac{0{,}0032\,\ell^2 A_{Sh2}}{I_2}}$$

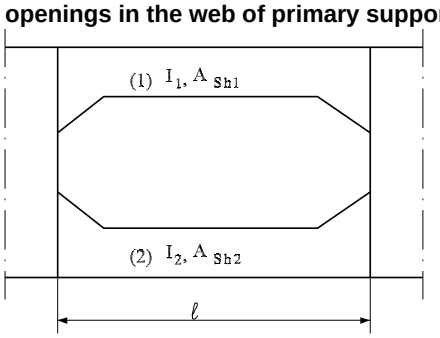
where (see Fig 6):

I_1, I_2 : Net moments of inertia, in cm^4, of deep webs (1) and (2), respectively, with attached plating around their neutral axes parallel to the plating

A_{Sh1}, A_{Sh2} : Net shear sectional areas, in cm^2, of deep webs (1) and (2), respectively, to be calculated according to [4.3.2]

ℓ : Span, in cm, of deep webs (1) and (2).

Figure 6 : Large openings in the web of primary supporting members



4.4 Bracketed end connections

4.4.1 The following requirements in [4.4.2] to [4.4.7] may be replaced by equivalent arrangements based on direct analysis of bending stress and shear stress in way of connections. In such a situation, case-by-case analysis or approval of details booklet is requested.

4.4.2 Arm lengths of end brackets are to be equal, as far as practicable.

With the exception of primary supporting members of transversely framed single sides (see Ch 4, Sec 5, [3.2]), the height of end brackets is to be not less than that of the primary supporting member.

4.4.3 The net thickness of the end bracket web is generally to be not less than that of the primary supporting member web.

4.4.4 The net scantlings of end brackets are generally to be such that the net section modulus of the primary supporting member with end brackets is not less than that of the primary supporting member at mid-span.

4.4.5 Brackets with net thickness, in mm, less than 15 L_b, where L_b is the length, in m, of the free edge of the end bracket, are to be flanged or stiffened by a welded face plate. The width, in mm, of the face plate of end brackets is to be not less than 50 (L_b + 1). Other dimensions of width of the face plate may be accepted if deemed equivalent or validated by experience.

Moreover, the net thickness of the face plate is to be not less than that of the bracket web.

4.4.6 Stiffening of end brackets is to be designed such that it provides adequate buckling web stability.

As a guidance, the following prescriptions may be applied:

- where the length L_b is greater than 1,5 m, the web of the bracket is to be stiffened
- the net sectional area, in cm^2, of web stiffeners is to be not less than 16,5 ℓ, where ℓ is the span, in m, of the stiffener
- tripping flat bars are to be fitted to prevent lateral buckling of web stiffeners. Where the width of the symmetrical face plate is greater than 400 mm, additional backing brackets are to be fitted.

4.4.7 In addition to the above requirements, the net scantlings of end brackets are to comply with the applicable requirements given in Ch 4, Sec 4 to Ch 4, Sec 7.

4.5 Bracketless end connections

4.5.1 In the case of bracketless crossing between primary supporting members (see Fig 7), the net thickness of the common part of the web is to be not less than the value obtained, in mm, from the following formula:

$$t = 15{,}75\frac{w}{\Omega}$$

where:

w : The lesser of w_1 and $w_{2,MAX}$

w_1 : Gross section modulus, in cm^3, of member 1

$w_{2,MAX}$: The greater value, in cm^3, of the gross section moduli of members 2 and 3

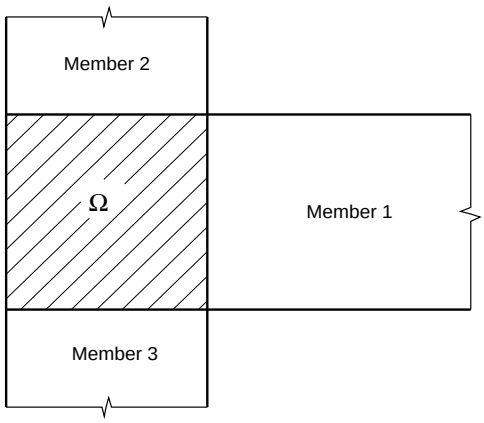
Ω : Area, in cm^2, of the common part of members 1, 2 and 3.

In the absence of one of members 2 and 3 shown in Fig 7, the value of the relevant gross section modulus is to be taken equal to zero.

4.5.2 In no case may the net thickness calculated according to [4.5.1] be less than the smallest web net thickness of the members forming the crossing.

4.5.3 In general, the continuity of the face plates is to be ensured.

Figure 7 : Bracketless end connections of primary supporting members



4.6 Cut-outs and holes

4.6.1 Cut-outs for the passage of ordinary stiffeners are to be as small as possible and well rounded with smooth edges.

In general, the depth of cut-outs is to be not greater than 50% of the depth of the primary supporting member.

4.6.2 Where openings such as lightening holes are cut in primary supporting members, they are to be equidistant from the face plate and corners of cut-outs. Other arrangement may be considered on a case-by-case basis.

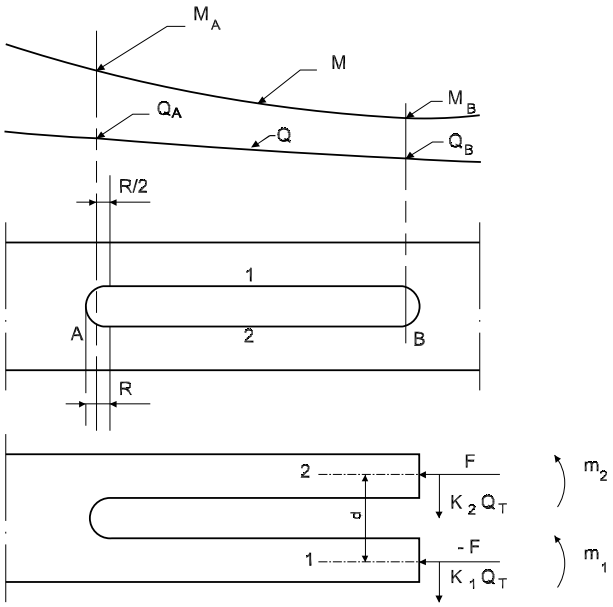
4.6.3 Openings may not be fitted in way of toes of end brackets.

4.6.4 Over half of the span of primary supporting members, the length of openings is to be not greater than the distance between adjacent openings.

At the ends of the span, the length of openings is to be not greater than 25% of the distance between adjacent openings.

4.6.5 In the case of large openings as shown in Fig 8, the secondary stresses in primary supporting members are to be considered for the reinforcement of the openings.

Figure 8 : Large openings in primary supporting members - Secondary stresses



The secondary stresses may be calculated in accordance with the following procedure.

Members (1) and (2) are subjected to the following forces, moments and stresses:

$$F = \frac{M_A + M_B}{2d}$$

$$m_1 = \left|\frac{M_A - M_B}{2}\right| K_1$$

$$m_2 = \left|\frac{M_A - M_B}{2}\right| K_2$$

$$\sigma_{F1} = 10\frac{F}{S_1}$$

$$\sigma_{F2} = 10\frac{F}{S_2}$$

$$\sigma_{m1} = \frac{m_1}{w_1}10^3$$

$$\sigma_{m2} = \frac{m_2}{w_2}10^3$$

$$\tau_1 = 10\frac{K_1 Q_T}{S_{w1}}$$

$$\tau_2 = 10\frac{K_2 Q_T}{S_{w2}}$$

where:

M_A, M_B : Bending moments, in kN·m, in sections A and B of the primary supporting member

m_1, m_2 : Bending moments, in kN·m, in (1) and (2)

d : Distance, in m, between the neutral axes of (1) and (2)

σ_{F1}, σ_{F2} : Axial stresses, in N/mm^2, in (1) and (2)

σ_{m1}, σ_{m2} : Bending stresses, in N/mm^2, in (1) and (2)

Q_T : Shear force, in kN, equal to Q_A or Q_B, whichever is greater

τ_1, τ_2 : Shear stresses, in N/mm^2, in (1) and (2)

w_1, w_2 : Net section moduli, in cm^3, of (1) and (2)

S_1, S_2 : Net sectional areas, in cm^2, of (1) and (2)

S_{w1}, S_{w2} : Net sectional areas, in cm^2, of webs in (1) and (2)

I_1, I_2 : Net moments of inertia, in cm^4, of (1) and (2) with attached plating

$$K_1 = \frac{I_1}{I_1 + I_2}$$

$$K_2 = \frac{I_2}{I_1 + I_2}$$

The combined stress σ_C calculated at the ends of members (1) and (2) is to be obtained from the following formula:

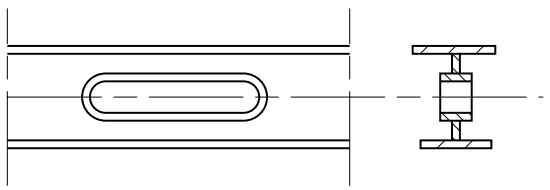
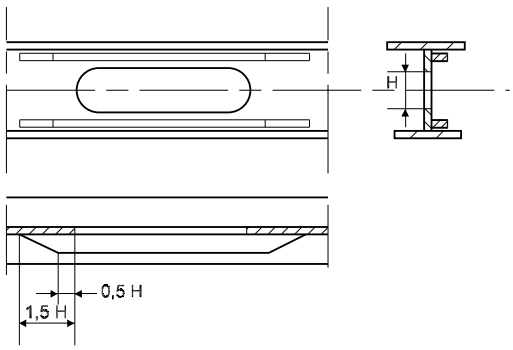
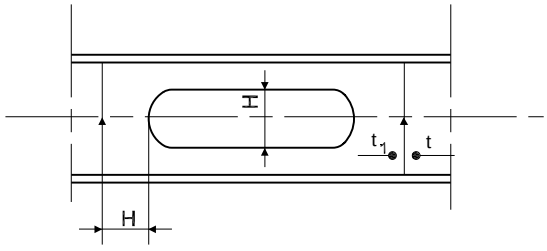
$$\sigma_c = \sqrt{(\sigma_F + \sigma_m)^2 + 3\tau^2}$$

The combined stress σ_C is to comply with the checking criteria in Ch 7, Sec 3, [2.6] or Ch 7, Sec 3, [3.3], as applicable. Where these checking criteria are not complied with, the cut-out is to be reinforced according to one of the solutions shown in Tab 3:

- continuous face plate (solution 1)
- straight face plate (solution 2)
- compensation of the opening (solution 3)
- combination of the above solutions.

Other arrangements may be accepted provided they are supported by direct calculations submitted to the Society for review.

Table 3 : Stiffening of large openings in primary supporting members

Continuous face plate - Solution 1	Straight face plate - Solution 2
	
Compensation of the opening - Solution 3 Inserted plate	
	

4.7 Stiffening arrangement

4.7.1 Webs of primary supporting members are generally to be stiffened where the height, in mm, is greater than 100 t, where t is the web net thickness, in mm, of the primary supporting member.

In general, the web stiffeners of primary supporting members are to be spaced not more than 110 t.

4.7.2 Where primary supporting member web stiffeners are welded to ordinary stiffener face plates, their net sectional area at the web stiffener mid-height is to be not less than the value obtained, in cm^2, from the following formula:

$A = 0,1\ k_1\ (\gamma_{S2}\ p_S + \gamma_{W2}\ p_W)\ s\ \ell$

where:

k_1 : Coefficient depending on the web connection with the ordinary stiffener, to be taken as:

- $k_1 = 0,300$ for connections without collar plate (see Tab 2)
- $k_1 = 0,225$ for connections with a collar plate (see Tab 2)
- $k_1 = 0,200$ for connections with one or two large collar plates (see Tab 2)

p_S, p_W : Still water and wave pressure, respectively, in kN/m^2, acting on the ordinary stiffener, defined in Ch 7, Sec 2, [3.3.2]

γ_{S2}, γ_{W2} : Partial safety factors, defined in Ch 7, Sec 2, Tab 1 for yielding check (general).

4.7.3 The net section modulus of web stiffeners of non-watertight primary supporting members is to be not less than the value obtained, in cm^3, from the following formula:

$w = 2,5\ s^2\ t\ S_s^2$

where:

s : Length, in m, of web stiffeners

t : Web net thickness, in mm, of the primary supporting member

S_s : Spacing, in m, of web stiffeners.

Moreover, web stiffeners located in areas subject to compression stresses are to be checked for buckling in accordance with Ch 7, Sec 2, [4].

4.7.4 Tripping brackets (see Fig 9) welded to the face plate are generally to be fitted:

- in way of ordinary stiffeners and spaced not more than 4 m
- at the toe of end brackets
- at rounded face plates
- in way of cross ties
- in way of concentrated loads.

However, when d, calculated according to [4.7.6] with net thickness of tripping bracket equal to the minimum of thicknesses of ordinary stiffener and primary member webs, is less than 100 mm, the tripping bracket may be omitted.

Where the width of the symmetrical face plate is greater than 400 mm, backing brackets are to be fitted in way of the tripping brackets.

4.7.5 In general, the width of the primary supporting member face plate is to be not less than one tenth of the depth of the web, where tripping brackets are spaced as specified in [4.7.4].

4.7.6 The arm length of tripping brackets is to be not less than the greater of the following values, in m:

$d = 0,38\ b$

$$d = 0,85 b \sqrt{\frac{s_t}{t}}$$

where:

b : Height, in m, of tripping brackets, shown in Fig 9

s_t : Spacing, in m, of tripping brackets

t : Net thickness, in mm, of tripping brackets.

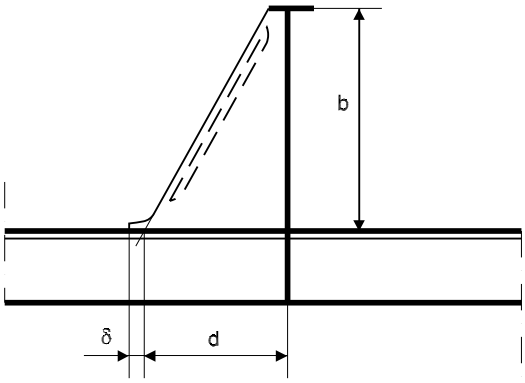
It is recommended that the bracket toe should be designed as shown in Fig 9.

4.7.7 Tripping brackets with a net thickness, in mm, less than 15 L_b are to be flanged or stiffened by a welded face plate.

The net sectional area, in cm^2, of the flanged edge or the face plate is to be not less than 10 L_b, where L_b is the length, in m, of the free edge of the bracket. Other dimensions of the net sectional area of the flanged edge or face plate may be accepted if deemed equivalent or validated by experience.

Where the depth of tripping brackets is greater than 3 m, an additional stiffener is to be fitted parallel to the bracket free edge.

Figure 9 : Primary supporting member: web stiffener in way of ordinary stiffener



Section 4 Bottom Structure

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinally or transversely framed single and double bottom structures.

1.2 General arrangement

1.2.1 In general the bottom is to be longitudinally framed.

1.2.2 The bottom structure is to be checked by the Designer to make sure that it withstands the loads resulting from the dry-docking of the ship.

1.2.3 The bottom is to be locally stiffened where concentrated loads are envisaged.

1.2.4 Girders or floors are to be fitted under each line of pillars, when deemed necessary by the Society on the basis of the loads carried by the pillars.

1.2.5 Adequate tapering is to be provided between double bottom and adjacent single bottom structures. Similarly, adequate continuity is to be provided in the case of height variation in the double bottom. Where such a height variation occurs within 0,6 L amidships, the inner bottom is generally to be maintained continuous by means of inclined plating.

1.2.6 Provision is to be made for the free passage of water from all parts of the bottom to the suctions, taking into account the pumping rate required.

1.2.7 When solid ballast is fitted, it is to be securely positioned. If necessary, intermediate floors may be required for this purpose.

1.3 Drainage and openings for air passage

1.3.1 Holes are to be cut into floors and girders to ensure the free passage of air and liquids from all parts of the double bottom.

1.3.2 Air holes are to be cut as near to the inner bottom and draining holes as near to the bottom shell as practicable.

2 Longitudinally framed single bottom

2.1 General

2.1.1 Single bottom ships are to be fitted with a centre girder formed by a vertical continuous or intercostal web plate and a horizontal face plate continuous over the floors.

Intercostal web plates are to be aligned and welded to floors.

2.1.2 In general, girders are to be fitted spaced not more than 2,5 m apart and formed by a vertical intercostal web plate and a horizontal face plate continuous over the floors.

Intercostal web plates are to be aligned and welded to floors.

2.1.3 Centre and side girders are to be extended as far aft and forward as practicable.

2.1.4 Where side girders are fitted in lieu of the centre girder, the scarfing is to be adequately extended and additional stiffening of the centre bottom may be required.

2.1.5 Longitudinal girders are to be fitted in way of each line of pillars.

2.1.6 Floors are to be made with a welded face plate between the collision bulkhead and 0,25L from the fore end.

2.2 Floors

2.2.1 In general, the floor spacing is to be not greater than 5 frame spacings.

2.3 Longitudinal ordinary stiffeners

2.3.1 Longitudinal ordinary stiffeners are generally to be continuous when crossing primary members.

3 Transversely framed single bottom

3.1 General

3.1.1 The requirements in [2.1] apply also to transversely framed single bottoms.

3.2 Floors

3.2.1 Floors are to be fitted at every frame.

3.2.2 The height, in m, of floors at the centreline is to be not less than B/16. In the case of ships with considerable rise of floor, this height may be required to be increased so as to assure a satisfactory connection to the frames.

4 Longitudinally framed double bottom

4.1 General

4.1.1 The centre girder is to be continuous and extended over the full length of ship and the spacing of adjacent longitudinal girders is generally to be not greater than 6,5 m.

4.2 Double bottom height

4.2.1 The double bottom height is to be sufficient to ensure access to all parts and, in way of the centre girder, is to be not less than 0,7 m.

4.2.2 Where the height of the double bottom varies, the variation is generally to be made gradually and over an adequate length; the knuckles of inner bottom plating are to be located in way of plate floors.

Where this is impossible, suitable longitudinal structures such as partial girders, longitudinal brackets etc., fitted across the knuckle are to be arranged.

4.2.3 In ships without a flat bottom, the height of double bottom specified in [4.2.1] may be required to be adequately increased such as to ensure sufficient access to the areas towards the sides.

4.3 Floors

4.3.1 The spacing of plate floors, in m, is generally to be not greater than 0,05L or 3,8 m, whichever is the lesser.

Additional plate floors are to be fitted in way of transverse watertight bulkheads.

4.3.2 Plate floors are generally to be provided with stiffeners in way of longitudinal ordinary stiffeners.

4.3.3 Where the double bottom height exceeds 0,9 m, watertight floors are to be fitted with stiffeners having a net section modulus not less than that required for tank bulkhead vertical stiffeners.

4.4 Bottom and inner bottom longitudinal ordinary stiffeners

4.4.1 Bottom and inner bottom longitudinal ordinary stiffeners are generally to be continuous through the floors.

4.5 Brackets to centreline girder and margin plate

4.5.1 In general, intermediate brackets are to be fitted connecting either the margin plate or the centre girder to the nearest bottom and inner bottom ordinary stiffeners.

4.5.2 Such brackets are to be stiffened at the edge with a flange having a width not less than 1/10 of the local double bottom height.

If necessary, the Society may require a welded flat bar to be arranged in lieu of the flange.

4.5.3 Where the side shell is transversely stiffened, margin plate brackets are to be fitted at every frame.

4.6 Duct keel

4.6.1 Where a duct keel is arranged, the centre girder may be replaced by two girders conveniently spaced, generally no more than 2 m apart.

4.6.2 The structures in way of the floors are to ensure sufficient continuity of the latter.

4.7 Bilge wells

4.7.1 Bilge wells arranged in the double bottom are to be limited in depth and formed by steel plates having a net thickness not less than the greater of that required for watertight floors and that required for the inner bottom.

4.7.2 In ships subject to subdivision requirements, such bilge wells are to be fitted so that the distance of their bottom from the shell plating is not less than 460 mm.

4.7.3 Where there is no margin plate, well arrangement is considered by the Society on a case by case basis.

5 Transversely framed double bottom

5.1 General

5.1.1 The requirements in [4.1], [4.2], [4.5], [4.6] and [4.7] apply also to transversely framed double bottoms.

5.2 Floors

5.2.1 Plate floors are to be fitted at every frame forward of 0,75L from the aft end.

Plate floors are also to be fitted:

- in way of transverse watertight bulkheads
- in way of double bottom steps.

Elsewhere, plate floors may be arranged at a distance not exceeding 3 m.

5.2.2 In general, plate floors are to be continuous between the centre girder and the margin plate.

5.2.3 Open floors are to be fitted in way of intermediate frames.

5.2.4 Where the double bottom height exceeds 0,9 m, plate floors are to be fitted with vertical stiffeners spaced not more than 1,5 m apart.

These stiffeners may consist of flat bars with a width equal to one tenth of the floor depth and a net thickness, in mm, not less than $0,8L^{0,5}$.

5.3 Girders

5.3.1 Side girders are to be arranged in such a way that their distance to adjacent girders or margin plate does not generally exceed 4,5 m.

5.3.2 Where the double bottom height exceeds 0,9 m, longitudinal girders are to be fitted with vertical stiffeners spaced not more than 1,5 m apart.

These stiffeners may consist of flat bars with a width equal to one tenth of the girder height and a net thickness, in mm, not less than $0,8L^{0,5}$.

5.3.3 In way of open floors, side girders are to be provided with stiffeners having a web height which is generally to be not less than 150 mm.

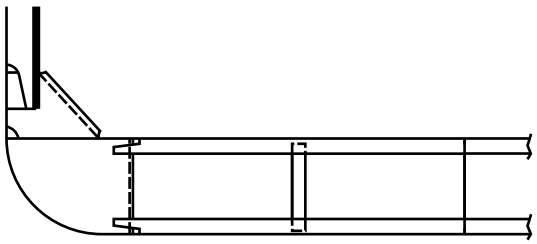
5.4 Open floors

5.4.1 At each frame between plate floors, open floors are to be arranged consisting of a frame connected to the bottom plating and a reverse frame connected to the inner bottom plating (see Fig 1).

5.4.2 Open floors are to be attached to the centreline girder and to the margin plate by means of flanged brackets having a width of flange not less than 1/10 of the local double bottom height.

5.4.3 Where frames and reverse frames are interrupted in way of girders, double brackets are to be fitted.

Figure 1 : Open floor



6 Bilge keel

6.1 Arrangement, scantlings and connections

6.1.1 Material

The material of the bilge keel and that of the ground bar is to be at least of the same yield stress as the material of the bilge plating to which they are attached.

In addition, when the bilge keel extends over a length greater than 0,15 L, the material of the ground bar and that of the bilge keel are to be, at least, of the same grade and of the same material class as the material of the bilge plating to which they are attached.

Exceptions will be specially considered by the Society on the basis of justification to be provided by the Designer, if it is shown that the bilge keel is able to resist the loads imposed on it.

6.1.2 Design

The design of single web bilge keels is to be such that failure of the web occurs before failure of the ground bar. This may be achieved by ensuring that the following conditions are both satisfied:

- the web thickness of the bilge keel does not exceed that of the ground bar
- the yield stress of the material of the bilge keel does not exceed that of the ground bar.

Other design principles which ensure that the bilge keel fails first without causing damage to the hull will be specially considered by the Society.

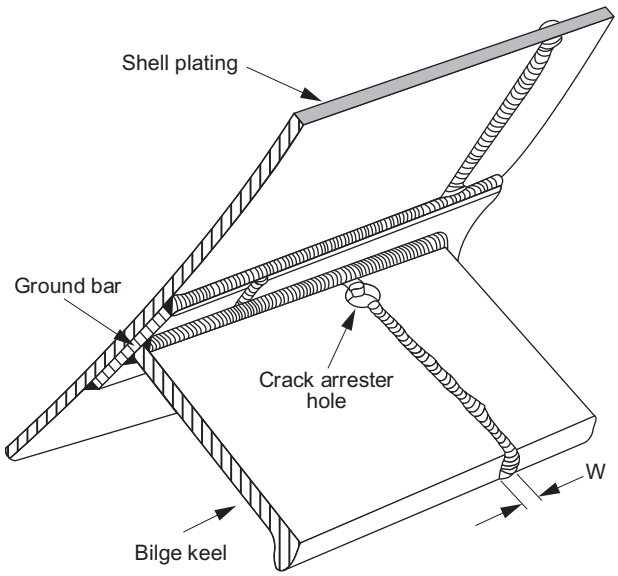
In general, scallops and cut-outs are not to be used. Crack arresting holes are to be drilled in the bilge keel butt welds as close as practicable to the ground bar. The diameter of the hole is to be greater than the width W of the butt weld and is to be a minimum of 25 mm (see Fig 2). Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

Bilge keels of a design different from that shown in Fig 2 are to be specially considered by the Society.

The design of box type bilge keels will be examined on a case-by-case basis, taking into account the following requirements:

- such designs and their connections to the shell are to account for the possibility that they may lead to damage to the hull, as well as the degree of inspection that will be possible
- such designs are to be watertight
- the thickness of the longitudinal members enclosing the bilge keel is not to exceed that of the surrounding plating
- as a rule, internal stiffening members are not to be attached to the shell.

Figure 2 : Single web bilge keel arrangement



6.1.3 Ground bars

Single web bilge keels are not to be welded directly to the shell plating. A ground bar, or doubler, is to be fitted on the shell plating as shown in Fig 2 to Fig 4. In general, the ground bar is to be continuous.

The gross thickness of the ground bar is not to be less than the gross thickness of the bilge plating or 14 mm, whichever is the lesser.

In the case of box type bilge keels:

- For designs directly attached to the shell plating (i.e. without doubler), insert plates having well-rounded corners and gross thickness at least 50 percent greater than the gross thickness of the surrounding plating are to be fitted at the ends.
- Other arrangements for attachment to the hull will be specially considered by the Society on the basis of justification to be provided by the Designer. This justification is to account for the possibility of crack initiation at the attachments to the shell.

Figure 3 : Single web bilge keel design

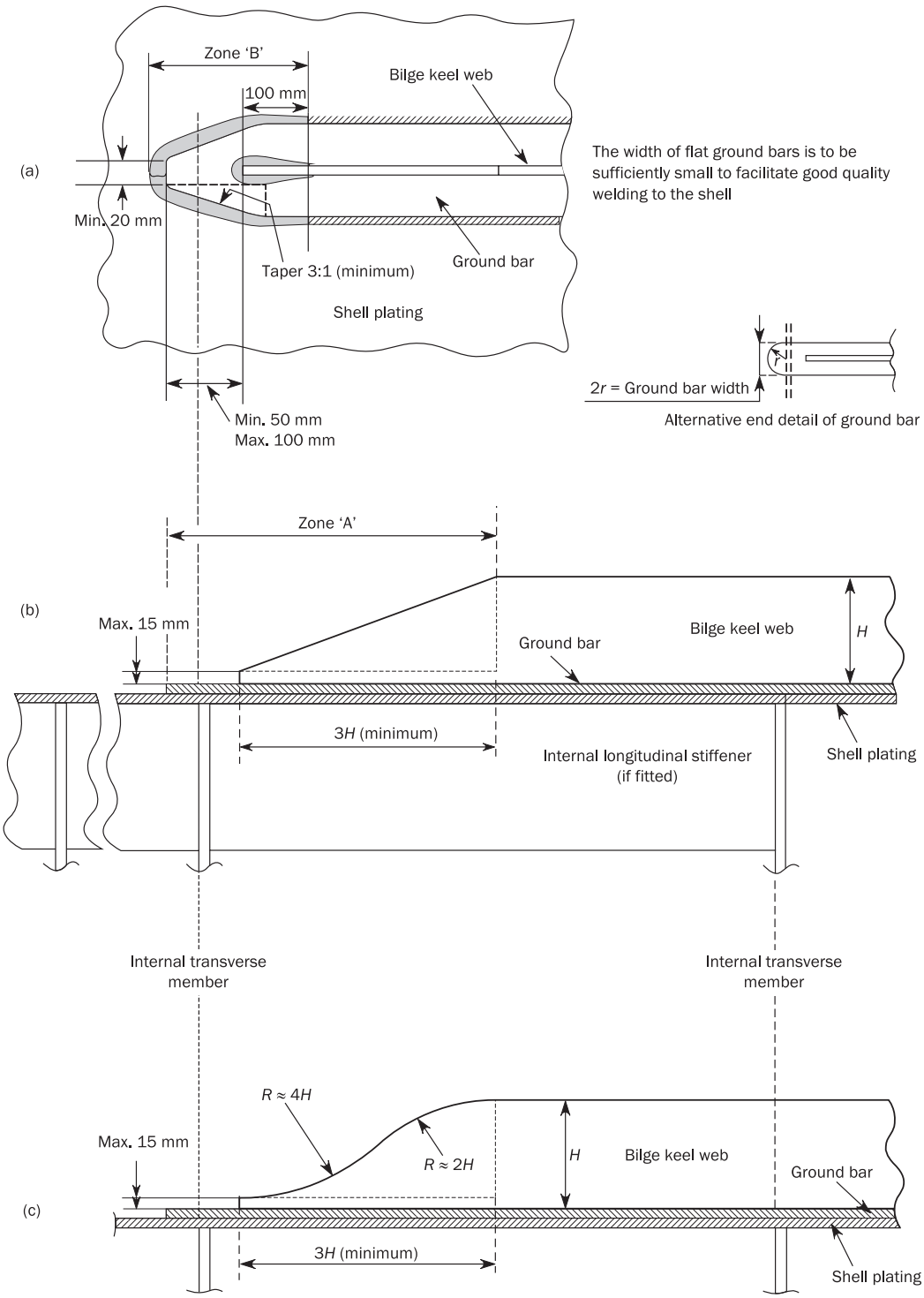
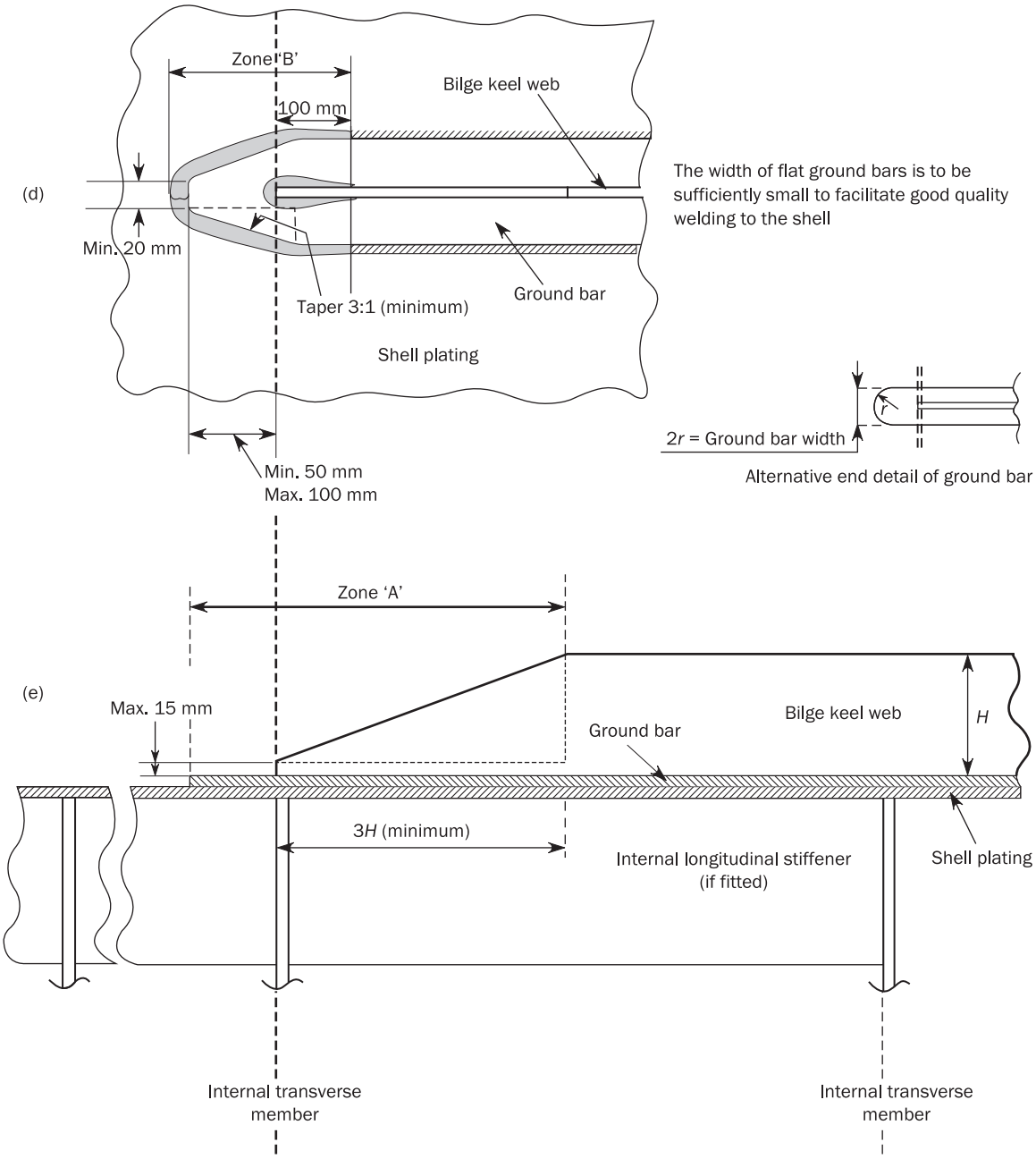


Figure 4 : Single web bilge keel design



6.1.4 End details

The ground bar and bilge keel ends are to be tapered or rounded. Tapering is to be gradual with a minimum ratio of 3:1, see Fig 3 items (a) and (b), and Fig 4items (d) and (e).

Rounded ends are to be as shown in Fig 3 item (c). Cutouts on the bilge keel web within zone A (see Fig 3, item (b) and Fig 4 item (e) are not permitted.

The end of the bilge keel web is to be not less than 50 mm and not greater than 100 mm from the end of the ground b ar, see Fig 3, item (a) and Fig 4, item (d).

Ends of the bilge keel and ground bar are to be supported by either transverse or longitudinal members inside the hull, as indicated as follows:

- transverse support member is to be fitted at mid-length between the end of the bilge keel web and the end of the ground bar, see Fig 3 items (a), (b) and (c)
- longitudinal stiffener is to be fitted in line with the bilge keel web, it is to extend to at least the nearest transverse member forward and aft of zone A (see Fig 3 item (b) and Fig 4 item (e)).

Alternative end arrangements may be considered by the Society on a case-by-case basis.

For box type bilge keels, end details will be examined on a case-by-case basis, paying due attention to structural continuity at the ends with respect to the stiffening members of the hull.

Section 5 Side Structure

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinally or transversely framed side structures.

1.1.2 The transversely framed side structures are built with transverse frames possibly supported by side girders (see [5.3.1]).

1.1.3 The longitudinally framed side structures are built with longitudinal ordinary stiffeners supported by side vertical primary supporting members.

1.2 General arrangement

1.2.1 Unless otherwise specified, side girders are to be fitted aft of the collision bulkhead up to 0,2L aft of the fore end, in line with fore peak girders.

1.2.2 Side vertical primary supporting members are to be fitted in way of hatch end beams.

1.3 Sheerstrake

1.3.1 The width of the sheerstrake is to be not less than the value obtained, in m, from the following formula:

$$b = 0{,}715 + 0{,}425\frac{L}{100}$$

For strength deck, the width of the sheerstrake is to be not less than the value given in Ch 4, Sec 1, [2.4.4].

1.3.2 The sheerstrake may be either welded to the stringer plate or rounded. If it is rounded, the radius, in mm, is to be not less than $17t_s$, where t_s is the net thickness, in mm, of the sheerstrake.

1.3.3 The upper edge of the welded sheerstrake is to be rounded and free of notches.

1.3.4 The transition from a rounded sheerstrake to an angled sheerstrake associated with the arrangement of superstructures at the ends of the ship is to be carefully designed so as to avoid any discontinuities.

Plans showing details of this transition are to be submitted for approval to the Society.

2 Longitudinally framed single side

2.1 Longitudinal ordinary stiffeners

2.1.1 Longitudinal ordinary stiffeners are generally to be continuous when crossing primary members.

2.2 Primary supporting members

2.2.1 In general, the side vertical primary supporting member spacing may not exceed 5 frame spacings.

2.2.2 In general, the side vertical primary supporting members are to be bracketed to the double bottom transverse floors.

3 Transversely framed single side

3.1 Frames

3.1.1 Transverse frames are to be fitted at every frame.

3.1.2 Frames are generally to be continuous when crossing primary members.

Otherwise, the detail of the connection is to be examined by the Society on a case by case basis.

3.1.3 In general, the net section modulus of 'tween deck frames is to be not less than that required for frames located immediately above.

3.2 Primary supporting members

3.2.1 In ‘tweendecks of more than 4 m in height, side girders or side vertical primary supporting members or both may be required by the Society.

3.2.2 Side girders are to be flanged or stiffened by a welded face plate.

The width of the flanged edge or face plate is to be not less than 22t, where t is the web net thickness, in mm, of the girder.

3.2.3 The height of end brackets is to be not less than half the height of the primary supporting member.

4 Longitudinally framed double side

4.1 General

4.1.1 Adequate continuity of strength is to be ensured in way of breaks or changes in width of the double side.

In particular, scarfing of the inner side is to be ensured beyond the cargo hold region.

4.1.2 Knuckles of the inner side are to be adequately stiffened by longitudinal stiffeners. Equivalent arrangement may be considered by the Society on a case by case basis.

4.2 Primary supporting members

4.2.1 The height of side vertical primary supporting members may be gradually tapered from bottom to deck. The maximum acceptable taper, however, is 8 cm per metre.

4.2.2 Side vertical primary supporting members supported by a strut and two diagonals converging on the former are to be considered by the Society on a case by case basis.

5 Transversely framed double side

5.1 General

5.1.1 The requirements in [4.1] also apply to transversely framed double side.

5.1.2 Transverse frames may be connected to the vertical ordinary stiffeners of the inner side by means of struts.

Struts are generally to be connected to transverse frames and vertical ordinary stiffeners of the inner side by means of vertical brackets.

5.2 Frames

5.2.1 Transverse frames are to be fitted at every frame.

5.3 Primary supporting members

5.3.1 Unless otherwise specified, transverse frames are to be supported by side girders if $D \geq 6{,}0$ m.

These girders are to be supported by side vertical primary supporting members spaced no more than 3,8 m apart.

5.3.2 In the case of ships having $4{,}5\text{m} < D < 6{,}0\text{m}$, side vertical primary supporting members are to be fitted, in general not more than 5 frame spacings apart.

6 Frame connections

6.1 General

6.1.1 End connections of frames are to be bracketed.

Other arrangement may be accepted on a case by case basis, when deemed equivalent.

6.1.2 ‘Tweendeck frames are to be bracketed at the top and welded or bracketed at the bottom to the deck.

In the case of bulb profiles, a bracket may be required to be fitted at bottom.

6.1.3 Brackets are normally connected to frames by lap welds. The length of overlap is to be not less than the depth of frames.

6.1.4 Arrangement and scantlings of bracketed ends other than those shown in [6.2] [6.3]may be accepted on a case by case basis, based on strength analysis.

6.2 Upper brackets of frames

6.2.1 The arm length of upper brackets connecting frames to deck beams is to be not less than the value obtained, in mm, from the following formula:

$$d = \varphi\sqrt{\frac{w + 30}{t}}$$

where:

φ : Coefficient equal to:

- for unflanged brackets:

  $\varphi = 48$

- for flanged brackets:

  $\varphi = 43,5$

w : Required net section modulus of the stiffener, in cm^3, given in [6.2.2] and [6.2.3] and depending on the type of connection

t : Bracket net thickness, in mm.

6.2.2 For connections of perpendicular stiffeners located in the same plane (see Fig 1) or connections of stiffeners located in perpendicular planes (see Fig 2), the required net section modulus is to be taken equal to:

$w = w_2$ if $w_2 \leq w_1$

$w = w_1$ if $w_2 > w_1$

where w_1 and w_2 are the required net section moduli of stiffeners, as shown in Fig 1 and Fig 2.

Figure 1 : Connections of perpendicular stiffeners in the same plane

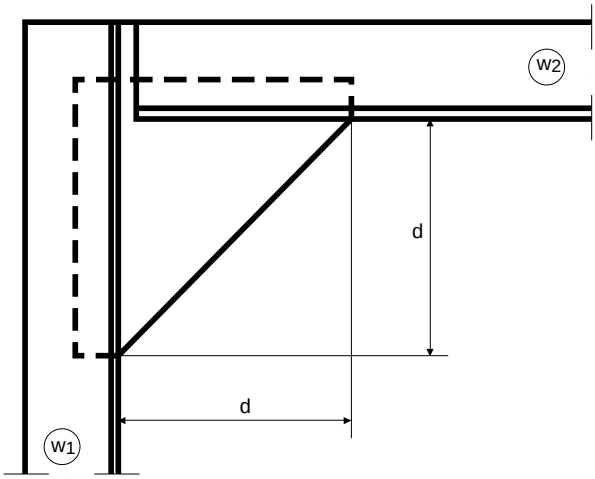
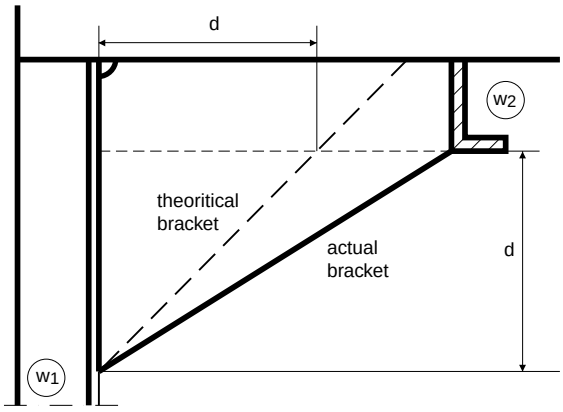


Figure 2 : Connections of stiffeners located in perpendicular planes



6.2.3 For connections of frames to deck beams (see Fig 3), the required net section modulus is to be taken equal to:

- for bracket "A":

  $w_A = w_1$ if $w_2 \leq w_1$

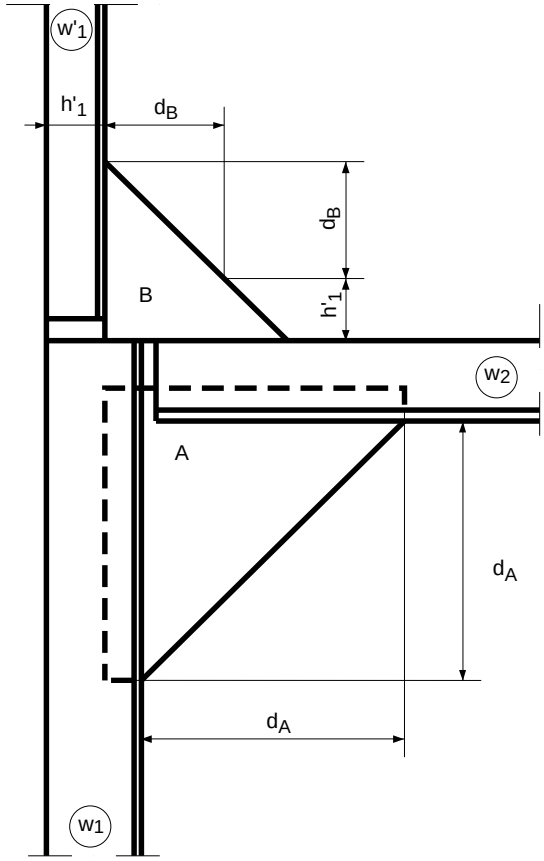
  $w_A = w_2$ if $w_2 > w_1$

- for bracket "B":

  $w_B = w'_1$ need not be greater than w_1

where w_1, w'_1 and w_2 are the required net section moduli of stiffeners, as shown in Fig 3.

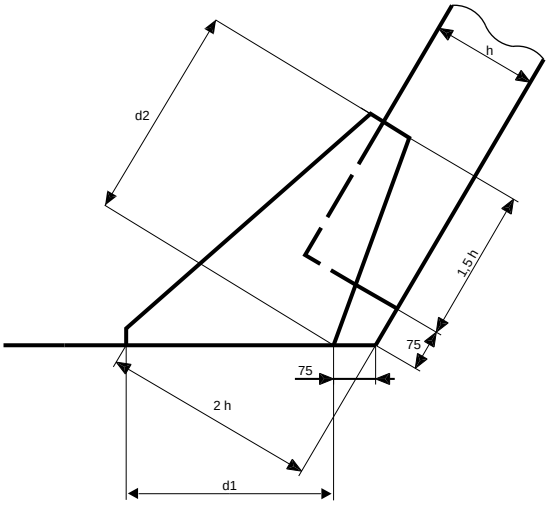
Figure 3 : Connections of frames to deck beams



6.3 Lower brackets of frames

6.3.1 In general, frames are to be bracketed to the inner bottom or to the face plate of floors as shown in Fig 4.

Figure 4 : Lower brackets of main frames



6.3.2 The arm lengths d_1 and d_2 of lower brackets of frames are to be not less than the value obtained, in mm, from the following formula:

$$d = \varphi\sqrt{\frac{w + 30}{t}}$$

where:

φ : Coefficient equal to:
- for unflanged brackets:
  $\varphi = 50$
- for flanged brackets:
  $\varphi = 45$

w : Required net section modulus of the frame, in cm^3

t : Bracket net thickness, in mm.

6.3.3 Where the bracket net thickness, in mm, is less than $15L_b$, where L_b is the length, in m, of the bracket free edge, the free edge of the bracket is to be flanged or stiffened by a welded face plate.

The net sectional area, in cm^2, of the flange or the face plate is to be not less than $10L_b$.

7 Openings in the shell plating

7.1 Position of openings

7.1.1 Openings in the shell plating are to be located at a vertical distance from the decks at side not less than:
- two times the opening diameter, in case of circular opening
- the opening minor axis, in case of elliptical openings.

See also Ch 4, Sec 6, Fig 1.

7.2 Local strengthening

7.2.1 Openings in the ship sides, e.g. for cargo ports, are to be well rounded at the corners and located well clear of superstructure ends or any openings in the deck areas at sides of hatchways.

7.2.2 Openings for sea intakes are to be well rounded at the corners and, within 0,6 L amidships, located outside the bilge strakes. Where arrangements are such that sea intakes are unavoidably located in the curved zone of the bilge strakes, such openings are to be elliptical with the major axis in the longitudinal direction. Openings for stabiliser fins are considered by the Society on a case by case basis. The thickness of sea chests is generally to be not less than that of the local shell plating.

7.2.3 Openings in [7.2.1] and [7.2.2] and, when deemed necessary by the Society, other openings of considerable size are to be adequately compensated by means of insert plates of increased thickness or doublers sufficiently extended in length. Such compensation is to be partial or total depending on the stresses occurring in the area of the openings.

Circular openings on the sheerstrake need not be compensated where their diameter does not exceed 20% of the sheerstrake minimum width, defined in [1.3], or 380 mm, whichever is the lesser, and where they are located away from openings on deck at the side of hatchways or superstructure ends.

Section 6 Deck Structure

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinally or transversely framed deck structures.

1.2 General arrangement

1.2.1 The deck supporting structure consists of ordinary stiffeners (beams or longitudinals), longitudinally or transversely arranged, supported by primary supporting members which may be sustained by pillars.

1.2.2 Where beams are fitted in a hatched deck, these are to be effectively supported by at least two longitudinal girders located in way of hatch side girders to which they are to be connected by brackets and/or clips.

1.2.3 In ships greater than 120 m in length, the zones outside the line of openings of the strength deck and other decks contributing to longitudinal strength are, in general, to be longitudinally framed.

Where a transverse framing type is adopted for such ships, it is considered by the Society on a case-by-case basis.

1.2.4 Adequate continuity of strength is to be ensured in way of:

- stepped or knuckled decks contributing to longitudinal strength
- changes in the framing system.

Details of structural arrangements are to be submitted for review to the Society.

1.2.5 Where applicable, deck transverses of reinforced scantlings are to be aligned with floors.

1.2.6 Inside the line of openings, a transverse structure is generally to be adopted for cross-deck structures, beams are to be adequately supported by girders and, in ships greater than 120 m in length, extend up to the second longitudinal from the hatch side girders toward the bulwark.

Where this is impracticable, intercostal stiffeners are to be fitted between the hatch side girder and the second longitudinal.

Other structural arrangements may be accepted, subject to their strength verification. In particular, their buckling strength against the transverse compression loads is to be checked. Where needed, deck transverses may be required to be fitted.

1.2.7 Deck supporting structures under deck machinery, cranes and king posts are to be adequately stiffened.

1.2.8 Pillars or other supporting structures are generally to be fitted under heavy concentrated weights.

1.2.9 Special arrangements, such as girders supported by cantilevers, are considered by the Society on a case-by-case basis.

1.2.10 Where devices for vehicle lashing arrangements and/or corner fittings for containers are directly attached to deck plating, provision is to be made for the fitting of suitable additional reinforcements of the sizes required by the load carried.

1.2.11 Stiffeners are also to be fitted in way of the ends and corners of deck houses and partial superstructures.

1.3 Construction of watertight decks

1.3.1 Watertight decks are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, are to be to the satisfaction of the Society.

1.4 Stringer plate

1.4.1 As a Rule, the width of the stringer plate is to be not less than the value obtained, in m, from the following formula:

$$b = 0,35 + 0,5\frac{L}{100}$$

However, the stringer plate is also to comply with the requirements in Ch 4, Sec 1, [2.4.4] and Ch 4, Sec 1, [2.5.5].

1.4.2 Stringer plates of lower decks not extending over the full ship's length are to be gradually tapered or overlapped by adequately sized brackets.

2 Longitudinally framed deck

2.1 General

2.1.1 Deck longitudinals are to be continuous, as far as practicable, in way of deck transverses and transverse bulkheads.

Other arrangements may be considered, provided adequate continuity of longitudinal strength is ensured.

2.1.2 In general, the spacing of deck transverses is not to exceed 5 frame spacings.

2.2 Longitudinal ordinary stiffeners

2.2.1 In ships equal to or greater than 120 m in length, strength deck longitudinal ordinary stiffeners are to be continuous through the watertight bulkheads and/or deck transverses.

2.2.2 Frame brackets, in ships with transversely framed sides, are generally to have their horizontal arm extended to the adjacent longitudinal ordinary stiffener.

3 Transversely framed deck

3.1 General

3.1.1 In general, deck beams are to be fitted at each frame.

4 Pillars

4.1 General

4.1.1 Pillars are to be fitted, as far as practicable, in the same vertical line.

4.1.2 In general, pillars are to be fitted below winches, cranes, windlasses and steering gear, in the engine room and at the corners of deckhouses.

4.1.3 In tanks, solid or open section pillars are generally to be fitted. Pillars located in spaces intended for products which may produce explosive gases are to be of open section type.

4.1.4 Tight or non-tight bulkheads may be considered as pillars, provided that their arrangement complies with Ch 4, Sec 7, [4].

4.2 Connections

4.2.1 Heads and heels of pillars are to be attached to the surrounding structure by means of brackets, insert plates so that the loads are well distributed.

Insert plates may be replaced by doubling plates, except in the case of pillars which may also work under tension such as those in tanks.

In general, the net thickness of doubling plates is to be not less than 1,5 times the net thickness of the pillar.

4.2.2 Pillars are to be attached at their heads and heels by continuous welding.

4.2.3 Pillars are to be connected to the inner bottom at the intersection of girders and floors.

4.2.4 Where pillars connected to the inner bottom are not located in way of intersections of floors and girders, partial floors or girders or equivalent structures suitable to support the pillars are to be arranged.

4.2.5 Manholes may not be cut in the girders and floors below the heels of pillars.

4.2.6 Where pillars are fitted in tanks, head and heel brackets may be required if tensile stresses are expected.

4.2.7 Where side pillars are not fitted in way of hatch ends, vertical stiffeners of bulkheads supporting hatch side girders or hatch end beams are to be bracketed at their ends.

5 Hatch supporting structures

5.1 General

5.1.1 Hatch side girders and hatch end beams of reinforced scantlings are to be fitted in way of cargo hold openings.

In general, hatched end beams and deck transverses are to be in line with bottom and side transverse structures, so as to form a reinforced ring.

5.1.2 Clear of openings, adequate continuity of strength of longitudinal hatch coamings is to be ensured by underdeck girders.

5.1.3 The details of connection of deck transverses to longitudinal girders and web frames are to be submitted to the Society for approval.

6 Openings in the strength deck

6.1 Position of openings and local strengthening

6.1.1 Openings in the strength deck are to be kept to a minimum and spaced as far apart from one another and from breaks of effective superstructures as practicable. Openings are generally to be cut outside the hatched areas; in particular, they are to be cut as far as practicable from hatchway corners.

The dashed areas in Fig 1 are those where openings are generally to be avoided. The meaning of the symbols in Fig 1 is as follows:

c, e : Longitudinal and transverse dimensions of hatched area:

$c = 0,07\ \ell + 0,10\ b$ without being less than $0,25\ b$

$e = 0,25\ (B - b)$

a : Transverse dimension of openings

g : Transverse dimension of the area where openings are generally to be avoided in way of the connection between deck and side (as shown in Fig 1), deck and longitudinal bulkheads, deck and large deck girders:

- in the case of circular openings: $g = 2\ a$
- in the case of elliptical openings: $g = a$

Figure 1 : Position of openings in the strength deck

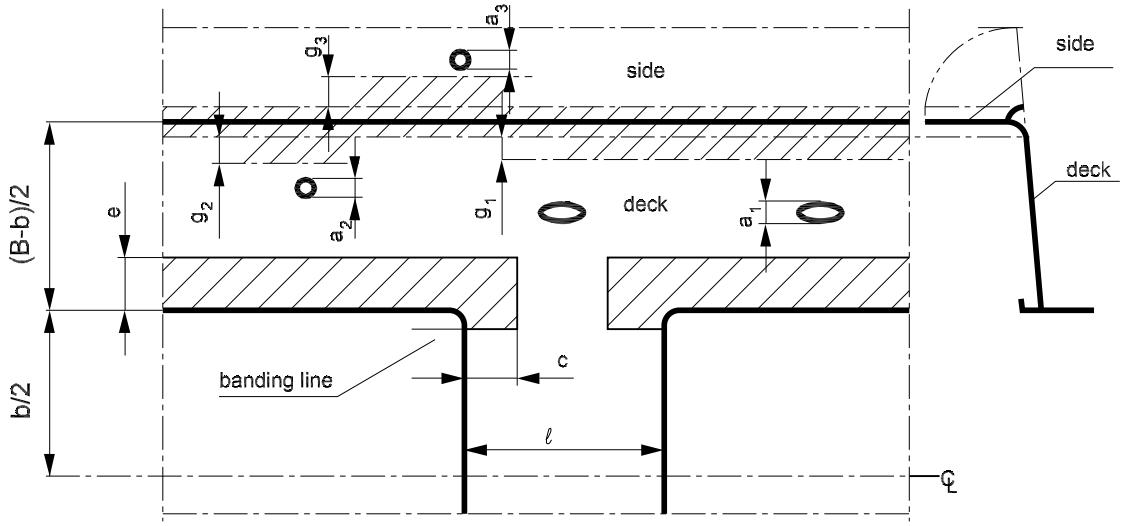
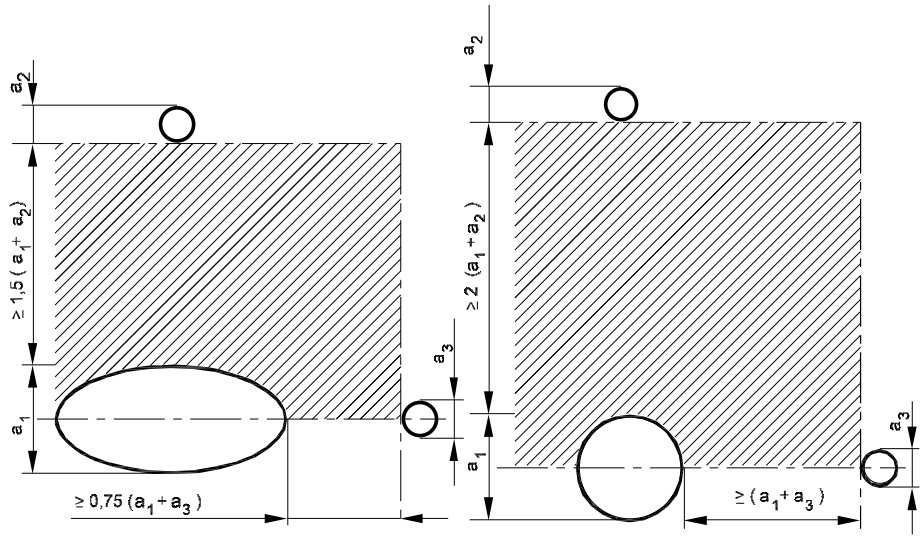


Figure 2 : Circular openings in the strength deck



6.1.2 No compensation is required where the openings are:

- circular of less than 350 mm in diameter and at a distance from any other opening in compliance with Fig 2
- elliptical with the major axis in the longitudinal direction and the ratio of the major to minor axis not less than 2.

6.1.3 Other criteria proposed by the shipyard may be accepted by the Society, if considered as equivalent with respect to [6.1.1] and [6.1.2].

6.2 Corners of hatchways

6.2.1 For hatchways located within the central part, insert plates, whose thickness is to be determined according to [6.2.3], are generally to be fitted in way of corners where the plating cut-out has a circular profile.

The radius of circular corners is to be not less than:

- 5% of the hatch width, where a continuous longitudinal deck girder is fitted below the hatch coaming
- 8% of the hatch width, where no continuous longitudinal deck girder is fitted below the hatch coaming.

Corner radiusing, in the case of the arrangement of two or more hatchways athwartship, is considered by the Society on a case-by-case basis.

6.2.2 For hatchways located in the positions specified in [6.2.1], insert plates are, in general, not required in way of corners where the plating cut-out has an elliptical or parabolic profile and the half axes of elliptical openings, or the half lengths of the parabolic arch, are not less than:

- 1/20 of the hatchway width or 600 mm, whichever is the lesser, in the transverse direction
- twice the transverse dimension, in the fore and aft direction.

6.2.3 Where insert plates are required, their thickness is obtained, in mm, from the following formula:

$$t_{INS} = \left(0,8 + 0,4\frac{\ell}{b}\right)t$$

without being taken less than t or greater than 1,6 t

where:

ℓ : Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction (see Fig 1)

b : Width, in m, of the hatchway considered, measured in the transverse direction (see Fig 1)

t : Actual thickness, in mm, of the deck at the side of the hatchways.

For the extreme corners of end hatchways, the thickness of insert plates is to be 60% greater than the actual thickness of the adjacent deck plating. A lower thickness may be accepted by the Society on the basis of calculations showing that stresses at hatch corners are lower than permissible values.

6.2.4 Where insert plates are required, the arrangement shown in Sheet 3.1 of Ch 11, App 2 of is to be complied with.

6.2.5 For hatchways located in positions other than those in [6.2.1], a reduction in the thickness of the insert plates in way of corners may be considered by the Society on a case-by-case basis.

6.2.6 Other reinforcements deemed equivalent by the Society or alternative arrangements justified by direct calculations may be accepted.

7 Openings in decks other than the strength deck

7.1 General

7.1.1 The requirements for such openings are similar to those in [6.1] for the strength deck. However, circular openings need not to be compensated.

7.1.2 Corners of hatchway openings are to be rounded, as specified in [6.2] for the strength deck; insert plates may be omitted, however, when deemed acceptable by the Society.

Section 7 Bulkhead Structure

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinal or transverse bulkhead structures which may be plane or corrugated.

1.1.2 Bulkheads may be horizontally or vertically stiffened.

Horizontally framed bulkheads consist of horizontal ordinary stiffeners supported by vertical primary supporting members.

Vertically framed bulkheads consist of vertical ordinary stiffeners which may be supported by horizontal girders.

1.2 General arrangement

1.2.1 The number and location of watertight bulkheads are to be in accordance with the relevant requirements given in Ch 2, Sec 1.

1.2.2 Transverse corrugated bulkheads having horizontal corrugations are to be fitted with vertical primary supporting members of number and size sufficient to ensure the required vertical stiffness of the bulkhead.

1.2.3 Where an inner bottom terminates on a bulkhead, the lowest strake of the bulkhead forming the watertight floor of the double bottom is to extend at least 300 mm above the inner bottom.

1.2.4 Longitudinal bulkheads are to terminate at transverse bulkheads and are to be effectively tapered to the adjoining structure at the ends and adequately extended in the machinery space, where applicable.

1.2.5 Where the longitudinal watertight bulkheads contribute to longitudinal strength, the plating thickness is to be uniform for a distance of at least 0,1D from the deck and bottom.

1.2.6 The structural continuity of the bulkhead vertical and horizontal primary supporting members with the surrounding supporting structures is to be carefully ensured.

1.2.7 The height of vertical primary supporting members of longitudinal bulkheads may be gradually tapered from bottom to deck. The maximum acceptable taper, however, is 8 cm per metre.

1.3 Watertight bulkheads of trunks, tunnels, etc.

1.3.1 Watertight trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, are to be to the satisfaction of the Society.

1.4 Openings in watertight bulkheads

1.4.1 Openings may not be cut in the collision bulkhead below the watertight deck.

The number of openings in the collision bulkhead above the watertight deck is to be kept to the minimum compatible with the design and proper working of the ship.

All such openings are to be fitted with means of closing to weathertight standards.

1.4.2 Certain openings below the watertight deck are permitted in the other bulkheads, but these are to be kept to a minimum compatible with the design and proper working of the ship and to be provided with watertight doors having strength such as to withstand the head of water to which they may be subjected. Ch 2, Sec 1, Tab 2 is to be referred to.

1.5 Watertight doors

1.5.1 The net thickness of watertight doors is to be not less than that of the adjacent bulkhead plating, taking account of their actual spacing.

1.5.2 Where vertical stiffeners are cut in way of watertight doors, reinforced stiffeners are to be fitted on each side of the door and suitably overlapped; cross-bars are to be provided to support the interrupted stiffeners.

1.5.3 Watertight doors are to be framed and capable of being secured watertight by handle-operated wedges which are suitably spaced and operable at both sides.

2 Plane bulkheads

2.1 General

2.1.1 Where a bulkhead does not extend up to the uppermost continuous deck (such as the after peak bulkhead), suitable strengthening is to be provided in the extension of the bulkhead.

2.1.2 Bulkheads are to be stiffened in way of deck girders.

2.1.3 The stiffener webs of hopper and topside tank watertight bulkheads are generally to be aligned with the webs of inner hull longitudinal stiffeners.

2.1.4 A primary supporting member is to be provided in way of any vertical knuckle in longitudinal bulkheads. The distance between the knuckle and the primary supporting member is to be taken not greater than 70 mm.

2.1.5 Plate floors are to be fitted in the double bottom in way of plane transverse bulkheads.

2.1.6 A doubling plate of the same net thickness as the bulkhead plating is to be fitted on the after peak bulkhead in way of the sterntube, unless the net thickness of the bulkhead plating is increased by at least 60%.

2.2 End connections of ordinary stiffeners

2.2.1 The crossing of ordinary stiffeners through a watertight bulkhead is to be watertight.

2.2.2 In general, end connections of ordinary stiffeners are to be bracketed (see [2.3]). However, stiffeners of watertight bulkheads in upper 'tweendecks may be sniped, provided the scantling of such stiffeners are modified accordingly.

2.2.3 Where hull lines do not enable compliance with the requirements of [2.2.2], sniped ends may be accepted, provided the scantlings of stiffeners are modified accordingly.

2.2.4 Where sniped ordinary stiffeners are fitted, the snipe angle is to be not greater than 30° and their ends are to be extended, as far as practicable, to the boundary of the bulkhead.

2.3 Bracketed ordinary stiffeners

2.3.1 Where bracketed ordinary stiffeners are fitted, the arm lengths of end brackets of ordinary stiffeners, as shown in Fig 1 and Fig 2, are to be not less than the following values, in mm:

- for arm length a:
  - brackets of horizontal stiffeners and bottom bracket of vertical stiffeners: $a = 100\,\ell$
  - upper bracket of vertical stiffeners: $a = 80\,\ell$
- for arm length b, the greater of:

$$b = 80\sqrt{\frac{w + 20}{t}}$$

$$b = \alpha\frac{ps\ell}{t}$$

where:

ℓ : Span, in m, of the stiffener measured between supports

w : Net section modulus, in cm^3, of the stiffener

t : Net thickness, in mm, of the bracket

p : Design pressure, in kN/m^2, calculated at mid-span

α : Coefficient equal to:

$\alpha = 4,9$ for tank bulkheads

$\alpha = 3,6$ for watertight bulkheads.

2.3.2 The connection between the stiffener and the bracket is to be such that the net section modulus of the connection is not less than that of the stiffener.

2.3.3 Scantlings of bracketed ends other than those calculated in [2.3.1] may be accepted by the Society on a case-by-case basis, based on strength analysis.

Figure 1 : Bracket at upper end of ordinary stiffener on plane bulkhead

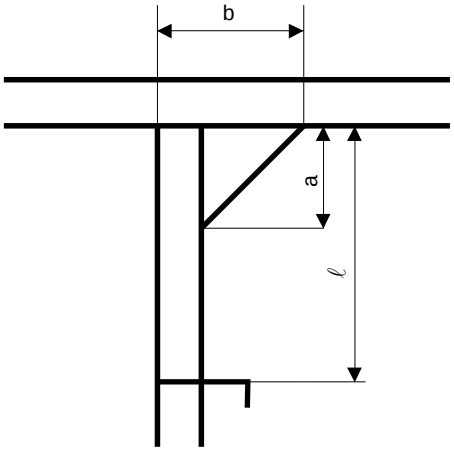
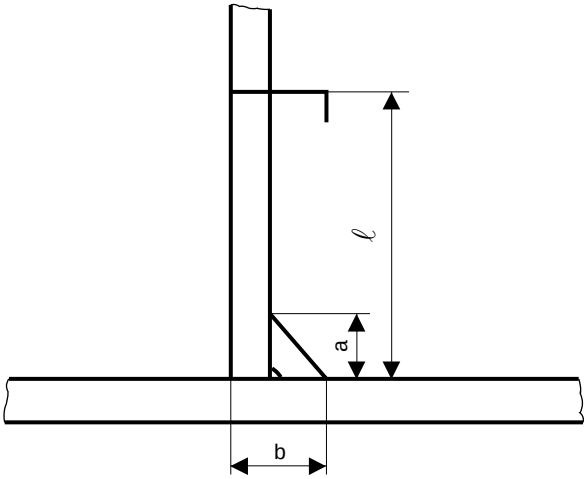


Figure 2 : Bracket at lower end of ordinary stiffener on plane bulkhead



3 Corrugated bulkheads

3.1 General

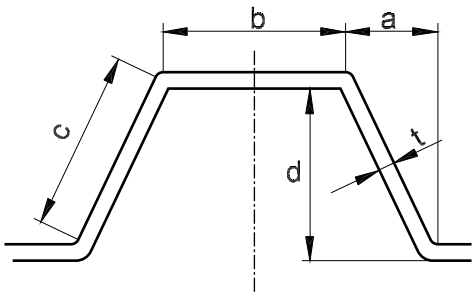
3.1.1 The main dimensions a, b, c and d of corrugated bulkheads are defined in Fig 3.

3.1.2 Unless otherwise specified, the following requirement is to be complied with:

$a \leq 1,2\ d$

Moreover, in some cases, the Society may prescribe an upper limit for the ratio b/t.

Figure 3 : Corrugated bulkhead



3.1.3 In general, the bending internal radius is to be not less than the following values, in mm:

- for normal strength steel: $R_i = 2,5\ t$
- for high tensile steel: $R_i = 3,0\ t$

where t is the net thickness, in mm, of the corrugated plate.

3.1.4 When butt welds in a direction parallel to the bend axis are provided in the zone of the bend, the welding procedures are to be submitted to the Society for approval, as a function of the importance of the structural element.

Moreover, when the gross thickness of the bulkhead plating is greater than 20 mm, the Society may require the use of steel grade E or EH.

3.1.5 In general, where girders or vertical primary supporting members are fitted on corrugated bulkheads, they are to be arranged symmetrically.

3.2 Structural arrangement

3.2.1 The strength continuity of corrugated bulkheads is to be ensured at ends of corrugations.

3.2.2 Where corrugated bulkheads are cut in way of primary members, attention is to be paid to ensure correct alignment of corrugations on each side of the primary member.

3.2.3 In general, where vertically corrugated transverse bulkheads are welded on the inner bottom, plate floors are to be fitted in way of the flanges of corrugations.

However, other arrangements ensuring adequate structural continuity may be accepted by the Society.

3.2.4 In general, where vertically corrugated longitudinal bulkheads are welded on the inner bottom, girders are to be fitted in way of the flanges of corrugations.

However, other arrangements ensuring adequate structural continuity may be accepted by the Society.

3.2.5 In general, the upper and lower parts of horizontally corrugated bulkheads are to be flat over a depth equal to 0,1 D.

3.2.6 Where stools are fitted at the lower part of transverse bulkheads, the net thickness of adjacent plate floors is to be not less than that of the stool plating.

3.3 Bulkhead stool

3.3.1 In general, plate diaphragms or web frames are to be fitted in bottom stools in way of the double bottom longitudinal girders or plate floors, as the case may be.

3.3.2 Brackets or deep webs are to be fitted to connect the upper stool to the deck transverses or hatch end beams, as the case may be.

3.3.3 The continuity of the corrugated bulkhead with the stool plating is to be adequately ensured. In particular, the upper strake of the lower stool is to be of the same net thickness and yield stress as those of the lower strake of the bulkhead.

4 Non-tight bulkheads

4.1 Non-tight bulkheads not acting as pillars

4.1.1 Non-tight bulkheads not acting as pillars are to be provided with vertical stiffeners with a maximum spacing equal to:

- 0,9 m for transverse bulkheads
- two frame spacings, with a maximum of 1,5 m, for longitudinal bulkheads.

4.2 Non-tight bulkheads acting as pillars

4.2.1 Non-tight bulkheads acting as pillars "(i.e. those that are designed to sustain the loads transmitted by a deck structure) are to be provided with vertical stiffeners with a maximum spacing equal to:

- two frame spacings, when the frame spacing does not exceed 0,75 m
- one frame spacing, when the frame spacing is greater than 0,75 m.

4.2.2 Each vertical stiffener, in association with a width of plating equal to 35 times the plating net thickness, is to comply with the applicable requirements for pillars in Ch 7, Sec 3, the load supported being determined in accordance with the same requirements.

4.2.3 In the case of non-tight bulkheads supporting longitudinally framed decks, vertical girders are to be provided in way of deck transverses.

5 Wash bulkheads

5.1 General

5.1.1 The requirements in [5.2] apply to transverse and longitudinal wash bulkheads whose main purpose is to reduce the liquid motions in partly filled tanks.

5.2 Openings

5.2.1 The total area of openings in a transverse wash bulkhead is generally to be between 10% and 30% of the total bulkhead area.

In the upper, central and lower portions of the bulkhead (the depth of each portion being 1/3 of the bulkhead height), the areas of openings, expressed as percentages of the corresponding areas of these portions, are to be within the limits given in Tab 1.

5.2.2 In any case, the distribution of openings is to fulfil the strength requirements specified in [4.2].

5.2.3 In general, openings may not be cut within 0,15 D from bottom and from deck.

Table 1 : Areas of openings in transverse wash bulkheads

Bulkhead portion	Lower limit	Upper limit
Upper	10 %	15 %
Central	10 %	50 %
Lower	2 %	10 %

CHAPTER 5
DESIGN LOADS

Section 1 General

Section 2 Hull Girder Loads

Section 3 Ship Motions and Accelerations

Section 4 Load Cases

Section 5 Sea Pressures

Section 6 Internal Pressures and Forces

Appendix 1 Inertial Pressure for Typical Tank Arrangement

Section 1 General

1 Definitions

1.1 Cargo

1.1.1 Cargo are liquids and dry units (e.g. containers, vehicles, etc.) carried inside compartments and on decks.

1.2 Still water loads

1.2.1 Still water loads are those acting on the ship at rest in calm water.

1.3 Wave loads

1.3.1 Wave loads are those due to wave pressures and ship motions, which can be assumed to have the same wave encounter period.

1.4 Dynamic loads

1.4.1 Dynamic loads are those that have a duration much shorter than the period of the wave loads.

1.5 Local loads

1.5.1 Local loads are pressures and forces which are directly applied to the individual structural members: plating panels, ordinary stiffeners and primary supporting members.

- Still water local loads are constituted by the hydrostatic external sea pressures and the static pressures and forces induced by the weights carried in the ship spaces.
- Wave local loads are constituted by the external sea pressures due to waves and the inertial pressures and forces induced by the ship accelerations applied to the weights carried in the ship spaces.
- Dynamic local loads are constituted by the impact and sloshing pressures.

1.5.2 For the structures which constitute the boundary of spaces not intended to carry liquids and which do not belong to the outer shell, the still water and wave pressures in flooding conditions are also to be considered.

1.6 Hull girder loads

1.6.1 Hull girder loads are (still water, wave and dynamic) forces and moments which result as effects of local loads acting on the ship as a whole and considered as a beam.

1.7 Loading condition

1.7.1 A loading condition is a distribution of weights carried in the ship spaces arranged for their storage.

1.8 Load case

1.8.1 A load case is a state of the ship structures subjected to a combination of hull girder and local loads.

2 Application criteria

2.1 Fields of application

2.1.1 General

The wave induced and dynamic loads defined in this Chapter corresponds to an operating life of the ship equal to 30 years.

Loads for an operating life different from 30 years are considered by the Society on a case-by-case basis.

2.1.2 Requirements applicable to all types of ships

The still water, wave induced and dynamic loads defined in this Chapter are to be used for the determination of the hull girder strength and structural scantlings in the central part (see Ch 1, Sec 1) of ships, according to the requirements in Part B, Chapter 6 and Part B, Chapter 7.

2.1.3 Requirements applicable to specific ship types

The design loads applicable to specific ship types are to be defined in accordance with the requirements in Part D.

2.1.4 Load direct calculation

As an alternative to the formulae in Ch 5, Sec 2 and Ch 5, Sec 3, the Society may accept the values of wave induced loads and dynamic loads derived from direct calculations, when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

2.2 Hull girder loads

2.2.1 The still water, wave and dynamic hull girder loads to be used for the determination of:

- the hull girder strength, according to the requirements of Part B, Chapter 6, and
- the structural scantling of plating, ordinary stiffeners and primary supporting members contributing to the hull girder strength, in combination with the local loads given in Ch 5, Sec 5 and Ch 5, Sec 6, according to the requirements in Part B, Chapter 7,

are specified in Ch 5, Sec 2.

2.3 Local loads

2.3.1 Load cases

The local loads defined in [1.5] are to be calculated in each of the mutually exclusive load cases described in Ch 5, Sec 4.

Dynamic loads are to be taken into account and calculated according to the criteria specified in Ch 5, Sec 5 and Ch 5, Sec 6.

2.3.2 Ship motions and accelerations

The wave local loads are to be calculated on the basis of the reference values of ship motions and accelerations specified in Ch 5, Sec 3.

2.3.3 Calculation and application of local loads

The criteria for calculating:

- still water local loads, and
- wave local loads on the basis of the reference values of ship motions and accelerations,

are specified in Ch 5, Sec 5 for sea pressures and in Ch 5, Sec 6 for internal pressures and forces.

2.3.4 Flooding conditions

The still water and wave pressures in flooding conditions are specified in Ch 5, Sec 6, [6]. The pressures in flooding conditions applicable to specific ship types are to be defined in accordance with the requirements in Part D.

2.4 Load definition criteria to be adopted in structural analyses based on plate or isolated beam structural models

2.4.1 Application

The requirements of this sub-article apply for the definition of local loads to be used in the scantling checks of:

- plating, according to Ch 7, Sec 1
- ordinary stiffeners, according to Ch 7, Sec 2
- primary supporting members for which a three-dimensional structural model is not required, according to Ch 7, Sec 3, [2].

2.4.2 Full load and operational load distributions

When calculating the local loads for the structural scantling of an element which separates two adjacent compartments, the latter may not be considered simultaneously loaded. The local loads to be used are those obtained considering the two compartments individually loaded.

For elements of the outer shell, the local loads are to be calculated considering separately:

- the still water and wave external sea pressures, considered as acting alone without any counteraction from the ship interior
- the still water and wave differential pressures (internal pressure minus external sea pressure) considering the compartment adjacent to the outer shell as being loaded.

2.4.3 Draught associated with full load and operational load

Local loads are to be calculated on the basis of the ship's draught T_1 corresponding to the full load or operational load distribution considered according to the criteria in [2.4.2]. The ship draught is to be taken as the distance measured vertically on the hull transverse section at the middle of the length L, from the moulded base line to the waterline in:

- full load condition, when:
  - one or more compartments are considered as being loaded and the ballast tanks are considered as being empty
  - the still water and wave external pressures are considered as acting alone without any counteraction from the ship's interior

- operational load condition, when one or more ballast tanks are considered as being loaded and the other compartments are considered as being empty. In the absence of more precise information, the ship's draught in light ballast condition may be obtained, in m, from the following formulae:

  $T_B = 0,03\ L \leq 7,5$ m

2.5 Load definition criteria to be adopted in structural analyses based on three- dimensional structural models

2.5.1 Application

The requirements of this sub-article apply for the definition of local loads to be used in the scantling checks of primary supporting members for which a three-dimensional structural model is required, according to Ch 7, Sec 3, [3].

2.5.2 Loading conditions

For all ship types for which analyses based on three-dimensional models are required according to Ch 7, Sec 3, [3], the most severe loading conditions for the structural elements under investigation are to be considered. These loading conditions are to be selected among those envisaged in the ship loading manual.

Further criteria applicable to specific ship types are specified in Part D.

2.5.3 Draught associated with each loading condition

Local loads are to be calculated on the basis of the ship's draught T_1 corresponding to the loading condition considered according to the criteria in [2.5.2].

Section 2 Hull Girder Loads

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 2, [2.1.1].

C : Wave parameter:

$$C = (118 - 0,36L)\frac{L}{1000} \quad \text{for } 65m \le L < 90m$$

$$C = 10,75 - \left(\frac{300 - L}{100}\right)^{1,5} \quad \text{for } 90m \le L < 300m$$

$$C = 10,75 \quad \text{for } 300m \le L \le 350m$$

$$C = 10,75 - \left(\frac{L - 350}{150}\right)^{1,5} \quad \text{for } L > 350m$$

F : Froude number calculated at the maximum ahead service speed:

$$F = 0,164\frac{V_{max}}{\sqrt{L}}$$

F_{CH} : Characteristic Froude number:

$$F_{CH} = 0,164\frac{V_{CH}}{\sqrt{L}}$$

H : Wave parameter:

$$H = 8,13 - \left(\frac{250 - 0,7L}{125}\right)^3$$

without being taken greater than 8,13

H_A : Wave parameter:

$$H_A = \frac{CL}{200}$$

without being taken greater than 0,8 C

V_{CH} : Characteristic ship speed; to be taken as the greatest between V_{cruise} and 0,75 V_{max}

V_{cruise} : Cruise speed, in knots.

V_{max} : Maximum ahead service speed, in knots

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships having the following characteristics:

$L / B > 5$

$B / D < 2,5$

$C_B \ge 0,4$

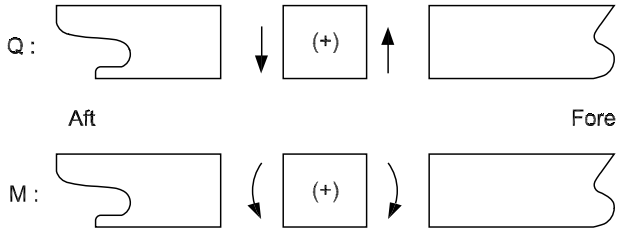
Ships not having one or more of these characteristics and ships of unusual type or design are considered by the Society on a case-by-case basis.

1.2 Sign conventions of vertical bending moments and shear forces

1.2.1 The sign conventions of bending moments and shear forces at any ship transverse section are as shown in Fig 1, namely:

- the vertical bending moment M is positive when it induces tensile stresses in the strength deck (hogging bending moment); it is negative in the opposite case (sagging bending moment)
- the vertical shear force Q is positive in the case of downward resulting forces preceding and upward resulting forces following the ship transverse section under consideration; it is negative in the opposite case.

Figure 1 : Sign conventions for shear forces Q and bending moments M



2 Still water loads

2.1 General

2.1.1 Still water load calculation

For all ships, the longitudinal distributions of still water bending moment and shear force are to be calculated, for each of the loading conditions in [2.1.2], on the basis of realistic data related to the amount of ballast, fuel, lubricating oil and fresh water.

The actual hull lines and lightweight distribution are to be taken into account in the calculations. The lightweight distribution may be replaced, if the actual values are not available, by a statistical distribution of weights accepted by the Society.

The designer is to supply the data necessary to verify the calculations of still water loads.

Ships with large openings are specially considered by the Society on a case-by-case basis.

2.1.2 Loading conditions

Still water loads are to be calculated at least for the design loading conditions corresponding to full load condition (end of life) and minimum operational load condition (at delivery) on which the approval of hull structural scantlings is based (see Ch 5, Sec 1, [1.2]). If other loading conditions are expected to be more severe than the above conditions, corresponding still water loads are also to be calculated.

For all ships, the following loading conditions are to be considered:

- homogeneous loading conditions at maximum draught
- operational load conditions
- special loadings (e.g. light load conditions at less than the maximum draught, etc., where applicable)
- short voyage or harbour conditions, where applicable
- loading and unloading transitory conditions, where applicable
- docking condition afloat
- ballast exchange at sea, if applicable.

2.2 Still water bending moments

2.2.1 The design still water bending moments $M_{SW,H}$ and $M_{SW,S}$ at any hull transverse section are the maximum still water bending moments calculated, in hogging and sagging conditions, respectively, at that hull transverse section for the loading conditions specified in [2.1.2].

Where no sagging bending moments act in the hull section considered, the value of $M_{SW,S}$ is to be taken as specified in Part B, Chapter 6 and Part B, Chapter 7.

2.2.2 If the design still water bending moments are not defined, at a preliminary design stage, at any hull transverse section, the longitudinal distributions shown in Fig 2 may be considered.

In Fig 2, M_{SW} is the design still water bending moment amidships, in hogging or sagging conditions, whose absolute values are to be taken not less than those obtained, in kN.m, from the following formulae:

- hogging conditions:

  $M_{SWM,H} = 175\ C\ L^2\ B\ (C_B + 0,7)\ 10^{-3} - M_{WV,H}$

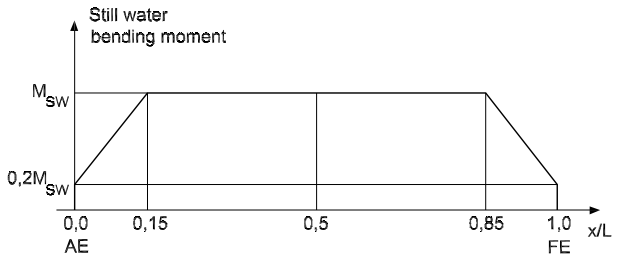
- sagging conditions:

  $M_{SWM,S} = 175\ C\ L^2\ B\ (C_B + 0,7)\ 10^{-3} + M_{WV,S}$

where $M_{WV,H}$ and $M_{WV,S}$ are the vertical wave bending moments, in kN.m, defined in [3.1].

The final structural checks are, in any case, to be carried out on the basis of the design still water bending moments as specified [2.2.1].

Figure 2 : Preliminary still water bending moment distribution



2.3 Still water shear force

2.3.1 The design still water shear force Q_{SW} at any hull transverse section is the maximum positive or negative shear force calculated, at that hull transverse section, for the loading conditions specified in [2.1.2].

3 Wave loads

3.1 Vertical wave bending moments

3.1.1 The vertical wave bending moments at any hull transverse section are obtained, in kN.m, from the following formulae:

- hogging conditions:
  $M_{WV,H} = 150\ F_M\ C\ L^2\ B\ C_B\ (1 + C_A)\ 10^{-3}$
- sagging conditions:
  $M_{WV,S} = -\ 85\ F_M\ C\ L^2\ B\ (C_B + 0,7)\ (1 + C_A)\ 10^{-3}$

where:

F_M : Distribution factor defined in Tab 1 and Fig 3

C_A : Coefficient equal to:

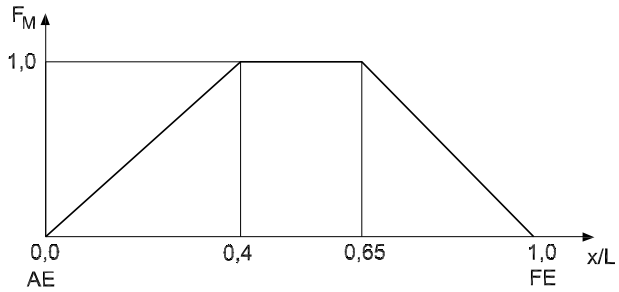
$$C_A = \frac{7,1 H_A (1 + 1,26 F_{CH})^2}{L}$$

3.1.2 The effects of bow flare impact are to be taken into account, for the cases specified in [4.1.1], according to [4.2.1].

Table 1 : Distribution factor F_M

Hull transverse section location	Distribution factor F_M
$0 \le x < 0,4\ L$	$2,5\frac{x}{L}$
$0,4\ L \le x \le 0,65\ L$	1,00
$0,65\ L < x \le L$	$2,86\left(1 - \frac{x}{L}\right)$

Figure 3 : Distribution factor F_M



3.2 Horizontal wave bending moment

3.2.1 The horizontal wave bending moment at any hull transverse section is obtained, in kN.m, from the following formula:

$M_{WH} = 0,42\ F_M\ H_A\ L^2\ T\ C_B$

where F_M is the distribution factor defined in [3.1.1].

3.3 Wave torque

3.3.1 The wave torque at any hull transverse section is to be calculated considering the ship in two different conditions:

- condition 1: ship direction forming an angle of 60° with the prevailing sea direction
- condition 2: ship direction forming an angle of 120° with the prevailing sea direction.

The values of the wave torques in these conditions, calculated with respect to the section centre of torsion, are obtained, in kN.m, from the following formula:

$$M_{WT} = \frac{HL}{4}(F_{TM}C_M + F_{TQ}C_Q d)$$

where:

F_{TM}, F_{TQ} : Distribution factors defined in Tab 2 for ship conditions 1 and 2 (see also Fig 4 and Fig 5)

C_M : Wave torque coefficient:

$C_M = 0,38\ B^2\ C_W^2$

C_Q : Horizontal wave shear coefficient:

$C_Q = 2,8\ T\ C_B$

C_W : Waterplane coefficient, to be taken not greater than the value obtained from the following formula:

$C_W = 0,165 + 0,95\ C_B$

where C_B is to be assumed not less than 0,6. In the absence of more precise determination, C_W may be taken equal to the value provided by the above formula

d : Vertical distance, in m, from the centre of torsion to a point located 0,6 T above the baseline.

Table 2 : Distribution factors F_{TM} and F_{TQ}

Ship condition	Distribution factor F_{TM}	Distribution factor F_{TQ}
1	$1 - \cos\frac{2\pi x}{L}$	$\sin\frac{2\pi x}{L}$
2	$1 - \cos\frac{2\pi(L-x)}{L}$	$\sin\frac{2\pi(L-x)}{L}$

Figure 4 : Ship condition 1 - Distribution factors F_{TM} and F_{TQ}

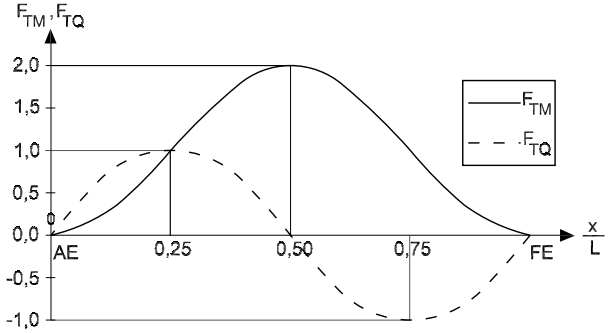
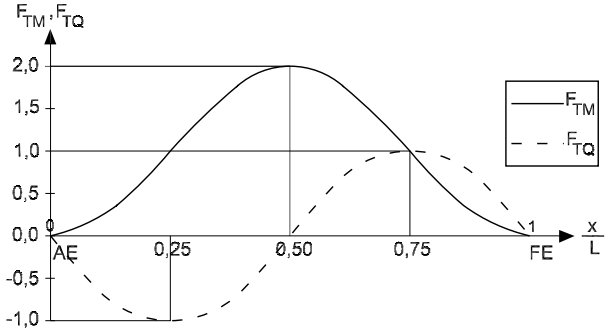


Figure 5 : Ship condition 2 - Distribution factors F_{TM} and F_{TQ}



3.4 Vertical wave shear force

3.4.1 The vertical wave shear force at any hull transverse section is obtained, in kN, from the following formula:

$Q_{WV} = 30\ F_Q\ C\ L\ B\ (C_B + 0,7)\ 10^{-2}$

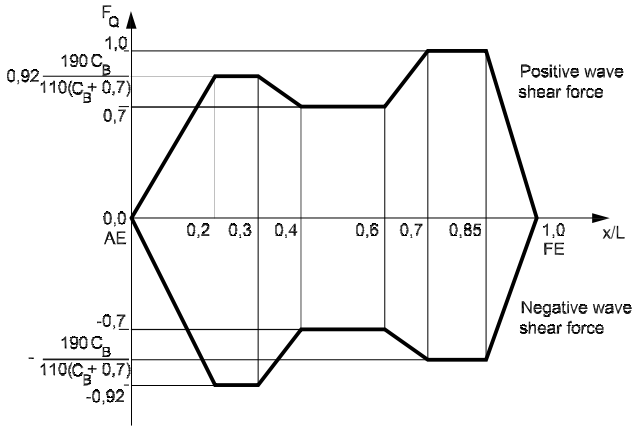
where:

F_Q : Distribution factor defined in Tab 3 for positive and negative shear forces (see also Fig 6).

Table 3 : Distribution factor F_Q

Hull transverse section location	Distribution factor F_Q	
	Positive wave shear force	Negative wave shear force
$0 \le x < 0,2\ L$	$4,6A\frac{x}{L}$	$-4,6\frac{x}{L}$
$0,2\ L \le x \le 0,3\ L$	0,92 A	– 0,92
$0,3\ L < x < 0,4\ L$	$(9,2A-7)\left(0,4-\frac{x}{L}\right)+0,7$	$-2,2\left(0,4-\frac{x}{L}\right)-0,7$
$0,4\ L \le x \le 0,6\ L$	0,70	– 0,70
$0,6\ L < x < 0,7\ L$	$3\left(\frac{x}{L}-0,6\right)+0,7$	$-(10A-7)\left(\frac{x}{L}-0,6\right)-0,7$
$0,7\ L \le x \le 0,85\ L$	1,00	– A
$0,85\ L < x \le L$	$6,67\left(1-\frac{x}{L}\right)$	$-6,67A\left(1-\frac{x}{L}\right)$
Note 1: $A = \frac{190C_B}{110(C_B+0,7)}$		

Figure 6 : Distribution factor F_Q



4 Dynamic loads due to bow flare impact

4.1 Application

4.1.1 The effects of bow flare impact are to be considered where all the following conditions occur:

- $V_{cruise} \ge 17,5$ knots
- $\frac{100FA_S}{LB} > 1$

where:

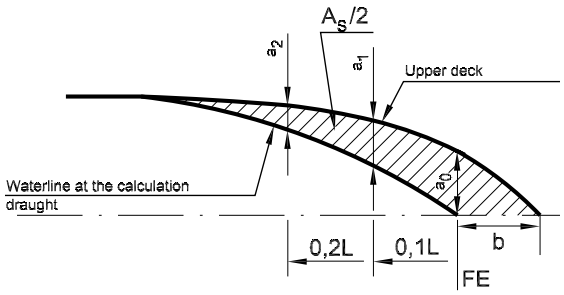
A_S : Twice the shaded area shown in Fig 7, to be obtained, in m^2, from the following formula:

$A_S = b\ a_0 + 0,1\ L\ (a_0 + 2\ a_1 + a_2)$

b, a_0, a_1, a_2 : Distances, in m, shown in Fig 7.

For multideck ships, the upper deck shown in Fig 7 is to be taken as the deck (including superstructures) which extends up to the extreme forward end of the ship and has the largest breadth forward of 0,2 L from the fore end.

Figure 7 : Area A_S



4.1.2 When the effects of bow flare impact are to be considered, according to [4.1.1], the sagging wave bending moment is to be increased as specified in [4.2.1] and [4.2.2].

4.1.3 The Society may require the effects of bow flare impact to be considered also when one of the conditions in [4.1.1] does not occur, if deemed necessary on the basis of the ship's characteristics.

In such cases, the increase in sagging wave bending moment is defined on a case-by-case basis.

4.2 Increase in sagging wave bending moment

4.2.1 General

The sagging wave bending moment at any hull transverse section, defined in [3.1], is to be multiplied by the coefficient F_D obtained from the formulae in Tab 4, which takes into account the dynamic effects of bow flare impact.

Where at least one of the conditions in [4.1.1] does not occur, the coefficient F_D may be taken equal to 1.

Table 4 : Coefficient F_D

Hull transverse section location	Coefficient F_D
$0 \leq x < 0,4\ L$	1,0
$0,4\ L \leq x < 0,5\ L$	$1 + 10(C_D - 1)\left(\frac{x}{L} - 0,4\right)$
$0,5\ L \leq x \leq L$	C_D
Note 1: $C_D = 262,5\frac{A_S}{CLB(C_B + 0,7)} - 0,6$ without being taken greater than 1,2 nor less than 1,0 A_S : Area, in m^2, defined in [4.1.1].	

4.2.2 Direct calculations

As an alternative to the formulae in [4.2.1], the Society may accept the evaluation of the effects of bow flare impact from direct calculations, when justified on the basis of the ship's characteristics. The calculations are to be submitted to the Society for approval.

Section 3 Ship Motions and Accelerations

Symbols

For the symbols not defined in this Section, refer to Ch 1, Sec 2, [2.1.1].

α_P : Pitch acceleration, in rad/s^2, defined in [2.5]

α_R : Roll acceleration, in rad/s^2, defined in [2.4]

α_Y : Yaw acceleration, in rad/s^2, defined in [2.6]

a_B : Motion and acceleration parameter:

$$a_B = 0,76F + 1,875\frac{h_W}{L}$$

a_H : Heave acceleration, in m/s^2, defined in [2.3]

a_{SU} : Surge acceleration, in m/s^2, defined in [2.1]

a_{SW} : Sway acceleration, in m/s^2, defined in [2.2]

A_P : Pitch amplitude, in rad, defined in [2.5].

A_R : Roll amplitude, in rad, defined in [2.4]

F : Froude number calculated at the maximum ahead service speed, defined in Ch 5, Sec 2

g : Gravity acceleration, in m/s^2:

$g = 9,81$ m/s^2

h_W : Wave parameter, in m:

$$h_W = 11,44 - \left|\frac{L-250}{110}\right|^3 \quad \text{for} \quad L < 350 \text{ m}$$

$$h_W = \frac{200}{\sqrt{L}} \quad \text{for} \quad L \geq 350 \text{ m}$$

T_1 : Draught, in m, defined in Ch 5, Sec 1, [2.4.3] or Ch 5, Sec 1, [2.5.3], as the case may be

T_P : Pitch period, in s, defined in [2.5]

T_R : Roll period, in s, defined in [2.4]

T_{SW} : Sway period, in s, defined in [2.2]

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6].

1 General

1.1

1.1.1 Ship motions and accelerations are defined, with their signs, according to the reference co-ordinate system in Ch 1, Sec 2, [10].

1.1.2 Ship motions and accelerations are assumed to be periodic. The motion amplitudes, defined by the formulae in this Section, are half of the crest to through amplitudes.

1.1.3 As an alternative to the formulae in this Section, the Society may accept the values of ship motions and accelerations derived from direct calculations or obtained from model tests, when justified on the basis of the ship's characteristics. In general, the values of ship motions and accelerations to be calculated are those which can be reached with a probability of 10^{-5}. In any case, the model tests or the calculations, including the assumed sea scatter diagrams and spectra, are to be submitted to the Society for approval.

2 Ship absolute motions and accelerations

2.1 Surge

2.1.1 The surge acceleration a_{SU} is to be taken equal to 0,5 m/s^2.

2.2 Sway

2.2.1 The sway period and acceleration are obtained from the formulae in Tab 1.

Table 1 : Sway period and acceleration

Period T_{SW}, in s	Acceleration a_{SW}, in m/s²
$\frac{0,8\sqrt{L}}{1,22F+1}$	$0,775\ a_B\ g$

2.3 Heave

2.3.1 The heave acceleration is obtained, in m/s², from the following formula:

$a_H = a_B\ g$

2.4 Roll

2.4.1 The roll amplitude, period and acceleration are obtained from the formulae in Tab 2.

Table 2 : Roll amplitude, period and acceleration

Amplitude A_R, in rad	Period T_R, in s	Acceleration α_R, in rad/s²
$a_B\sqrt{E}$ without being taken greater than 0,35	$2,2\frac{\delta}{\sqrt{GM}}$	$A_R\left(\frac{2\pi}{T_R}\right)^2$
Note 1: $E = 1,39\frac{GM}{\delta^2}B_{WS}$ to be taken not less than 1,0 GM : Distance, in m, from the ship's centre of gravity to the transverse metacentre, for the loading considered; when GM is not known, the following values may be assumed: GM = 0,07 B_{WS} δ : Roll radius of gyration, in m, for the loading considered; when δ is not known, it may be taken equal to: $\delta = 0,35\ B_{WS}$		

2.5 Pitch

2.5.1 The pitch amplitude, period and acceleration are obtained from the formulae in Tab 3.

Table 3 : Pitch amplitude, period and acceleration

Amplitude A_P, in rad	Period T_P, in s	Acceleration α_P, in rad/s²
$0,328a_B\left(1,32-\frac{h_W}{L}\right)\left(\frac{0,6}{C_B}\right)^{0,75}$	$0,575\sqrt{L}$	$A_p\left(\frac{2\pi}{T_p}\right)^2$

2.6 Yaw

2.6.1 The yaw acceleration is obtained, in rad/s², from the following formula:

$\alpha_Y = 1,581\frac{a_B g}{L}$

3 Ship relative motions and accelerations

3.1 Definitions

3.1.1 Ship relative motions

The ship relative motions are the vertical oscillating translations of the sea waterline on the ship side. They are measured, with their sign, from the waterline at draught T_1.

3.1.2 Accelerations

At any point, the accelerations in X, Y and Z direction are the acceleration components which result from the ship motions defined in [2.1] to [2.6].

3.2 Ship conditions

3.2.1 General

Ship relative motions and accelerations are to be calculated considering the ship in the following conditions:

- upright ship condition
- inclined ship condition.

3.2.2 Upright ship condition

In this condition, the ship encounters waves which produce ship motions in the X-Z plane, i.e. surge, heave and pitch.

3.2.3 Inclined ship condition

In this condition, the ship encounters waves which produce ship motions in the X-Y and Y-Z planes, i.e. sway, roll and yaw.

3.3 Ship relative motions

3.3.1 The reference value of the relative motion in the upright ship condition is obtained, at any hull transverse section, from the formulae in Tab 4.

Table 4 : Reference value of the relative motion h_1 in the upright ship condition

Location	Reference value of the relative motion h_1 in the upright ship condition, in m
x = 0	$0,7\left(\frac{4,35}{\sqrt{C_B}} - 3,25\right) h_{1,M}$
0 < x < 0,3 L	$h_{1,AE} - \frac{h_{1,AE} - h_{1,M}}{0,3}\frac{x}{L}$
0,3 L ≤ x ≤ 0,7 L	0,42 C (C_B + 0,7) without being taken greater than the minimum of T_1 and D – 0,9 T
0,7 L < x < L	$h_{1,M} + \frac{h_{1,FE} - h_{1,M}}{0,3}\left(\frac{x}{L} - 0,7\right)$
x = L	$\left(\frac{4,35}{\sqrt{C_B}} - 3,25\right) h_{1,M}$
Note 1: C : Wave parameter defined in Ch 5, Sec 2 $h_{1,AE}$: Reference value h_1 calculated for x = 0 $h_{1,M}$: Reference value h_1 calculated for x = 0,5 L $h_{1,FE}$: Reference value h_1 calculated for x = L.	

3.3.2 The reference value, in m, of the relative motion in the inclined ship condition is obtained, at any hull transverse section, from the following formula:

$$h_2 = 0,5h_1 + A_R\frac{B_W}{2}$$

where:

h_1 : Reference value, in m, of the relative motion in the upright ship, calculated according to [3.3.1]

B_W : Moulded breadth, in m, measured at the waterline at draught T_1 at the hull transverse section considered.

3.4 Accelerations

3.4.1 The reference values of the longitudinal, transverse and vertical accelerations at any point are obtained from the formulae in Tab 5 for upright and inclined ship conditions.

Table 5 : Reference values of the accelerations a_X, a_Y and a_Z

Direction		Upright ship condition	Inclined ship condition
X - Longitudinal	a_{X1} and a_{X2} in m/s²	$a_{X1} = \sqrt{a_{SU}^2 + [A_P g + \alpha_p(z - T_1)]^2}$	$a_{x2} = 0$
Y - Transverse	a_{Y1} and a_{Y2} in m/s²	$a_{Y1} = 0$	$a_{Y2} = \sqrt{a_{SW}^2 + [A_R g + \alpha_R(z - T_1)]^2 + \alpha_Y^2 K_X L^2}$
Z - Vertical	a_{Z1} and a_{Z2} in m/s²	$a_{Z1} = \sqrt{a_H^2 + \alpha_p^2 K_X L^2}$	$a_{z2} = \sqrt{0,25 a_H^2 + \alpha_R^2 y^2}$
Note 1: $K_X = 1,2\left(\frac{x}{L}\right)^2 - 1,1\frac{x}{L} + 0,2$ without being taken less than 0,018			

Section 4 Load Cases

Symbols

a_{X1}, a_{Y1}, a_{Z1}: Reference values of the accelerations in the upright ship condition, defined in Ch 5, Sec 3, [3.4]

a_{X2}, a_{Y2}, a_{Z2}: Reference values of the accelerations in the inclined ship condition, defined in Ch 5, Sec 3, [3.4]

h_1 : Reference value of the ship relative motion in the upright ship condition, defined in Ch 5, Sec 3, [3.3]

h_2 : Reference value of the ship relative motion in the inclined ship condition, defined in Ch 5, Sec 3, [3.3]

M_{WV} : Reference value of the vertical wave bending moment, defined in Ch 5, Sec 2, [3.1]

M_{WH} : Reference value of the horizontal wave bending moment, defined in Ch 5, Sec 2, [3.2]

M_{WT} : Reference value of the wave torque, defined in Ch 5, Sec 2, [3.3]

Q_{WV} : Reference value of the vertical wave shear force, defined in Ch 5, Sec 2, [3.4]

T_1 : Draught, in m, defined in Ch 5, Sec 1, [2.4.3] or Ch 5, Sec 1, [2.5.3], as the case may be.

1 General

1.1 Load cases for structural analyses based on partial ship models

1.1.1 The load cases described in this Section are those to be used for structural element analyses which do not require complete ship modelling. They are:

- the analyses of plating (see Ch 7, Sec 1)
- the analyses of ordinary stiffeners (see Ch 7, Sec 2)
- the analyses of primary supporting members through isolated beam structural models or three-dimensional structural models (see Ch 7, Sec 3)
- the fatigue analysis of the structural details of the above elements (see Ch 7, Sec 4).

1.1.2 These load cases are the mutually exclusive load cases “a”, “b”, “c” and “d” described in Article [2].

Load cases “a” and “b” refer to the ship in upright conditions (see Ch 5, Sec 3, [3.2]), i.e. at rest or having surge, heave and pitch motions.

Load cases “c” and “d” refer to the ship in inclined conditions (see Ch 5, Sec 3, [3.2]), i.e. having sway, roll and yaw motions.

1.2 Load cases for structural analyses based on complete ship models

1.2.1 When primary supporting members are to be analysed through complete ship models according to Ch 7, Sec 3, [1.1.2], specific load cases are to be considered.

These load cases are to be defined considering the ship as sailing in regular waves with different length, height and heading angle, each wave being selected in order to maximise a design load parameter. The procedure for the determination of these load cases is specified in Ch 7, App 3.

2 Load cases

2.1 Upright ship conditions (load cases “a” and “b”)

2.1.1 Ship condition

The ship is considered to encounter a wave which produces (see Fig 1 for load case “a” and Fig 2 for load case “b”) a relative motion of the sea waterline (both positive and negative) symmetric on the ship sides and induces wave vertical bending moment and shear force in the hull girder. In load case “b”, the wave is also considered to induce heave and pitch motions.

2.1.2 Local loads

The external pressure is obtained by adding to or subtracting from the still water head a wave head corresponding to the relative motion.

The internal loads are the still water loads induced by the weights carried, including those carried on decks. For load case “b”, those induced by the accelerations are also to be taken into account.

2.1.3 Hull girder loads

The hull girder loads are:

- the vertical still water bending moment and shear force
- the vertical wave bending moment and the shear force.

Figure 1 : Wave loads in load case “a”

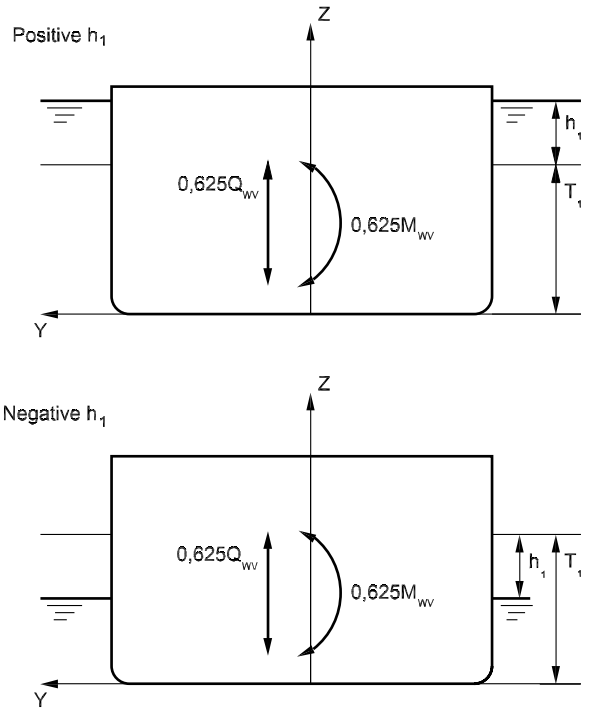
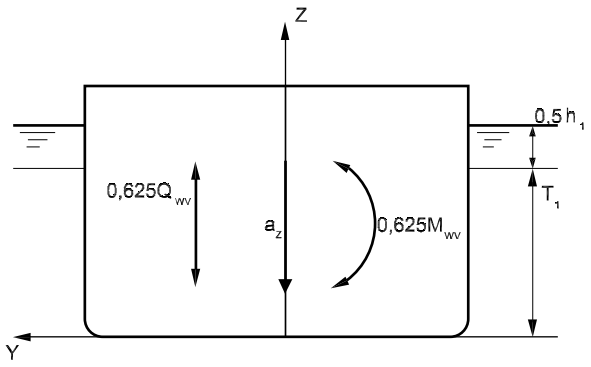


Figure 2 : Wave loads in load case “b”



2.2 Inclined ship conditions (load cases “c” and “d”)

2.2.1 Ship condition

The ship is considered to encounter a wave which produces (see Fig 3 for load case “c” and Fig 4 for load case “d”):

- sway, roll and yaw motions
- a relative motion of the sea waterline anti-symmetric on the ship sides,

and induces:

- vertical wave bending moment and shear force in the hull girder
- horizontal wave bending moment in the hull girder
- in load case “c”, torque in the hull girder.

2.2.2 Local loads

The external pressure is obtained by adding or subtracting from the still water head a wave head linearly variable from positive values on one side of the ship to negative values on the other.

The internal loads are the still water loads induced by the weights carried, including those carried on decks, and the wave loads induced by the accelerations.

Figure 3 : Wave loads in load case “c”

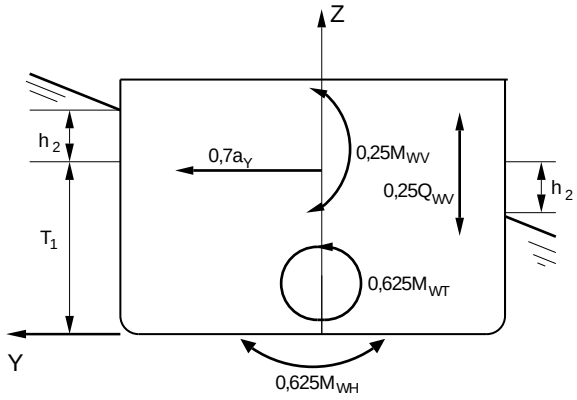
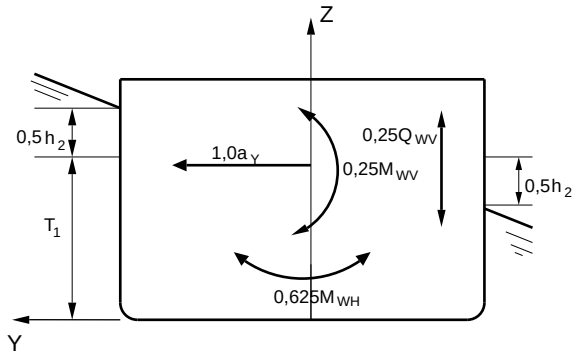


Figure 4 : Wave loads in load case “d”



2.2.3 Hull girder loads

The hull girder loads are:

- the still water bending moment and shear force
- the vertical wave bending moment and shear force
- the horizontal wave bending moment
- the wave torque (for load case “c”).

2.3 Summary of load cases

2.3.1 The wave local and hull girder loads to be considered in each load case are summarised in Tab 1 and Tab 2, respectively. These loads are obtained by multiplying, for each load case, the reference value of each wave load by the relevant combination factor.

Table 1 : Wave local loads in each load case

Ship condition	Load case	Relative motions		Accelerations a_X, a_Y, a_Z	
		Reference value	Combination factor	Reference value	Combination factor
Upright	“a”	h_1	1,0	a_{X1} ; 0; a_{Z1}	0,0
	“b” **(1)**	h_1	0,5	a_{X1} ; 0; a_{Z1}	1,0
Inclined	“c” **(2)**	h_2	1,0	0; a_{Y2} ; a_{Z2}	0,7
	“d” **(2)**	h_2	0,5	0; a_{Y2} ; a_{Z2}	1,0

(1) For a ship moving with a positive heave motion:
- h_1 is positive
- the acceleration a_{X1} is directed towards the positive part of the X axis
- the acceleration a_{Z1} is directed towards the negative part of the Z axis

(2) For a ship rolling with a negative roll angle:
- h_2 is positive for the points located in the positive part of the Y axis and, vice-versa, it is negative for the points located in the negative part of the Y axis
- the acceleration a_{Y2} is directed towards the positive part of the Y axis
- the acceleration a_{Z2} is directed towards the negative part of the Z axis for the points located in the positive part of the Y axis and, vice-versa, it is directed towards the positive part of the Z axis for the points located in the negative part of the Y axis.

Table 2 : Wave hull girder loads in each load case

Ship condition	Load case	Vertical bending moment		Vertical shear force		Horizontal bending moment		Torque	
		Reference value	Comb. factor	Reference value	Comb. factor	Reference value	Comb. factor	Reference value	Comb. factor
Upright	"a"	0,625 M_{WV}	1,0	0,625 Q_{WV}	1,0	0,625 M_{WH}	0,0	0,625 M_{WT}	0,0
	"b"	0,625 M_{WV}	1,0	0,625 Q_{WV}	1,0	0,625 M_{WH}	0,0	0,625 M_{WT}	0,0
Inclined	"c"	0,625 M_{WV}	0,4	0,625 Q_{WV}	0,4	0,625 M_{WH}	1,0	0,625 M_{WT}	1,0
	"d"	0,625 M_{WV}	0,4	0,625 Q_{WV}	0,4	0,625 M_{WH}	1,0	0,625 M_{WT}	0,0

Note 1: The sign of the hull girder loads, to be considered in association with the wave local loads for the scantling of plating, ordinary stiffeners and primary supporting members contributing to the hull girder longitudinal strength, is defined in Part B, Chapter 7.

Section 5 Sea Pressures

Symbols

For the symbols not defined in this Section, refer to Ch 1, Sec 2, [2.1.1].

ρ : Sea water density, taken equal to 1,025 t/m^3

g : Gravity acceleration, in m/s^2:

$g = 9{,}81$ m/s^2

h_1 : Reference values of the ship relative motions in the upright ship condition, defined in Ch 5, Sec 3, [3.3]

h_2 : Reference values of the ship relative motions in the inclined ship conditions, defined in Ch 5, Sec 3, [3.3].

T_1 : Draught, in m, defined in Ch 5, Sec 1, [2.4.3] or Ch 5, Sec 1, [2.5.3], as the case may be

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6].

1 Still water pressure

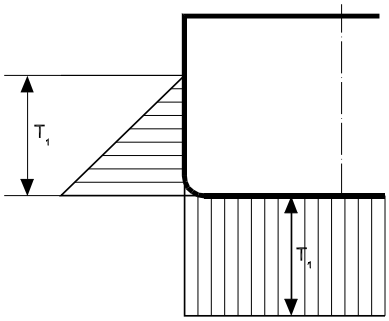
1.1 Pressure on sides and bottom

1.1.1 The still water pressure at any point of the hull is obtained from the formulae in Tab 1 (see also Fig 1).

Table 1 : Still water pressure

Location	Still water pressure p_S, in kN/m^2
Points at and below the waterline ($z \le T_1$)	$\rho\, g\, (T_1 - z)$
Points above the waterline ($z > T_1$)	0

Figure 1 : Still water pressure



2 Wave pressure

2.1 Upright ship conditions (load cases “a” and “b”)

2.1.1 Pressure on sides and bottom

The wave pressure at any point of the sides and bottom is obtained from the formulae in Tab 2 (see also Fig 2 for load case “a” and Fig 3 for load case “b”).

Table 2 : Wave pressure on sides and bottom in upright ship conditions (load cases “a” and “b”)

Location	Wave pressure p_W, in kN/m²	
	Crest	Trough
Bottom and sides below the waterline ($z \leq T_1$)	$\rho g h e^{\frac{-2\pi(T_1 - z)}{L}}$	$-\rho g h e^{\frac{-2\pi(T_1 - z)}{L}}$ without being taken less than $\rho g (z - T_1)$
Sides above the waterline ($z > T_1$)	$\rho g (T_1 + h - z)$ without being taken, for case “a” only, less than $0,15 \varphi_1 \varphi_2 L$	0,0
Note 1: $h = C_{F1} h_1$ C_{F1} : Combination factor, to be taken equal to: • $C_{F1} = 1,0$ for load case “a” • $C_{F1} = 0,5$ for load case “b”.		

Figure 2 : Wave pressure in load case “a”

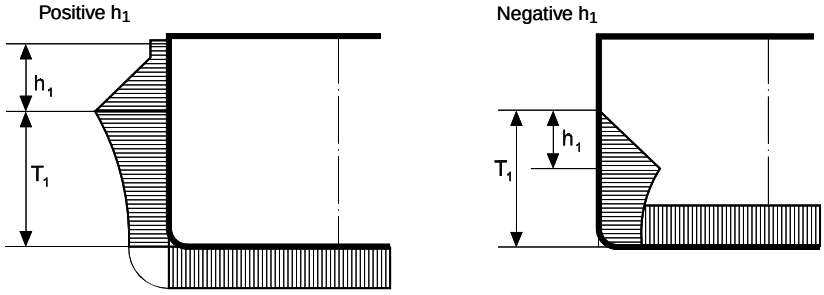
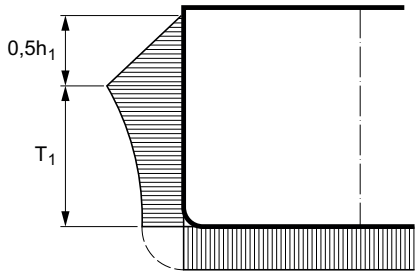


Figure 3 : Wave pressure in load case “b”



2.2 Inclined ship conditions (load cases “c” and “d”)

2.2.1 The wave pressure at any point of the sides and bottom is obtained from the formulae in Tab 3 (see also Fig 4 for load case “c” and Fig 5 for load case “d”).

Figure 4 : Wave pressure in load case “c”

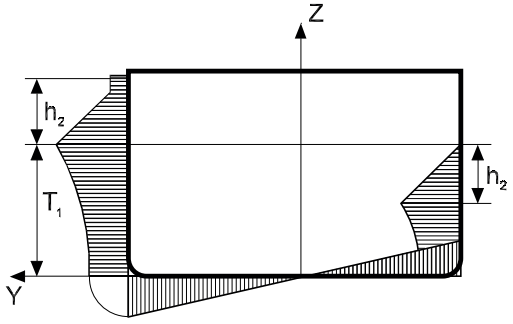


Figure 5 : Wave pressure in load case "d"

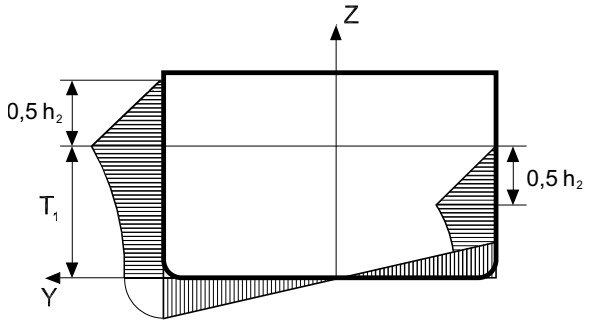


Table 3 : Wave pressure on sides, bottom and exposed decks in inclined ship conditions (load cases "c" and "d")

Location	Wave pressure p_W, in kN/m² (negative roll angle) **(1)**	
	$y \geq 0$	$y < 0$
Bottom and sides below the waterline ($z \leq T_1$)	$\beta C_{F2} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{L}} + A_R y e^{\frac{-\pi(T_1 - z)}{L}} \right]$	$\beta C_{F2} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{L}} + A_R y e^{\frac{-\pi(T_1 - z)}{L}} \right]$ without being taken less than $\rho g (z - T_1)$
Sides above the waterline ($z > T_1$)	$\rho g \left[T_1 + \beta C_{F2} \left(\frac{y}{B_W} h_1 + A_R y \right) - z \right]$ without being taken, for case "c" only, less than $0,15\ \varphi_1\ \varphi_2\ L$	0
Exposed decks	$0,4 \rho g \left[T_1 + \beta C_{F2} \left(\frac{y}{B_W} h_1 + A_R y \right) - z \right]$ without being taken, for case "c" only, less than $0,15\ \varphi_1\ \varphi_2\ L$	0

(1) In the formulae giving the wave pressure p_W, the ratio (y / B_W) is not to be taken greater than 0,5.

Note 1:

φ_1 : Coefficient defined in Tab 4

φ_2 : Coefficient defined in Tab 5

C_{F2} : Combination factor, to be taken equal to:

- $C_{F2} = 1,0$ for load case "c"
- $C_{F2} = 0,5$ for load case "d"

β : coefficient, to be taken as the minimum of:

- 1
- $T_1 / \left(0,5 h_1 + A_R \frac{B_W}{2} \right)$
- $(D - 0,9T) / \left(0,5 h_1 + A_R \frac{B_W}{2} \right)$

B_W : Moulded breadth, in m, measured at the waterline at draught T_1, at the hull transverse section considered

A_R : Roll amplitude, defined in Ch 5, Sec 3, [2.4.1].

3 Exposed decks

3.1 Application

3.1.1 The pressures defined in [3.2] for exposed decks are to be considered independently of the pressures due to dry uniform cargoes, dry unit cargoes or wheeled cargoes, if any, as defined in Ch 5, Sec 6, [2], Ch 5, Sec 6, [3] and Ch 5, Sec 6, [4] respectively.

3.2 Sea pressures on exposed decks

3.2.1 Still water pressure

The still water pressure on exposed decks p_S, in kN/m², is to be taken equal to $10.\varphi_1.\varphi_2$, where φ_1 is defined in Tab 4 and φ_2 in Tab 5.

3.2.2 Green sea loads

The wave pressure on exposed decks due to green sea is obtained from the formulae in Tab 3 and Tab 5.

Table 4 : Coefficient for pressure on exposed decks

Exposed deck location	φ_1
Watertight deck and below	1,00
Top of lowest tier	0,75
Top of second tier	0,56
Top of third tier	0,42
Top of fourth tier	0,32
Top of fifth tier	0,25
Top of sixth tier	0,20
Top of seventh tier	0,15
Top of eighth tier and above	0,10

Table 5 : Wave pressure on exposed decks in upright ship conditions (load cases “a” and “b”)

Location	Wave pressure p_W, in kN/m²	
	Crest	Through
$0 \le x \le 0,5\ L$	$17,5\varphi_1\varphi_2$	0
$0,5\ L < x < 0,75\ L$	$\left\{17,5 + \left[\frac{19,6\sqrt{H_F} - 17,5}{0,25}\right]\left(\frac{x}{L} - 0,5\right)\right\}\varphi_1\varphi_2$	0
$0,75\ L \le x \le L$	$19,6\varphi_1\varphi_2\sqrt{H}$	0

Note 1:

$H = C_{F1}\left[2,66\left(\frac{x}{L} - 0,7\right)^2 + 0,14\right]\sqrt{\frac{VL}{C_B}} - (z - T_1)$ without being taken less than 0,8

φ_1 : Coefficient defined in Tab 4

φ_2 : Coefficient taken equal to:

- $\varphi_2 = 1$ if $L \ge 120$ m
- $\varphi_2 = L/120$ if $L < 120$ m

H_F : Value of H calculated at $x = 0,75\ L$

C_{F1} : Combination factor, to be taken equal to:

- $C_{F1} = 1,0$ for load case “a”
- $C_{F1} = 0,5$ for load case “b”

V : Maximum ahead service speed, in knots, to be taken not less than 13 knots.

4 Sea chests

4.1 Design pressure

4.1.1 The pressure to be considered for the scantling of sea chests is the maximum between:

- sea pressure as calculated in Articles [1] and [2] for sides and bottom
- pressure covering the hazard of an overpressure in case of sea chests fitted with an inlet grating clearing system functioning by use of compressed air or steam devices, to be specified by the Designer and taken not less than 200 kN/m².

Section 6 Internal Pressures and Forces

Symbols

For the symbols not defined in this Section, refer to Ch 1, Sec 2, [2.1.1].

ρ_L : Density, in t/m^3, of the liquid carried

a_{X1} , a_{Y1} , a_{Z1} : Reference values of the accelerations in the upright ship condition, defined in Ch 5, Sec 3, [3.4], calculated in way of the centre of gravity:

- of the compartment, in general
- of any dry unit cargo, in the case of this type of cargo

a_{X2} , a_{Y2} , a_{Z2} : Reference values of the accelerations in the inclined ship condition, defined in Ch 5, Sec 3, [3.4], calculated in way of the centre of gravity:

- of the compartment, in general
- of any dry unit cargo, in the case of this type of cargo

C_{FA} : Combination factor, to be taken equal to:

- for load case "c":
  $C_{FA} = 0,7$
- for load case "d":
  $C_{FA} = 1,0$

d_0 : Distance, in m, to be taken equal to:

for 65 m ≤ L < 120 m:

$d_0 = 0,02\ L$

for L ≥ 120 m:

$d_0 = 2,4$

g : Gravity acceleration, in m/s^2:

$g = 9,81$ m/s^2

H : Height, in m, of a tank, to be taken as the vertical distance from the bottom to the top of the tank, excluding any small hatchways

M : Mass, in t, of a dry unit cargo carried

p_{PV} : Setting pressure, in bar, of safety valves

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]

z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend, to be taken not less than z_{TOP}

z_L : Z co-ordinate, in m, of the highest point of the liquid:

$z_L = z_{TOP} + 0,5\ (z_{AP} - z_{TOP})$

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank in the z direction.

1 Liquids

1.1 Still water pressure

1.1.1 Still water pressure

The still water pressure to be used in combination with the inertial pressure in [1.2] is the greater of the values obtained, in kN/m^2, from the following formulae:

$p_S = \rho_L\ g\ (z_L - z)$

$p_S = \rho_L\ g\ (z_{TOP} - z) + 100\ p_{PV}$

1.2 Inertial pressure

1.2.1 Inertial pressure

The inertial pressure is obtained from the formulae in Tab 1, or from Ch 5, App 1 for typical tank arrangements.

Moreover, the inertial pressure is to be taken such that:

$p_S + p_W \geq 0$

where p_S is defined in [1.1].

Table 1 : Liquids - Inertial pressure

Ship condition	Load case	Inertial pressure p_W, in kN/m²
Upright	"a"	No inertial pressure
	"b"	$\rho_L [0,5\ a_{X1}\ \ell_B + a_{Z1}\ (z_{TOP} - z)]$
Inclined (negative roll angle)	"c"	$\rho_L [a_{TY}\ (y - y_H) + a_{TZ}\ (z - z_H) + g\ (z - z_{TOP})]$
	"d"	

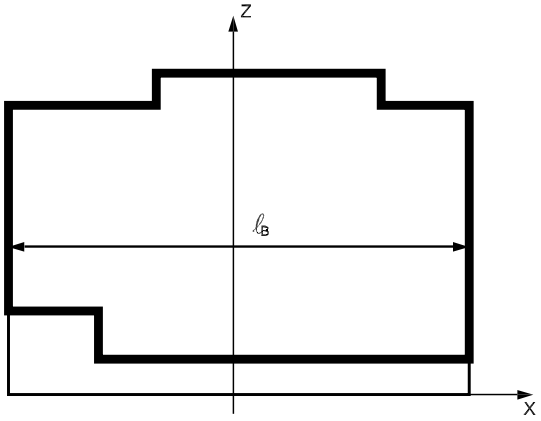
Note 1:

ℓ_B : Longitudinal distance, in m, between the transverse tank boundaries, without taking into account small recesses in the lower part of the tank (see Fig 1)

a_{TY} , a_{TZ} : Y and Z components, in m/s², of the total acceleration vector defined in [1.2.2] for load case "c" and load case "d"

y_H , z_H : Y and Z co-ordinates, in m, of the highest point of the tank in the direction of the total acceleration vector, defined in [1.2.3] for load case "c" and load case "d".

Figure 1 : Upright ship conditions - Distance ℓ_B



1.2.2 Total acceleration vector

The total acceleration vector is the vector obtained from the following formula:

$$\vec{A_T} = \vec{A} + \vec{G}$$

where:

A : Acceleration vector whose absolute values of X, Y and Z components are the longitudinal, transverse and vertical accelerations defined in Ch 5, Sec 3, [3.4]

G : Gravity acceleration vector.

The Y and Z components of the total acceleration vector and the angle it forms with the z direction are defined in Tab 2.

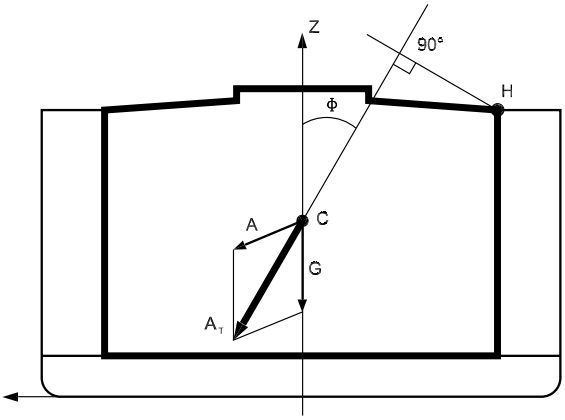
Table 2 : Inclined ship conditions Y and Z components of the total acceleration vector and angle Φ it forms with the z direction

Components (negative roll angle)		Angle Φ, in rad
a_{TY}, in m/s²	a_{TZ}, in m/s²	
$0,7\ C_{FA}\ a_{Y2}$	$-0,7\ C_{FA}\ a_{Z2} - g$	$\text{atan}\frac{a_{TY}}{a_{TZ}}$

1.2.3 Highest point of the tank in the direction of the total acceleration vector

The highest point of the tank in the direction of the total acceleration vector A_T, defined in [1.2.2], is the point of the tank boundary whose projection on the direction forming the angle Φ with the vertical direction is located at the greatest distance from the tank's centre of gravity. It is to be determined for the inclined ship condition, as indicated in Fig 2, where A and G are the vectors defined in [1.2.2] and C is the tank's centre of gravity.

Figure 2 : Inclined ship conditions Highest point H of the tank in the direction of the total acceleration vector



2 Dry uniform loads

2.1 Still water and inertial pressures

2.1.1 General

The still water and inertial pressures are obtained, in kN/m^2, as specified in Tab 3.

Table 3 : Dry uniform loads Still water and inertial pressure

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m^2
Still water		The value of p_S is generally specified by the Designer; in any case, it may not be taken less than 10 kN/m^2. When the value of p_S is not specified by the Designer, it may be taken, in kN/m^2, equal to 6,9 h_{TD}, where h_{TD} is the compartment 'tweendeck height at side, in m
Upright (positive heave motion)	"a"	No inertial pressure
	"b"	$p_{W,Z} = p_S \frac{a_{Z1}}{g}$ in z direction
Inclined (negative roll angle)	"c"	$p_{W,Y} = p_S \frac{C_{FA} a_{Y2}}{g}$ in y direction
	"d"	$p_{W,Z} = p_S \frac{C_{FA} a_{Z2}}{g}$ in z direction

3 Dry unit cargoes

3.1 Still water and inertial forces

3.1.1 The still water and inertial forces transmitted to the hull structures are to be determined on the basis of the forces obtained, in kN, as specified in Tab 4 taking into account the elastic characteristics of the lashing arrangement and/or the structure which contains the unit.

Table 4 : Dry unit - Still water and inertial forces

Ship condition	Load case	Still water force F_S and inertial force F_W, in kN
Still water		$F_S = M\,g$
Upright (positive heave motion)	"a"	No inertial force
	"b"	$F_{W,X} = M\,a_{X1}$ in x direction $F_{W,Z} = M\,a_{Z1}$ in z direction
Inclined (negative roll angle)	"c"	$F_{W,Y} = M\,C_{FA}\,a_{Y2}$ in y direction $F_{W,Z} = M\,C_{FA}\,a_{Z2}$ in z direction
	"d"	

4 Vehicles and helicopters

4.1 Still water and inertial forces

4.1.1 Tyred vehicles and helicopters

The forces transmitted through the tyres are to be considered as a pressure uniformly distributed over the tyre print. With the exception of dimensioning of plating, such forces may be considered as concentrated in the tyre print centre.

The designer is to provide the following information for each tyred vehicle or helicopter:

- the number of axles and the relative arrangement of axles
- the number of wheels on axles and their arrangement
- the maximum mass of the vehicle or helicopter
- the distribution of load per axle
- the dimensions of the tyre prints
- the tyre pressures, if the dimensions of the tyre prints is not specified.

The above information is to be specified for all relevant operating and non-operating conditions.

In the case of vehicles having a Safe Working Load or maximum rated lifting capacity (for example, forklifts and movable cranes), the maximum mass and distribution of load per axle are to be specified with respect to these values.

The still water and inertial forces transmitted to the hull structures are to be determined on the basis of the forces obtained, in kN, as specified in Tab 5.

4.1.2 Non-tyred rolling vehicles

The requirements of [4.1.1] also apply to tracked vehicles; in this case the print to be considered is that below each wheel or wheelwork.

4.1.3 Other vehicles

For other vehicles on fixed supports, all the forces transmitted are to be considered as concentrated at the contact area centre.

Table 5 : Vehicles and helicopters Still water and inertial forces

Ship condition	Load case	Still water force F_S and inertial force F_W, in kN
Still water **(1) (2)**		$F_S = M\ g$
Upright (positive heave motion)**(1)**	"a"	No inertial force
	"b"	$F_{W,Z} = \alpha\ M\ a_{Z1}$ in z direction
Inclined (negative roll angle)**(2)**	"c"	$F_{W,Y} = M\ C_{FA}\ a_{Y2}$ in y direction
	"d"	$F_{W,Z} = M\ C_{FA}\ a_{Z2}$ in z direction
Harbour		$F_{W,X} = 0,035\ M\ g$ in x direction $F_{W,Y} = 0,087\ M\ g$ in y direction $F_{W,Z} = 0,100\ M\ g$ in z direction

(1) This condition defines the force, applied by one wheel, to be considered for the determination of scantlings of plating, ordinary stiffeners and primary supporting members, as defined in Part B, Chapter 7, where:

α : Coefficient taken equal to 0,5

M : Mass, in t, taken equal to:

$$M = \frac{Q_A}{n_W}$$

Q_A : Axle load, in t

n_W : Number of wheels for the axle considered.

(2) This condition is to be considered for the racking analysis, as defined in Ch 7, App 2, with M taken equal to the mass, in t, of wheeled loads located on the structural member under consideration.

5 Accommodation and ammunition storage

5.1 Still water and inertial pressures

5.1.1 The still water and inertial pressures transmitted to the deck structures are obtained, in kN/m^2, as specified in Tab 6 and Tab 7.

5.1.2 In addition to the pressures defined in [5.1.1], the effect of significant concentrated loads must be taken into account, when deemed necessary by the Society.

5.1.3 Manoeuvring areas are always to be considered as exposed areas, and as such, subject to the relevant loads in Ch 5, Sec 5.

5.1.4 For ammunition storages, the case of fire-extinguishing by flooding as per Pt C, Ch 4, Sec 6 is to be taken into consideration, in addition to Tab 7. Loads on decks and side walls are to be checked according to [1]. In case the water-spraying system is fitted with an automatic closing of the water supply valve when the water level reaches the top of the storage area, this maximum water level is to be clearly specified on relevant drawings and is to be considered for calculation of liquid pressure in Article [1].

Doors and hatches giving access to ammunition storage are to have a strength equivalent to the one of the surrounding structure.

For ammunition storages above the deepest waterline and fitted with scuppers, reduction of pressure may be considered on a case-by-case basis, based on justification provided by the Designer.

Table 6 : Accommodations and ammunition storage - Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water		The value of p_S is defined in Tab 7 depending on the type of the accommodation compartment
Upright (positive heave motion)	"a"	No inertial force
	"b"	$p_W = p_S \frac{a_{Z1}}{g}$
Inclined	"c"	The inertial pressure transmitted to the deck structures in inclined condition may generally be disregarded. Specific cases in which this simplification is not deemed permissible by the Society are considered individually
	"d"	

Table 7 : Still water deck pressure in operational and accommodation compartments

Type of operational and accommodation compartments	p_S, in kN/m²
Operational rooms (COC, COP, TLC, ECG, ADT, GE, RADAR room, EMPAR, METEO)	6,5
Cabins, hospitals, kitchens, baggage rooms	3,0
Galleys, restaurant, meeting rooms, briefing rooms, corridors, lounges	5,0
Other storages	10,0
Ammunition storages	**(1)**
(1) The value of p_S is to be specified by the Designer; in any case, it may not be less than 15,0 kN/m². This value may also be assumed for the scantling checks where, at a preliminary design stage, the value of p_S is not yet defined by the Designer.	

6 Machinery

6.1 Still water and inertial pressures

6.1.1 The still water and inertial pressures transmitted to the deck structures are obtained, in kN/m², as specified in Tab 8.

Table 8 : Machinery - Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water		$p_S = 10$
Upright (positive heave motion)	"a"	No inertial pressure
	"b"	$p_W = p_S \frac{a_{Z1}}{g}$
Inclined	"c"	The inertial pressure transmitted to the deck structures in inclined condition may generally be disregarded. Specific cases in which this simplification is not deemed permissible by the Society are considered individually
	"d"	

7 Flooding

7.1 Still water and inertial pressures

7.1.1 Unless otherwise specified, the still water pressure p_{SF}, in kN/m², and the inertial pressure p_{WF}, in kN/m², to be considered as acting on structural watertight elements defined as per Internal Watertight Plan and located below the deepest equilibrium waterline (excluding side shell structural elements) which constitute boundaries intended to stop vertical and horizontal flooding are obtained from the formulae in Tab 9.

Table 9 : Flooding - Still water and inertial pressures

Still water pressure p_{SF}, in kN/m²	Inertial pressure p_{WF}, in kN/m²
$\rho\ g\ (z_F - z)$ without being taken less than $0,4\ g\ d_0$	$0,6\ \rho\ a_{Z1}\ (z_F - z)$ without being taken less than $0,4\ g\ d_0$
Note 1: z_F : Z co-ordinate, in m, at the deepest equilibrium waterline at side in way of the transverse section considered, obtained from the damage stability calculations, for which the transient conditions are to be taken into account d_0 : Distance, in m, to be taken equal to: $d_0 = 0,02\ L$ for $65\ m \le L \le 120\ m$ $d_0 = 2,4$ for $L > 120\ m$.	

8 Testing

8.1 Still water pressures

8.1.1 The still water pressure to be considered as acting on plates and stiffeners subject to structural testing is obtained, in kN/m², from the formulae in Tab 10.

No inertial pressure is to be considered as acting on plates and stiffeners subject to structural testing.

Table 10 : Testing - Still water pressures

Compartment or structure to be tested	Still water pressure p_{ST}, in kN/m²
Double bottom tanks Double side tanks Fuel oil overflow tanks not intended to hold fuel	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + h_{air}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$ $p_{ST} = 10\ (z_{ML} - z)$
Peak tanks Tanks and tank bulkheads other than those listed elsewhere in this table	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + h_{air}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$
Fuel oil tanks	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + h_{air}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$ $p_{ST} = 10\ [(z_{TOP} - z) + 10\ p_{PV}]$ $p_{ST} = 10\ [(z_{ML} - z)$
Chain locker **(1)**	$p_{ST} = 10\ (z_{cp} - z)$
Ballast ducts	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + 0,1 p_{PV}]$ Ballast pump maximum pressure
h_{air} : Height, in m, of air pipe or overflow pipe above the top of the tank or compartment Z_{cp} : Z co-ordinate, in m, of the top of chain pipe z_f : Z co-ordinate, in m, of the maximum height of water in case of fire extinguishing by flooding z_{ML} : Z co-ordinate, in m, of the margin line at the position of the compartment **(1)** Unless except from structural testing as per Ch 11, Sec 3, [2.2.6]	

9 Weapons firing dynamic loads

9.1 Dynamic loads

9.1.1 General

The following weapons firing dynamic loads are to be specified by the Designer:

- missile blast dynamic pressure
- accidental missile ignition dynamic pressure
- gun blast dynamic pressure
- gun recoil dynamic force, for all the possible combinations of elevation and slewing angle of the weapon system.

As guidance, they may be obtained from the formulae specified in [9.2].

9.1.2 Other loads

Weapon firing dynamic loads other than those specified in [9.1.1], such as loads on vertical missile launching systems (VLS) and loads on rocket or missile launching systems with elevation and slewing capabilities, are generally to be specified by the weapon manufacturer. In any event, they are to be considered by the Society on a case-by-case basis.

9.1.3 Additional loads

At the request of the interested parties, additional weapon firing dynamic loads other than those specified in [9.1.1] and [9.1.2], such as collision or hitting against fixed devices fitted in way of the weapon system rail limits, may be considered by the Society on a case-by-case basis, together with the relevant weapon manufacturer specification.

9.2 Guidance values

9.2.1 Missile blast dynamic pressure

As guidance, the missile blast dynamic pressure may be obtained, in kN/m^2, from the following formula:

$$p_W = \frac{T\left(\sin\alpha + \left(\frac{0,0225}{\sin\alpha}\right)\right)}{A}$$

where (see Fig 3):

T : Total thrust, in kN, of the missile

α : Angle, in degrees, of incidence for missile blast with respect to the considered surface

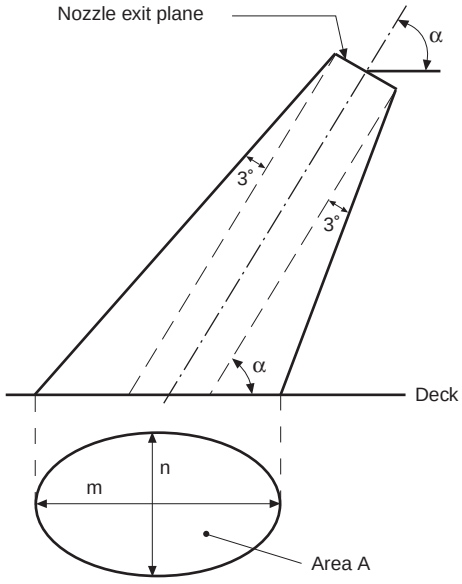
A : Impingement area, in m^2, of the considered surface bounded by the blast cone, i.e. the cone generated by rotating about the missile axis a line with a 3° divergence from the axis and passing through the circumference of the exit nozzle. The impingement area is to be obtained, in m^2, from the following formula:

$$A = \alpha m \frac{n}{4}$$

m : Major axis, in m, of the impingement area

n : Minor axis, in m, of the impingement area.

Figure 3 : Missile blast impingement area



9.2.2 Accidental missile ignition dynamic pressure

As guidance, the accidental missile ignition dynamic pressure may be obtained, in kN/m^2, from the following formula:

$$p_W = \frac{67,4R}{A_B}$$

where:

R : Burning rate, in kg / s, of the missile booster

A_B : Total area, in m^2, of blow-out opening.

9.2.3 Gun blast dynamic pressure

As guidance, the blast dynamic pressure for one gun may be obtained, in kN/m^2, from the following formula:

$$p_W = \frac{1380(1 + \cos\beta)}{\left(\frac{r}{d}\right)^{1,5}}$$

where (see Fig 4):

β : Angle, in degrees, between the gun barrel axis and the straight line passing through the gun muzzle and the calculation point P

r : Distance, in mm, from the gun muzzle to the calculation point P

d : Gun diameter (calibre), in mm.

When two or more guns firing simultaneously are considered, the blast dynamic pressure is the greater of the values obtained by applying the above formula for each gun, considered as being firing independently from the others.

9.2.4 Gun recoil dynamic force

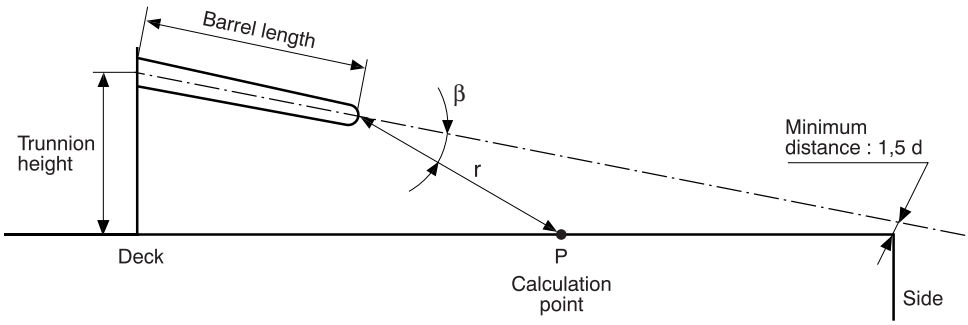
As guidance, the gun recoil dynamic force may be obtained, in kN, from the following formula:

$F_W = 1,3\ F_B$

where:

F_B : Rated brake load, in kN, of the recoil mechanism.

Figure 4 : Angle β and distance r for gun blast dynamic pressure calculation



Appendix 1 Inertial Pressure for Typical Tank Arrangement

1 Inertial ballast pressure

1.1 Introduction

1.1.1 Ch 5, Sec 6, [1] defines the criteria to calculate the inertial pressure p_W induced by ballast water in any type of tank. The relevant formulae are specified in Ch 5, Sec 6, Tab 1 and entail the definition of the highest point of the tank in the direction of the total acceleration vector. As specified in Ch 5, Sec 6, [1.2], this point depends on the geometry of the tank and the values of the acceleration. For typical tank arrangements, the highest point of the tank in the direction of the total acceleration vector can easily be identified and the relevant formulae written using the tank geometric characteristics.

1.1.2 This Appendix provides the formulae for calculating the inertial pressure p_W in the case of typical tank arrangements.

1.2 Formulae for the inertial pressure calculation

1.2.1 For typical tank arrangements, the inertial pressure transmitted to the hull structures at the calculation point P in inclined ship condition may be obtained from the formulae in Tab 1, obtained by applying to those tanks the general formulae in Ch 5, Sec 6, Tab 1.

Table 1 : Inertial ballast pressure for typical tank arrangements

Ship condition	Load case	Inertial pressure p_W, in kN/m^2
Inclined (negative roll angle)	"c"	$0,7\ C_{FA}\ \rho_L\ (a_{Y2}\ b_L + a_{Z2}\ d_H)$
	"d"	

Note 1:

C_{FA} : Combination factor, to be taken equal to:
- for load case "c": $C_{FA} = 0,7$
- for load case "d": $C_{FA} = 1,0$

ρ_L : Density, in t/m^3, of the liquid carried

a_{Y2}, a_{Z2} : Reference values of the acceleration in the inclined ship condition, defined in Ch 5, Sec 3, [3.4], calculated in way of the centre of gravity of the tank

b_L, d_H : Transverse and vertical distances, in m, to be taken as indicated in Fig 1 to Fig 4 for various types of tanks; for the cases in Fig 1, where the central area is divided into two or more tanks by longitudinal bulkheads, b_L and d_H for calculation points inside each tank are to be taken as indicated in Fig 3 for the double side.

Figure 1 : Distances b_L and d_H

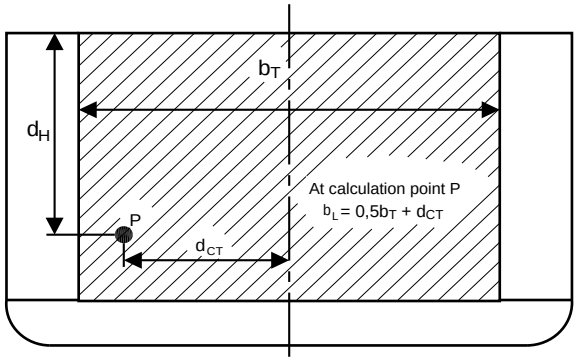


Figure 2 : Distances b_L and d_H

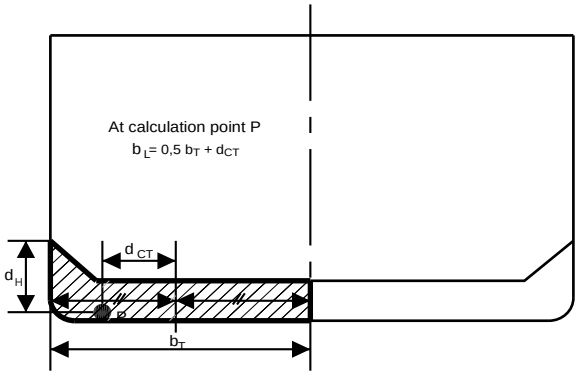


Figure 3 : Distances b_L and d_H

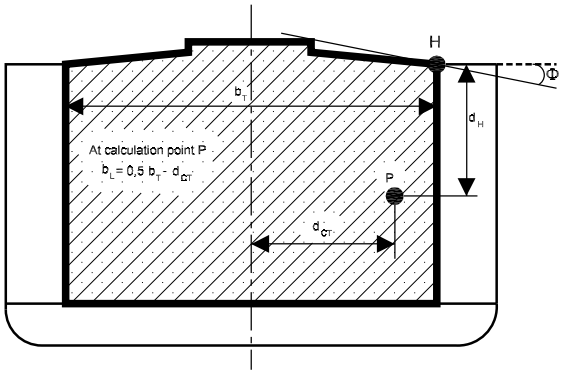
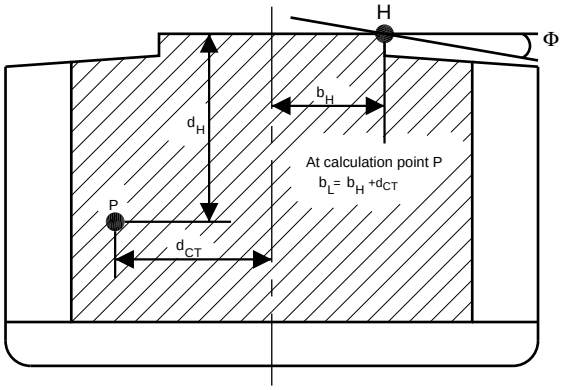


Figure 4 : Distances b_L and d_H



CHAPTER 6
HULL GIRDER STRENGTH

Section 1 Strength Characteristics of the Hull Girder Transverse Sections

Section 2 Yielding Checks

Section 3 Ultimate Strength Check

Appendix 1 Hull Girder Ultimate Strength

Section 1 Strength Characteristics of the Hull Girder Transverse Sections

Symbols

For the symbols not defined in this Section, refer to Ch 1, Sec 2, [2.1.1].

E : Young's modulus, in N/mm^2, to be taken equal to:

- for steels in general:
  E = 2,06.10^5 N/mm^2
- for stainless steels:
  E = 1,95.10^5 N/mm^2
- for aluminium alloys:
  E = 7,0.10^4 N/mm^2

1 Application

1.1 General

1.1.1 This Section specifies the criteria for calculating the hull girder strength characteristics to be used for the checks in Ch 6, Sec 2 and Ch 6, Sec 3, in association with the hull girder loads specified in Ch 5, Sec 2.

2 Calculation of the strength characteristics of hull girder transverse sections

2.1 Hull girder transverse sections

2.1.1 General

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder longitudinal strength, i.e. all continuous longitudinal members below the strength deck defined in [2.2], taking into account the requirements in [2.1.2] to [2.1.9].

These members are to be considered as having net scantlings (see also Ch 4, Sec 2).

2.1.2 Continuous trunks and continuous longitudinal hatch coamings

Continuous trunks and continuous longitudinal hatch coamings may be included in the hull girder transverse sections, provided they are effectively supported by longitudinal bulkheads or primary supporting members.

2.1.3 Longitudinal ordinary stiffeners or girders welded above the decks

Longitudinal ordinary stiffeners or girders welded above the decks (including the deck of any trunk fitted as specified in [2.1.2]) may be included in the hull girder transverse sections.

2.1.4 Longitudinal girders between hatchways

Where longitudinal girders are fitted between hatchways, the sectional area that can be included in the hull girder transverse sections is obtained, in m^2, from the following formula:

$A_{EFF} = A_{LG}\, a$

where:

A_{LG} : Sectional area, in m^2, of longitudinal girders

a : Coefficient:

- for longitudinal girders effectively supported by longitudinal bulkheads or primary supporting members:
  a = 1
- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0 / r \leq 60$:

$$a = 0,6\left(\frac{s}{b_1} + 0,15\right)^{0,5}$$

- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0 / r > 60$:
  a = 0

ℓ_0 : Span, in m, of longitudinal girders, to be taken as shown in Fig 1

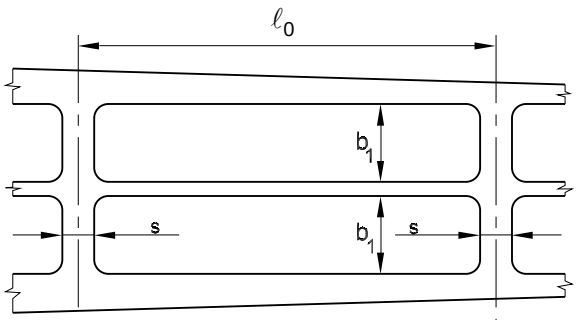
r : Minimum radius of gyration, in m, of the longitudinal girder transverse section

s, b_1 : Dimensions, in m, defined in Fig 1.

2.1.5 Longitudinal bulkheads with vertical corrugations

Longitudinal bulkheads with vertical corrugations may not be included in the hull girder transverse sections.

Figure 1 : Longitudinal girders between hatchways



2.1.6 Members in materials other than steel

Where a member contributing to the longitudinal strength is made in material other than steel with a Young's modulus E equal to $2{,}06\ 10^5$ N/mm^2, the steel equivalent sectional area that may be included in the hull girder transverse sections is obtained, in m^2, from the following formula:

$$A_{SE} = \frac{E}{2{,}06{,}10^5} A_M$$

where:

A_M : Sectional area, in m^2, of the member under consideration.

2.1.7 Large openings

Large openings are:

- elliptical openings exceeding 2,5 m in length or 1,2 m in breadth
- circular openings exceeding 0,9 m in diameter.

Large openings and scallops, where scallop welding is applied, are always to be deducted from the sectional areas included in the hull girder transverse sections.

2.1.8 Small openings

Smaller openings than those in [2.1.7] in one transverse section in the strength deck or bottom area need not be deducted from the sectional areas included in the hull girder transverse sections, provided that:

$\Sigma b_S \leq 0{,}06\ (B - \Sigma b)$

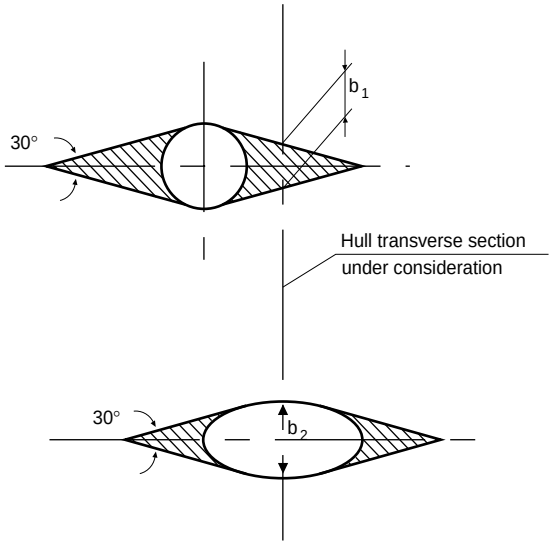
where:

Σb_S : Total breadth of small openings, in m, in the strength deck or bottom area at the transverse section considered, determined as indicated in Fig 2

Σb : Total breadth of large openings, in m, at the transverse section considered, determined as indicated in Fig 2.

Where the total breadth of small openings Σb_S does not fulfil the above criteria, only the excess of breadth is to be deducted from the sectional areas included in the hull girder transverse sections.

Figure 2 : Calculation of Σb and Σb_S



2.1.9 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals need not be deducted if their height is less than $0,25\ h_W\ 10^{-3}$, without being greater than 75 mm, where h_W is the web height, in mm, defined in Ch 4, Sec 3.

Otherwise, the excess is to be deducted from the sectional area or compensated.

2.2 Strength deck

2.2.1 The strength deck is, in general, the uppermost continuous deck.

In the case of a superstructure or deckhouses contributing to the longitudinal strength, the strength deck is the deck of the superstructure or the deck of the uppermost deckhouse.

2.2.2 A superstructure extending at least 0,15 L within 0,4 L amidships may generally be considered as contributing to the longitudinal strength. For other superstructures and for deckhouses, their contribution to the longitudinal strength is to be assessed on a case by case basis, through a finite element analysis of the whole ship, which takes into account the general arrangement of the longitudinal elements (side, decks, bulkheads).

The presence of openings in the side shell and longitudinal bulkheads is to be taken into account in the analysis. This may be done in two ways:

- by including these openings in the finite element model
- by assigning to the plate panel between the side frames beside each opening an equivalent thickness, in mm, obtained from the following formula:

$$t_{EQ} = 10^3 \left[\ell_P \left(\frac{G h^2}{12 E I_J} + \frac{1}{A_J} \right) \right]^{-1}$$

where (see Fig 3):

ℓ_P : Longitudinal distance, in m, between the frames beside the opening

h : Height, in m, of openings

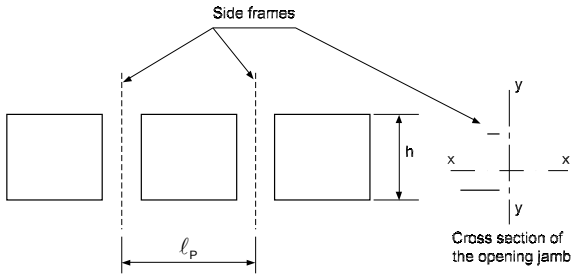
I_J : Moment of inertia, in m^4, of the opening jamb about the transverse axis y-y

A_J : Shear area, in m^2, of the opening jamb in the direction of the longitudinal axis x-x

G : Coulomb's modulus, in N/mm^2, of the material used for the opening jamb, to be taken equal to:

- for steels: $G = 8,0 \cdot 10^4$ N/mm^2
- for aluminium alloys: $G = 2,7 \cdot 10^4$ N/mm^2.

Figure 3 : Side openings



2.3 Section modulus

2.3.1 The section modulus at any point of a hull transverse section is obtained, in m^3, from the following formula:

$$Z_A = \frac{I_Y}{|z - N|}$$

where:

I_Y : Moment of inertia, in m^4, of the hull transverse section defined in [2.1], about its horizontal neutral axis

z : Z co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section defined in [2.1], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6].

2.3.2 The section moduli at bottom and at the equivalent deck line are obtained, in m^3, from the following formulae:

- at bottom:

$$Z_{AB} = \frac{I_Y}{N}$$

- at the equivalent deck line:

$$Z_{AD} = \frac{I_Y}{V_D}$$

where:

I_Y, N : Defined in [2.3.1]

V_D : Vertical distance to the equivalent deck line, in m:

- when no effective longitudinal members specified in [2.1.2] and [2.1.3] are positioned above a line extending from strength deck at side to a position $(z_D - N)/0,9$ from the neutral axis at the centreline:

  $V_D = z_D - N$

  where:

  z_D : Z co-ordinate, in m, of strength deck, defined in [2.2], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]

- when effective longitudinal members specified in [2.1.2] and [2.1.3] are positioned above a line extending from strength deck at side to a position $(z_D - N)/0,9$ from the neutral axis at the centreline:

  $$V_D = (z_T - N)\left(0,9 + 0,2\frac{y_T}{B}\right) \geq z_D - N$$

  where:

  y_T, z_T : Y and Z co-ordinates, in m, of the top of continuous trunk or hatch coaming or longitudinal ordinary stiffeners or girders welded above the strength deck, with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]; y_T and z_T are to be measured for the point which maximises the value of V_D

2.4 Moments of inertia

2.4.1 The moments of inertia I_Y and I_Z, in m^4, are those, calculated about the horizontal and vertical neutral axes, respectively, of the hull transverse sections defined in [2.1].

2.5 First moment

2.5.1 The first moment S, in m^3, at a level z above the baseline is that, calculated with respect to the horizontal neutral axis, of the portion of the hull transverse sections defined in [2.1] located above the z level.

2.6 Structural models for the calculation of normal warping stresses and shear stresses

2.6.1 The structural models that can be used for the calculation of normal warping stresses, induced by torque, and shear stresses, induced by shear forces or torque, are:

- three-dimensional finite element models
- thin walled beam models,

representing the members which constitute the hull girder transverse sections according to [2.1].

Section 2 Yielding Checks

Symbols

For the symbols not defined in this Section, refer to Ch 1, Sec 2, [2.1.1].

C : Wave parameter defined in Ch 5, Sec 2

E : Young's modulus, in N/mm^2, to be taken equal to:

- for steels in general:

  $E = 2{,}06.10^5$ N/mm^2

- for stainless steels:

  $E = 1{,}95.10^5$ N/mm^2

- for aluminium alloys:

  $E = 7{,}0.10^4$ N/mm^2

I_Y : Moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to Ch 6, Sec 1, [2.4]

I_Z : Moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to Ch 6, Sec 1, [2.4]

k : Material factor, as defined in Ch 4, Sec 1, [2.3]

M_{SW} : Still water bending moment, in kN.m:

- in hogging conditions:

  $M_{SW} = M_{SW,H}$

- in sagging conditions:

  $M_{SW} = M_{SW,S}$

$M_{SW,H}$: Design still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [2.2]

$M_{SW,S}$: Design still water bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [2.2]. When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0

M_{WH} : Horizontal wave bending moment, in kN·m, defined in Ch 5, Sec 2, [3.2]

M_{WT} : Wave torque, in kN·m, defined in Ch 5, Sec 2, [3.3]

M_{WV} : Vertical wave bending moment, in kN.m:

- in hogging conditions:

  $M_{WV} = M_{WV,H}$

- in sagging conditions:

  $M_{WV} = M_{WV,S}$

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1]

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1]

Q_{SW} : Design still water shear force, in kN, defined in Ch 5, Sec 2, [2.3]

Q_{WV} : Vertical wave shear force, to be calculated according to Ch 5, Sec 2, [3.4]:

- if $Q_{SW} \geq 0$, Q_{WV} is the positive wave shear force
- if $Q_{SW} < 0$, Q_{WV} is the negative wave shear force

S : First moment, in m^3, of the hull transverse section, to be calculated according to Ch 6, Sec 1, [2.5]

x : X co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]

Z_A : Section modulus, in cm^3, at any point of the hull transverse section, to be calculated according to Ch 6, Sec 1, [2.3.1]

Z_{AB},Z_{AD} : Section moduli, in cm^3, at bottom and deck, respectively, to be calculated according to Ch 6, Sec 1, [2.3.2].

1 Application

1.1 General

1.1.1 The requirements of this Section apply to ships having the following characteristics:

- $L < 500$ m
- $L / B > 5$
- $B / D < 2,5$
- $C_B \geq 0,4$

Ships not having one or more of these characteristics and ships of unusual type or design are considered by the Society on a case-by-case basis.

2 Hull girder stresses

2.1 Normal stresses induced by vertical bending moments

2.1.1 The normal stresses induced by vertical bending moments are obtained, in N/mm^2, from the following formulae:

- at any point of the hull transverse section:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_A} 10^3$$

- at bottom:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AB}} 10^3$$

- at the equivalent deck line:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AD}} 10^3$$

2.1.2 The formulae given in [2.1.1] are valid only when the distribution of vertical bending stress across the hull girder transverse section can be assumed to be linear.

2.1.3 The normal stresses in a member made in material other than steel with a Young's modulus E equal to $2,06 \cdot 10^5$ N/mm^2, included in the hull girder transverse sections as specified in Ch 6, Sec 1, [2.1.6], are obtained from the following formula:

$$\sigma_1 = \frac{E}{2,06 \cdot 10^5} \sigma_{1S}$$

where:

σ_{1S} : Normal stress, in N/mm^2, in the member under consideration, calculated according to [2.1.1] considering this member as having the steel equivalent sectional area A_{SE} defined in Ch 6, Sec 1, [2.1.6].

2.2 Normal stresses induced by vertical and horizontal bending moments

2.2.1 The normal stresses induced by vertical and horizontal bending moments are to be calculated for the load case constituted by the hull girder loads specified in Tab 1 together with their combination factors. They are to be obtained, in N/mm^2, from the following formula:

$$\sigma_1 = \frac{M_{SW}}{Z_A} + \frac{0,4 M_{WV}}{Z_A} + \frac{M_{WH}}{I_Z} y$$

where:

y : Y co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6].

Table 1 : Torque and bending moments

Still water loads		Wave loads					
Vertical bending moment		Torque **(1)**		Vertical bending moment		Horizontal bending moment	
Reference value	Combination factor	Reference value	Combination factor	Reference value	Combination factor	Reference value	Combination factor
M_{SW}	1,0	M_{WT}	1,0	M_{WV}	0,4	M_{WH}	1,0
(1) To be considered only when deemed necessary by the Society (e.g. wave torque is not applicable to frigates).							

2.3 Shear stresses

2.3.1 The shear stresses induced by shear forces and torque are obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6].

2.3.2 The hull girder loads to be considered in these analyses are the vertical shear forces Q_{SW} and Q_{WV}.

When deemed necessary by the Society on the basis of the ship's characteristics and intended service, the horizontal shear force and torque are also to be calculated and taken into account in the calculation of shear stresses.

2.3.3 As an alternative to the above procedure, the shear stresses induced by the vertical shear forces Q_{SW} and Q_{WV} may be obtained through the simplified procedure in [2.4].

2.4 Simplified calculation of shear stresses induced by vertical shear forces

2.4.1 Ships without effective longitudinal bulkheads or with one effective longitudinal bulkhead

In this context, effective longitudinal bulkhead means a bulkhead extending from the bottom to the strength deck.

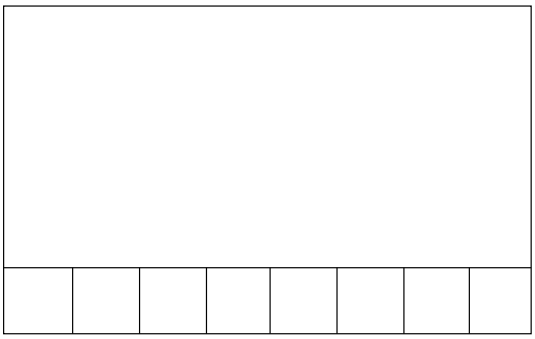
The shear stresses induced by the vertical shear forces in the calculation point are obtained, in N/mm^2, from the following formula:

$$\tau_1 = 0,5(Q_{SW} + Q_{WV})\frac{S}{I_Y t_S}$$

where:

t_S : Minimum thickness, in mm, of side plating (see Fig 1) according to Tab 2.

Figure 1 : Single side ship without effective longitudinal bulkheads



2.4.2 Single side ships with two effective longitudinal bulkheads

In this context, effective longitudinal bulkhead means a bulkhead extending from the bottom to the strength deck.

The shear stresses induced by the vertical shear force in the calculation point are obtained, in N/mm^2, from the following formula:

$$\tau_1 = [(Q_{SW} + Q_{WV})\delta]\frac{S}{I_Y t}$$

where:

δ : Shear distribution coefficient defined in Tab 2

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable (see Fig 2), according to Tab 2.

Figure 2 : Single side ship with two effective longitudinal bulkheads

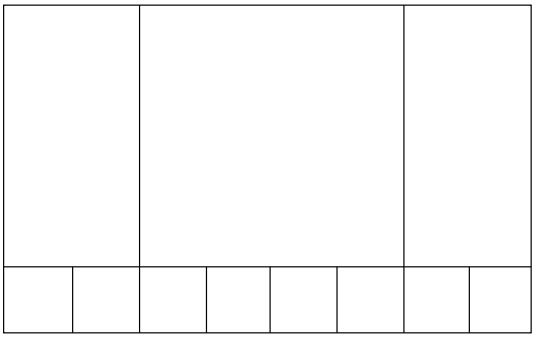


Table 2 : Shear stresses induced by vertical shear forces

Location	t, in mm	δ
Sides	t_S	$(1 - \Phi) / 2$
Longitudinal bulkheads	t_B	$\Phi / 2$

Note 1:

$\Phi = 0,3 + 0,21\ t_{BM} / t_{SM}$

t_S, t_B : Minimum net thicknesses, in mm, of side and longitudinal bulkhead plating, respectively

t_{SM}, t_{BM} : Mean thicknesses, in mm, over all the strakes of side and longitudinal bulkhead plating, respectively. They are calculated as: $\Sigma\ (\ell_i\ t_i) / \Sigma\ \ell_i$, where ℓ_i and t_i are the length, in m, and the thickness, in mm, of the i^{th} strake of side and longitudinal bulkheads.

3 Checking criteria

3.1 General

3.1.1 The material factors k are to be defined with respect to the material used at each calculation point, for the members contributing to the longitudinal strength according to Ch 6, Sec 1, [2].

3.2 Normal stresses induced by vertical bending moments

3.2.1 It is to be checked that the normal stresses σ_1 calculated according to [2.1]with vertical wave bending moment M_{WV} increased by 10%, and, when applicable, [2.2] are in compliance with the following formula:

$\sigma_1 \leq \sigma_{1,ALL}$

where:

$\sigma_{1,ALL}$: Allowable normal stress, in N/mm^2, obtained from the following formulae:

$$\sigma_{1,ALL} = \frac{139}{k} \quad \text{for } \frac{x}{L} \leq 0,1$$

$$\sigma_{1,ALL} = \frac{194}{k} + \frac{275}{k}\left(\frac{x}{L} - 0,3\right) \quad \text{for } 0,1 < \frac{x}{L} < 0,3$$

$$\sigma_{1,ALL} = \frac{194}{k} \quad \text{for } 0,3 \leq \frac{x}{L} \leq 0,7$$

$$\sigma_{1,ALL} = \frac{194}{k} - \frac{275}{k}\left(\frac{x}{L} - 0,7\right) \quad \text{for } 0,7 < \frac{x}{L} < 0,9$$

$$\sigma_{1,ALL} = \frac{139}{k} \quad \text{for } \frac{x}{L} \geq 0,9$$

Note 1: For naval ships having a service notation other than **frigate** or **aircraft carrier**, the increased of M_{WV} by 10% may generally be disregarded.

3.3 Shear stresses

3.3.1 It is to be checked that the shear stresses τ_1 calculated according to [2.3] are in compliance with the following formula:

$\tau_1 \leq \tau_{1,ALL}$

where:

$\tau_{1,ALL}$: Allowable shear stress, in N/mm^2

$\tau_{1,ALL} = 122/k$

4 Section modulus and moment of inertia

4.1 General

4.1.1 The requirements in [4.2] to [4.5] provide for the minimum hull girder section modulus, complying with the checking criteria indicated in [3], and the midship section moment of inertia required to ensure sufficient hull girder rigidity.

4.1.2 The material factors k are to be defined with respect to the materials used for the bottom and deck members contributing to the longitudinal strength according to Ch 6, Sec 1, [2]. When material factors for higher strength steels are used, the requirements in [4.5] apply.

4.2 Section modulus within 0,4L amidships

4.2.1 The section moduli Z_{AB} and Z_{AD} within 0,4 L amidships are to be not less than the value obtained, in m^3, from the following formula:

$$Z_R = \frac{M_{SW} + nM_{WV}}{\sigma_{1,ALL}} 10^{-3}$$

where:

- n = 1,1 for service notation **frigate** or **aircraft carrier**
- n = 1,0 for the other service notations.

In addition, the section moduli Z_{AB} and Z_{AD} at the midship section are to be not less than the value obtained, in m^3, from the following formula:

$$Z_{R\Delta} = \frac{M_{WV,H} + M_{WV,S}}{2\sigma_{\Delta,ALL}} 10^{-3}$$

where:

$\sigma_{\Delta,ALL}$: Allowable normal stress, in N/mm^2 to be taken equal to:

- 122 N/mm^2 for steel with R_{eH} = 235 N/mm^2
- 155 N/mm^2 for steel with R_{eH} = 315 N/mm^2
- 166 N/mm^2 for steel with R_{eH} = 355 N/mm^2 or 390 N/mm^2.

4.2.2 Where the total breadth Σb_S of small openings, as defined in Ch 6, Sec 1, [2.1.8], is deducted from the sectional areas included in the hull girder transverse sections, the values Z_R and $Z_{R\Delta}$ defined in [4.2.1] may be reduced by 3%.

4.2.3 Scantlings of members contributing to the longitudinal strength (see Ch 6, Sec 1, [2]) are to be maintained within 0,4 L amidships.

4.3 Section modulus outside 0,4L amidships

4.3.1 The net section moduli Z_{AB} and Z_{AD} outside 0,4 L amidships are to be not less than the value obtained, in m^3, from the following formula:

$$Z_R = \frac{M_{SW} + M_{WV}}{\sigma_{1,ALL}} 10^{-3}$$

4.4 Midship section moment of inertia

4.4.1 The midship section moment of inertia about its horizontal neutral axis is to be not less than the value obtained, in m^4, from the following formula:

$$I_{YR} = 2{,}77\ Z'_{R\Delta}\ L\ 10^{-2}$$

where:

$Z'_{R\Delta}$: Required midship section modulus $Z_{R\Delta}$, in m^3, calculated as specified in [4.2.1], but assuming $\sigma_{\Delta,ALL}$ = 130 N/mm^2 in all cases.

4.5 Extent of higher strength steel

4.5.1 When a material factor for higher strength steel is used in calculating the required section modulus at bottom or at the equivalent deck line according to [4.2] or [4.3], and when the distribution of vertical bending stress across the hull girder transverse section can be assumed to be linear, the vertical extent of higher strength steel, $z_{hts,i}$ used in the deck zone or bottom zone and measured respectively from the equivalent deck line or baseline is not to be taken less the value obtained from the following formula:

$$z_{hts,i} = z_1 \left(1 - \frac{\sigma_{perm,i}}{\sigma_L}\right)$$

where:

σ_L : Normal stress, in N/mm^2, at the equivalent deck line or at bottom, calculated according to [2.1.1]

z_1 : Distance from horizontal neutral axis, to the equivalent deck line defined in Ch 6, Sec 1, [2.3.2], or to the baseline respectively, in m, with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]

$\sigma_{perm,i}$: Allowable normal stress defined in [3.1.1], in N/mm^2, for the adjacent zone of steel having lower strength (see Fig 3).

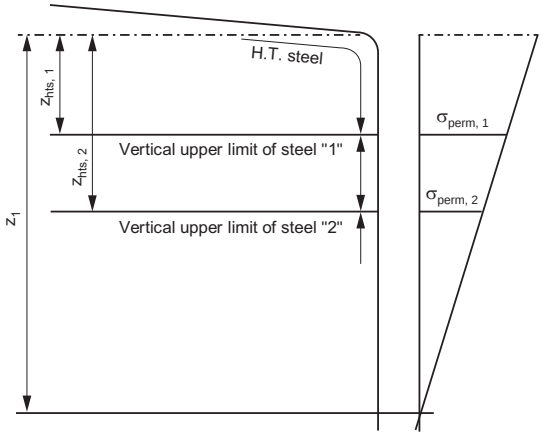
4.5.2 The relevant higher strength steel is to be adopted for all members contributing to the longitudinal strength (see Ch 6, Sec 1, [2]) within the extent defined in [4.5.1].

4.5.3 The higher strength steel is to extend in length at least throughout 0,4 L amidships where it is required for strength purposes according to the provisions of Part B.

4.5.4 Longitudinal members not contributing to the hull girder longitudinal strength and welded to the strength deck or bottom plating and bilge strake, such as longitudinal hatch coamings, gutter bars, strengthening of deck openings, bilge keel, are to be made of steel with the same specified minimum yield stress as the strength deck or bottom structure steel.

4.5.5 The requirement in [4.5.4] is also applicable to non-continuous longitudinal stiffeners welded to the web of a primary structural member contributing to the hull girder longitudinal strength such as hatch coamings, stringers and girders or on the inner bottom when the hull girder stress in those members is higher than the permissible stress as defined in [3.1.1] for normal strength steel.

Figure 3 : Vertical extent of higher strength steel



5 Permissible still water bending moment and shear force during navigation

5.1 Permissible still water bending moment

5.1.1 The permissible still water bending moment at any hull transverse section during navigation, in hogging or sagging conditions, is the value M_{SW} considered in the hull girder section modulus calculation according to Article [4].

In the case of structural discontinuities in the hull transverse sections, the distribution of permissible still water bending moments is considered on a case-by-case basis.

5.2 Permissible still water shear force

5.2.1 Direct calculations

Where the shear stresses are obtained through calculation analyses according to [2.3], the permissible positive or negative still water shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \varepsilon|Q_T| - Q_{WV}$$

where:

ε = sgn (Q_{SW})

Q_T : Shear force, in kN, which produces a shear stress $\tau = 122/k$ N/mm^2 in the most stressed point of the hull transverse section.

5.2.2 Single side ships without effective longitudinal bulkheads

Where the shear stresses are obtained through the simplified procedure in [2.4.1], the permissible positive or negative still water shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \varepsilon\left(\frac{122}{0,5k} \cdot \frac{I_Y t_S}{S}\right) - Q_{WV}$$

where:

ε = sgn (Q_{SW})

t_S : Minimum net thickness, in mm, of side plating according to Tab 2.

5.2.3 Single side ships with two effective longitudinal bulkheads

Where the shear stresses are obtained through the simplified procedure in [2.4.2], the permissible positive or negative still water shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \frac{1}{\delta}\left(\varepsilon\frac{122}{k}\cdot\frac{I_Y t}{S}\right) - Q_{WV}$$

where:

δ : Shear distribution coefficient defined in Tab 2

$\varepsilon = sgn\,(Q_{SW})$

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable, according to Tab 2.

6 Permissible still water bending moment and shear force in harbour conditions

6.1 Permissible still water bending moment

6.1.1 The permissible still water bending moment at any hull transverse section in harbour conditions, in hogging or sagging conditions, is obtained, in kN·m, from the following formula:

$M_{P,H} = M_P + 0,6\,M_{WV}$

where M_P is the permissible still water bending moment during navigation in KN·m, to be calculated according to [5.1.1].

6.2 Permissible shear force

6.2.1 The permissible positive or negative still water shear force at any hull transverse section, in harbour conditions, is obtained, in kN, from the following formula:

$Q_{P,H} = \varepsilon\,Q_P + 0,7\,Q_{WV}$

where:

$\varepsilon = sgn(Q_{SW})$

Q_P : Permissible still water shear force during navigation, in kN, to be calculated according to [5.2].

Section 3 Ultimate Strength Check

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships equal to or greater than 90 m in length.

1.2 Net scantlings

1.2.1 As specified in Ch 4, Sec 2, [1], the ultimate strength of the hull girder is to be checked on the basis of the net strength characteristics of the transverse section which is to be calculated according to Ch 4, Sec 2, [2].

1.3 Partial safety factors

1.3.1 The partial safety factors to be considered for checking the ultimate strength of the hull girder are specified in Tab 1.

Table 1 : Partial safety factors

Partial safety factor covering uncertainties on:	Symbol	Value
Still water hull girder loads	γ_{S1}	1,00
Wave induced hull girder loads	γ_{W1}	1,20
Material	γ_m	1,02
Resistance	γ_R	1,15

2 Hull girder ultimate strength check

2.1 Hull girder loads

2.1.1 Bending moments

The bending moment in sagging and hogging conditions, to be considered in the ultimate strength check of the hull girder, is to be obtained, in kN·m, from the following formula:

$M = \gamma_{S1} M_{SW} + \gamma_{W1} M_{WV}$

where:

M_{SW} : Still water bending moment, in kN.m, defined in Ch 6, Sec 2

M_{WV} : Vertical wave bending moment, in kN.m, defined in Ch 6, Sec 2.

2.2 Hull girder ultimate bending moment capacities

2.2.1 Curve M-χ

The ultimate bending moment capacities of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment capacity M versus the curvature χ of the transverse section considered (see Fig 1).

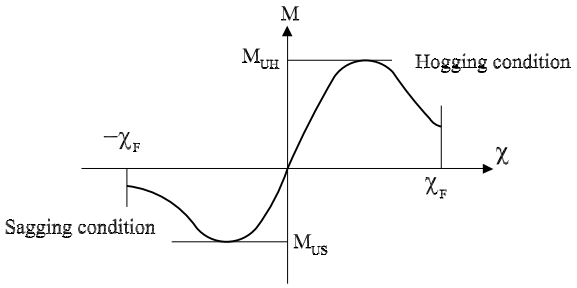
The curvature χ is positive for hogging condition and negative for sagging condition.

The curve M-χ is to be obtained through an incremental-iterative procedure according to the criteria specified in Ch 6, App 1.

2.2.2 Hull girder transverse sections

The hull girder transverse sections are constituted by the elements contributing to the hull girder longitudinal strength, considered with their net scantlings, according to Ch 6, Sec 1, [2].

Figure 1 : Curve bending moment capacity M versus curvature χ



2.3 Checking criteria

2.3.1 It is to be checked that the hull girder ultimate bending capacity at any hull transverse section is in compliance with the following formula:

$$\frac{M_U}{\gamma_R \gamma_m} \geq M$$

where:

M_U : Ultimate bending moment capacity of the hull transverse section considered, in kN·m:

- in hogging conditions: $M_U = M_{UH}$
- in sagging conditions: $M_U = M_{US}$

M_{UH} : Ultimate bending moment capacity in hogging conditions, defined in [2.2.1]

M_{US} : Ultimate bending moment capacity in sagging conditions, defined in [2.2.1]

M : Bending moment, in kN·m, defined in [2.1.1].

Appendix 1 Hull Girder Ultimate Strength

Symbols

A_S : Net sectional area, in cm^2, of an ordinary stiffener

b_f : Face plate width, in mm, of an ordinary stiffener

E : Young's modulus, in N/mm^2, to be taken equal to:

- for steels in general:

  $E = 2{,}06.10^5$ N/mm^2

- for stainless steels:

  $E = 1{,}95.10^5$ N/mm^2

- for aluminium alloys:

  $E = 7{,}0.10^4$ N/mm^2

h_w : Web height, in mm, of an ordinary stiffener

I_Y : Moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Ch 6, Sec 1, [2.4]

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members (see Ch 4, Sec 3, Tab 1)

R_{eH} : Minimum upper yield stress, in N/mm^2, of the material

s : Spacing, in m, of ordinary stiffeners

t_f : Face plate net thickness, in mm, of an ordinary stiffener

t_p : Net thickness, in mm, of the plating attached to an ordinary stiffener.

t_w : Web net thickness, in mm, of an ordinary stiffener

Z_{AB} , Z_{AD} : Section moduli, in cm^3, at bottom and deck, respectively, defined in Ch 6, Sec 1, [2.3.2]

1 Hull girder ultimate strength check

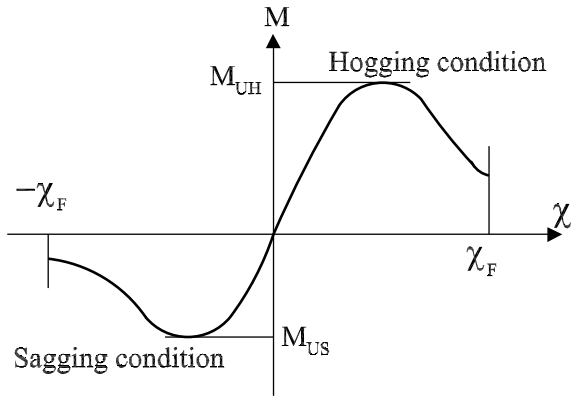
1.1 Introduction

1.1.1 Ch 6, Sec 3, [2]defines the criteria for calculating the ultimate bending moment capacities in hogging condition M_{UH} and sagging condition M_{US} of a hull girder transverse section.

As specified in Ch 6, Sec 3, [2], the ultimate bending moment capacities are defined as the maximum values of the curve of bending moment capacity M versus the curvature χ of the transverse section considered (see Fig 1).

1.1.2 This Appendix provides the criteria for obtaining the curve M-χ.

Figure 1 : Curve bending moment capacity M versus curvature χ



1.2 Criteria for the calculation of the curve M-χ

1.2.1 Procedure

The curve M-χ is to be obtained by means of an incremental-iterative approach, summarized in the flow chart in Fig 2.

Each step of the incremental procedure is represented by the calculation of the bending moment M_i which acts on the hull transverse section as the effect of an imposed curvature χ_i.

For each step, the value χ_i is to be obtained by summing an increment of curvature $\Delta\chi$ to the value relevant to the previous step χ_{i-1}. This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis.

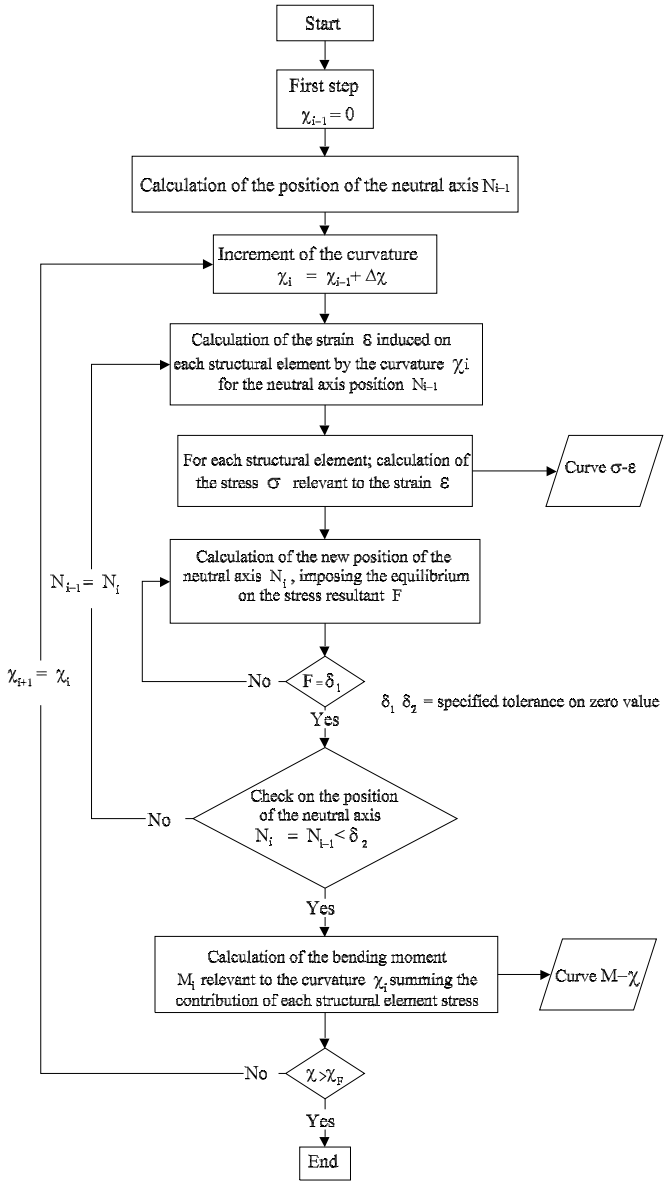
This rotation increment induces axial strains ε in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened. Vice-versa in sagging condition.

The stress σ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve σ-ε of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.

The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position, since the relationship σ-ε is non-linear. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements.

Once the position of the neutral axis is known and the relevant stress distribution in the section structural elements is obtained, the bending moment of the section M_i around the new position of the neutral axis, which corresponds to the curvature χ_i imposed in the step considered, is to be obtained by summing the contribution given by each element stress.

Figure 2 : Flow chart of the procedure for the evaluation of the curve M-χ



1.2.2 Assumption

In applying the procedure described in [1.2.1], the following assumptions are generally to be made:

- The ultimate strength is calculated at hull transverse sections between two adjacent reinforced rings.
- The hull girder transverse section remains plane during each curvature increment.
- The hull material has an elasto-plastic behaviour.
- The hull girder transverse section is divided into a set of elements, which are considered to act independently. These elements are:
  - transversely framed plating panels and/or ordinary stiffeners with attached plating, whose structural behaviour is described in [1.3.1]
  - hard corners, constituted by plating crossing, whose structural behaviour is described in [1.3.2].
- According to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i is obtained by summing the contribution given by the stress σ acting on each element. The stress σ, corresponding to the element strain ε, is to be obtained for each curvature increment from the non-linear load-end shortening curves σ-ε of the element.

  These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in [1.3]. The stress σ is selected as the lowest among the values obtained from each of the considered load-end shortening curves σ-ε.
- The procedure is to be repeated for each step, until the value of the imposed curvature reaches the value χ_F, in m^{-1}, in hogging and sagging condition, obtained from the following formula:

$$\chi_F = \pm 0{,}003 \frac{M_Y}{EI_Y}$$

where:

M_Y : The lesser of the values M_{Y1} and M_{Y2}, in kN·m:

$M_{Y1} = 10^{-3} R_{eH} Z_{AB}$

$M_{Y2} = 10^{-3} R_{eH} Z_{AD}$

If the value χ_F is not sufficient to evaluate the peaks of the curve M-χ, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

1.3 Load-end shortening curves σ-ε

1.3.1 Plating panels and ordinary stiffeners

Plating panels and ordinary stiffeners composing the hull girder transverse sections may collapse following one of the modes of failure specified in Tab 1.

Table 1 : Modes of failure of plate panels and ordinary stiffeners

Element	Mode of failure	Curve σ-ε defined in
Lengthened plate panel or ordinary stiffeners	Elasto-plastic collapse	[1.3.3]
Shortened ordinary stiffeners	Beam columnbuckling	[1.3.4]
	Torsional buckling	[1.3.5]
	Web local buckling of flanged profiles	[1.3.6]
	Web local buckling of flat bars	[1.3.7]
Shortened transversely framed plate panel	Plate buckling	[1.3.8]
Shortened transversely framed curved plate panel	Curved plate buckling	[1.3.9]

1.3.2 Hard corners

Hard corners are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure. The relevant load-end shortening curve σ-ε is to be obtained for lengthened and shortened hard corners according to [1.3.3].

1.3.3 Elasto-plastic collapse

The equation describing the load-end shortening curve σ-ε for the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula, valid for both positive (shortening) and negative (lengthening) strains (see Fig 3):

$\sigma = \Phi R_{eH}$

where:

Φ : Edge function:

- for $\varepsilon < -1$:

  $\Phi = -1$

- for $-1 < \varepsilon < 1$:

  $\Phi = \varepsilon$

- for $\varepsilon > 1$:

  $\Phi = 1$

ε : Relative strain:

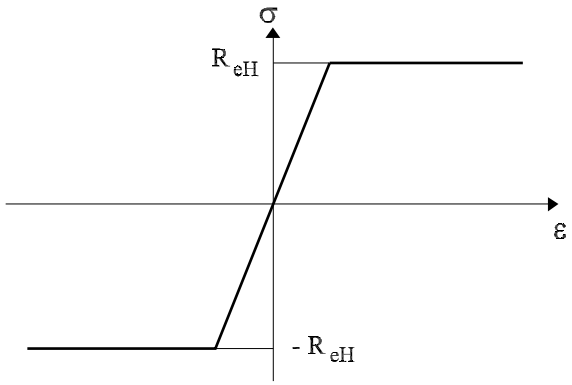
$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

ε_E : Element strain

ε_Y : Strain inducing yield stress in the element:

$$\varepsilon_Y = \frac{R_{eH}}{E}$$

Figure 3 : Load-end shortening curve σ-ε for elasto-plastic collapse



1.3.4 Beam column buckling

The equation describing the load-end shortening curve σ_{CR1}-ε for the beam column buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see Fig 4):

$$\sigma_{CR1} = \Phi\sigma_{C1}\frac{A_S + 10b_E t_P}{A_S + 10st_P}$$

where:

Φ : Edge function defined in [1.3.3]

σ_{C1} : Critical stress, in N/mm^2:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \qquad \text{for} \qquad \sigma_{E1} \le \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{C1} = R_{eH}\left(1 - \frac{R_{eH}\varepsilon}{4\sigma_{E1}}\right) \qquad \text{for} \qquad \sigma_{E1} > \frac{R_{eH}}{2}\varepsilon$$

ε : Relative strain defined in [1.3.3]

σ_{E1} : Euler column buckling stress, in N/mm^2:

$$\sigma_{E1} = \pi^2 E\frac{I_E}{A_E \ell^2}10^{-4}$$

I_E : Net moment of inertia of ordinary stiffeners, in cm^4, with attached shell plating of width b_{E1}

b_{E1} : Width, in m, of the attached shell plating:

$$b_{E1} = \frac{s}{\beta_E} \qquad \text{for} \qquad \beta_E > 1{,}0$$

$$b_{E1} = s \qquad \text{for} \qquad \beta_E \le 1{,}0$$

$$\beta_E = 10^3\frac{s}{t_p}\sqrt{\frac{\varepsilon R_{eH}}{E}}$$

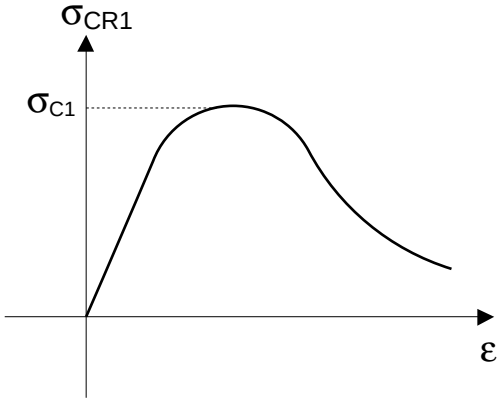
A_E : Net sectional area, in cm^2, of ordinary stiffeners with attached shell plating of width b_E

b_E : Width, in m, of the attached shell plating:

$$b_E = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right)s \quad \text{for} \quad \beta_E > 1,25$$

$$b_E = s \quad \text{for} \quad \beta_E \leq 1,25$$

Figure 4 : Load-end shortening curve σ_{CR1}-ε for beam column buckling



1.3.5 Torsional buckling

The equation describing the load-end shortening curve σ_{CR2}-ε for the lateral-flexural buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained according to the following formula (see Fig 5):

$$\sigma_{CR2} = \Phi\frac{A_S\sigma_{C2} + 10st_P\sigma_{CP}}{A_S + 10st_P}$$

where:

Φ : Edge function defined in [1.3.3]

σ_{C2} : Critical stress, in N/mm^2:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \quad \text{for} \quad \sigma_{E2} \leq \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{C2} = R_{eH}\left(1 - \frac{R_{eH}\varepsilon}{4\sigma_{E2}}\right) \quad \text{for} \quad \sigma_{E2} > \frac{R_{eH}}{2}\varepsilon$$

σ_{E2} : Euler torsional buckling stress, in N/mm^2, defined in Ch 7, Sec 2, [4.3.3]

ε : Relative strain defined in [1.3.3]

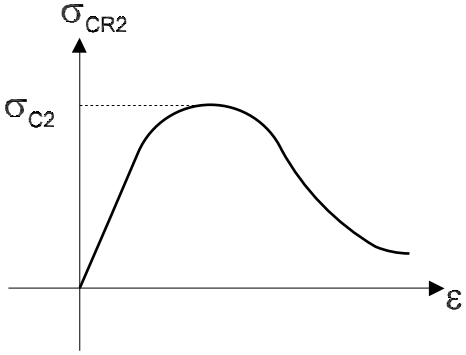
σ_{CP} : Buckling stress of the attached plating, in N/mm^2:

$$\sigma_{CP} = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right)R_{eH} \quad \text{for} \quad \beta_E > 1,25$$

$$\sigma_{CP} = R_{eH} \quad \text{for} \quad \beta_E \leq 1,25$$

β_E : Coefficient defined in [1.3.4].

Figure 5 : Load-end shortening curve σ_{CR2}-ε for flexural-torsional buckling



1.3.6 Web local buckling of flanged ordinary stiffeners

The equation describing the load-end shortening curve σ_{CR3}-ε for the web local buckling of flanged ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi R_{eH} \frac{10^3 b_E t_P + h_{WE} t_W + b_F t_F}{10^3 s t_P + h_W t_W + b_F t_F}$$

where:

Φ : Edge function defined in [1.3.3]

b_E : Width, in m, of the attached shell plating, defined in [1.3.4]

h_{WE} : Effective height, in mm, of the web:

$$h_{WE} = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right) h_W \quad \text{for} \quad \beta_W > 1,25$$

$$h_{WE} = h_W \quad \text{for} \quad \beta_W \leq 1,25$$

β_E : Coefficient defined in [1.3.4]

$$\beta_W = \frac{h_W}{t_W}\sqrt{\frac{\varepsilon R_{eH}}{E}}$$

ε : Relative strain defined in [1.3.3].

1.3.7 Web local buckling of flat bar ordinary stiffeners

The equation describing the load-end shortening curve σ_{CR4}-ε for the web local buckling of flat bar ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see Fig 6):

$$\sigma_{CR4} = \Phi \frac{10 s t_P \sigma_{CP} + A_S \sigma_{C4}}{A_S + 10 s t_P}$$

where:

Φ : Edge function defined in [1.3.3]

σ_{CP} : Buckling stress of the attached plating, in N/mm^2, defined in [1.3.5]

σ_{C4} : Critical stress, in N/mm^2:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \quad \text{for} \quad \sigma_{E4} \leq \frac{R_{eH}}{2}\varepsilon$$

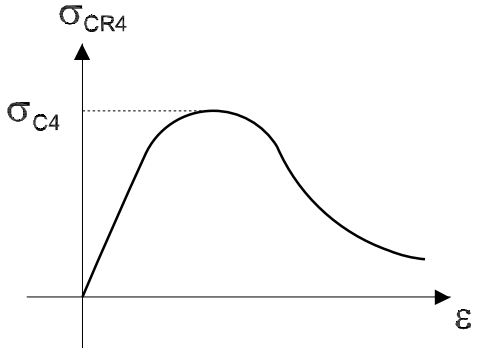
$$\sigma_{C4} = R_{eH}\left(1 - \frac{R_{eH}\varepsilon}{4\sigma_{E4}}\right) \quad \text{for} \quad \sigma_{E4} > \frac{R_{eH}}{2}\varepsilon$$

σ_{E4} : Local Euler buckling stress, in N/mm^2:

$$\sigma_{E4} = 160000\left(\frac{t_W}{h_W}\right)^2$$

ε : Relative strain defined in [1.3.3].

Figure 6 : Load-end shortening curve σ_{CR4}-ε for web local buckling of flat bars



1.3.8 Plate buckling

The equation describing the load-end shortening curve σ_{CR5}-ε for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR5} = \min\begin{cases} \Phi R_{eH} \\ \Phi R_{eH}\left[\frac{s}{\ell}\left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right) + 0,1\left(1 - \frac{s}{\ell}\right)\left(1 + \frac{1}{\beta_E^2}\right)^2\right] \end{cases}$$

where:

β_E : Coefficient defined in [1.3.4].

1.3.9 Transversely stiffened curved panels

The equation describing the load-end shortening curve σ_{CR6}-ε for the buckling of transversely stiffened curved panels is to be obtained from the following formulae:

$$\sigma_{CR6} = \frac{\Phi\sigma_{EC}}{\varepsilon} \qquad \text{for } \sigma_{EC} \leq \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{CR6} = \Phi R_{eH}\left(1 - \frac{R_{eH}\varepsilon}{4\sigma_{EC}}\right) \text{ for } \sigma_{EC} > \frac{R_{eH}}{2}\varepsilon$$

where:

σ_{EC} : Euler buckling stress, to be obtained, in N/mm^2, from the following formula:

$$\sigma_{EC} = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2 K_3 10^{-6}$$

b : Width of curved panel, in m, measured on arc between two adjacent supports

K_3 : Buckling factor to be taken equal to:

$$K_3 = 2\left\{1 + \sqrt{1 + \frac{12(1-\nu^2)}{\pi^4}\frac{b^4}{r^2 t^2}10^6}\right\}$$

r : Radius of curvature, in m.

CHAPTER 7
HULL SCANTLINGS

Section 1 Plating

Section 2 Ordinary Stiffeners

Section 3 Primary Supporting Members

Section 4 Fatigue Check of Structural Details

Appendix 1 Analyses Based on Three-Dimensional Models

Appendix 2 Analyses of Primary Supporting Members Subjected to Wheeled Loads

Appendix 3 Analyses Based on Complete Ship Models

Section 1 Plating

Symbols

For the symbols not defined in this Section, refer to Ch 1, Sec 2, [2.1.1].

ν : Poisson's ratio. Unless otherwise specified, a value of 0,3 is to be taken into account

σ_{X1} : In-plane hull girder normal stress, in N/mm^2, defined in:

- [3.2.6] for the strength check of plating subjected to lateral pressure
- [5.2.2] for the buckling check of plating

τ_1 : In-plane hull girder shear stress, in N/mm^2, defined in [3.2.7]

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1,21\sqrt{1 + 0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell}$$

to be taken not greater than 1,0

c_r : Coefficient of curvature of the panel, equal to:

$c_r = 1 - 0,5\ s / r$

to be taken not less than 0,5

E : Young's modulus, in N/mm^2, to be taken equal to:

- for steels in general:

  $E = 2,06.10^5$ N/mm^2
- for stainless steels:

  $E = 1,95.10^5$ N/mm^2
- for aluminium alloys:

  $E = 7,0.10^4$ N/mm^2

F_S : Still water wheeled force, in kN (see [4.2.2]

$F_{W,Z}$: Inertial wheeled force, in kN (see [4.2.2])

I_Y : Net moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings

I_Z : Net moment of inertia, in m^4, of the hull transverse section around its vertical neutral axis, to be calculated according to Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings

k : Material factor, defined in:

- Ch 4, Sec 1, [2.3], for steel
- Ch 4, Sec 1, [4.4], for aluminium alloys

ℓ : Length, in m, of the longer side of the plate panel

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.2]

$M_{SW,H}$: Design still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [2.2]

$M_{SW,Hmin}$: Minimum still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, without being taken greater than $0,3M_{WV,S}$

$M_{SW,S}$: Design still water bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [2.2]

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1]

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1]

N : Z co-ordinate, in m, with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6], of the centre of gravity of the hull transverse section constituted by members contributing to the hull girder longitudinal strength considered as having their net scantlings (see Ch 6, Sec 1, [2])

p_S : Still water pressure, in kN/m² (see [3.2.2]

p_{SF}, p_{WF} : Still water and wave pressure, in kN/m², in flooding conditions, defined in Ch 5, Sec 6, [7] (see [3.2.3])

p_W : Wave pressure and, if necessary, dynamic pressures, according to the criteria in Ch 5, Sec 5, [2] and Ch 5, Sec 6, [2], in kN/m² (see [3.2.2])

r : Radius of curvature, in m

R_{eH} : Minimum guaranteed yield stress, in N/mm², of the plating material, defined in Ch 4, Sec 1, [2]

R_y : Minimum yield stress, in N/mm², of the material to be taken equal to 235/k N/mm², unless otherwise specified

s : Length, in m, of the shorter side of the plate panel

t_{net} : Net thickness, in mm, of a plate panel

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6].

1 General

1.1 Net thicknesses

1.1.1 As specified in Ch 4, Sec 2, [1], all thicknesses referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross thicknesses are obtained as specified in Ch 4, Sec 2.

1.2 Partial safety factors

1.2.1 The partial safety factors to be considered for the checking of the plating are specified in Tab 1.

1.3 Elementary plate panel

1.3.1 The elementary plate panel is the smallest unstiffened part of plating.

1.4 Load point

1.4.1 Unless otherwise specified, lateral pressure and hull girder stresses are to be calculated:

- for longitudinal framing, at the lower edge of the elementary plate panel or, in the case of horizontal plating, at the point of minimum y-value among those of the elementary plate panel considered
- for transverse framing, at the lower edge of the strake.

Table 1 : Plating - Partial safety factors

Partial safety factors covering uncertainties regarding	Symbol	Strength check of plating subjected to lateral pressure			Buckling check
		General	Flooding pressure	Testing check	
		(see [3.2], [3.3.1], [3.4.1], [3.5.1] and [4])	(see [3.3.2], [3.4.2] and [3.5.2])	(see [3.3.2], [3.4.2] and [3.5.2])	(see [5])
Still water hull girder loads	γ_{S1}	1,00	1,00	Not applicable	1,00
Wave hull girder loads	γ_{W1}	1,15	1,15	Not applicable	1,15
Still water pressure	γ_{S2}	1,00	1,00	1,00	Not applicable
Wave pressure	γ_{W2}	1,20	1,20	Not applicable	Not applicable
Material	γ_m	1,02	1,02	1,02	1,02
Resistance	γ_R	1,20**(2)**	1,05 **(1)**	1,05**(2)**	1,10

(1) For plating of the collision bulkhead, γ_R = 1,25. This requirement may be disregarded when damage stability considers at least two adjacent compartments flooded.

(2) For plating of decks and side walls of ammunition storage, for assessment under flooding by fire-extinguishing system, γ_R = 1,05. This requirement may be disregarded when the extinguishing system used for ammunition storage is not by flooding of the compartment

2 General requirements

2.1 General

2.1.1 The requirements in [2.2] and [2.3] are to be applied to plating in addition of those in [3] to [5].

2.2 Minimum net thicknesses

2.2.1 As a rule, the net thickness of plating is to be not less than the values given in Tab 2.

The Society may consider lower thicknesses than those in Tab 2, on a case by case basis, when this is deemed appropriate on the basis of scantlings calculations for all types of loading cases.

Table 2 : Minimum net thickness of plating

Plating	Minimum net thickness, in mm
Deck Longitudinal bulkhead Shell	5
Transverse bulkhead	4

2.3 Bilge plating

2.3.1 The net thickness of the longitudinally framed bilge plating, in mm, is to be not less than the greater of the:

- value obtained from [3.3.1]
- value obtained from [5], to be checked as curved panel.

2.3.2 The net thickness of the transversely framed bilge plating, in mm, is to be not less than the greater of:

- $t = 0,7\ [\gamma_R\ \gamma_m\ (\gamma_{S2}\ p_S + \gamma_{W2}\ p_W)\ s_b]^{0,4}\ R^{0,6}\ k^{1/2}$

  where:

  R : Bilge radius, in m
- value obtained from [5], to be checked as curved panel.

2.3.3 The net thickness bilge plating is to be not less than the actual thicknesses of the adjacent bottom or side plating, whichever is the greater.

2.4 Sheerstrake

2.4.1 Welded sheerstrake

The net thickness of a welded sheerstrake is to be not less than that of the adjacent side plating, taking into account higher strength steel corrections if needed.

In general, the required net thickness of the adjacent side plating is to be taken as a reference. In specific case, depending on its actual net thickness, this latter may be required to be considered when deemed necessary by the Society.

2.4.2 Rounded sheerstrake

The net thickness of a rounded sheerstrake is to be not less than the actual net thickness of the adjacent deck plating.

2.4.3 Net thickness of the sheerstrake in way of breaks of long superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of long superstructures occurring within 0,5L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 40%, but need not exceed 4,5 mm.

Where the breaks of superstructures occur outside 0,5 L amidships, the increase in net thickness may be reduced to 30%, but need not exceed 2,5 mm.

Alternative arrangements justified by direct calculations or compliance with other regulations may be accepted, if deemed equivalent by the Society.

2.4.4 Net thickness of the sheerstrake in way of breaks of short superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of short superstructures occurring within 0,6 L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 15%, but need not exceed 4,5 mm.

Alternative arrangements justified by direct calculations or compliance with other regulations may be accepted, if deemed equivalent by the Society.

2.5 Stringer plate

2.5.1 General

The net thickness of the stringer plate is to be not less than the actual net thickness of the adjacent deck plating.

2.5.2 Net thickness of the stringer plate in way of breaks of long superstructures

The net thickness of the stringer plate is to be increased in way of breaks of long superstructures occurring within 0,5L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 40%, but need not exceed 4,5 mm.

Where the breaks of superstructures occur outside 0,5L amidships, the increase in net thickness may be reduced to 30%, but need not exceed 2,5 mm.

Alternative arrangements justified by direct calculations or compliance with other regulations may be accepted, if deemed equivalent by the Society.

2.5.3 Net thickness of the stringer plate in way of breaks of short superstructures

The net thickness of the stringer plate is to be increased in way of breaks of short superstructures occurring within 0,6L amidships, over a length of about one sixth of the ship breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 15%, but need not exceed 4,5 mm.

Alternative arrangements justified by direct calculations or compliance with other regulations may be accepted, if deemed equivalent by the Society.

3 Strength check of plating subjected to lateral pressure

3.1 General

3.1.1 The requirements of this Article apply for the yielding check of plating subjected to lateral pressure, wheeled loads or weapon firing dynamic loads and, for plating contributing to the longitudinal strength, to in-plane hull girder normal and shear stresses.

3.2 Load model

3.2.1 General

The still water and wave lateral pressures induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the plating under consideration and the type of the compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

The plating located below the deepest equilibrium waterline (excluding side shell plating) which constitute boundaries intended to stop vertical and horizontal flooding is to be subjected to lateral pressure in flooding conditions.

The wave lateral pressures and hull girder loads are to be calculated in the mutually exclusive load cases "a", "b", "c" and "d" in Ch 5, Sec 4.

3.2.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case "a", "b", "c" and "d"
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case "a", "b", "c" and "d"
- the dynamic pressures, according to the criteria in Ch 5, Sec 6, [2].

3.2.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and wave pressure p_{WF} defined in Ch 5, Sec 6, [7].

3.2.4 Lateral pressure in testing conditions

The lateral pressure (p_T) in testing conditions is taken equal to:

- $p_{ST} - p_S$ for bottom shell plating and side shell plating
- p_{ST} otherwise,

where:

p_{ST} : Still water pressure defined in Ch 5, Sec 6, Tab 10

p_S : Still water sea pressure defined in Ch 5, Sec 5, [1.1.1] for the draught T_1 at which the testing is carried out.

If the draught T_1 is not defined by the Designer, it may be taken equal to the light ballast draught T_B defined in Ch 5, Sec 1, [2.4.3].

3.2.5 Pressures induced by weapon firing dynamic loads

The following weapon firing dynamic loads are to be considered, depending on the location of the plating under consideration:

- missile blast dynamic pressure
- accidental missile ignition dynamic pressure
- gun blast dynamic pressure.

The lateral pressure p_W induced by the above dynamic loads are to be calculated according to the requirements specified in Ch 5, Sec 6, [9].

3.2.6 In-plane hull girder normal stresses

The in-plane hull girder normal stresses to be considered for the strength check of plating are obtained, in N/mm^2, from the following formulae:

- for plating contributing to the hull girder longitudinal strength:
  $\sigma_{X1} = \gamma_{S1}\,\sigma_{S1} + \gamma_{W1}\,(C_{FV}\,\sigma_{WV1} + C_{FH}\,\sigma_{WH1})$
- for plating not contributing to the hull girder longitudinal strength:
  $\sigma_{X1} = 0$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm^2, defined in Tab 3

C_{FV}, C_{FH} : Combination factors defined in Tab 4.

Table 3 : Hull girder normal stresses

Condition	σ_{S1}, in N/mm^2 **(1)**	σ_{WV1}, in N/mm^2	σ_{WH1}, in N/mm^2
$\dfrac{\lvert\gamma_{S1}M_{SW,S} + 0{,}625\gamma_{W1}C_{FV}M_{WV,S}\rvert}{\gamma_{S1}M_{SW,H} + 0{,}625\gamma_{W1}C_{FV}M_{WV,H}} \geq 1$	$\left\lvert\dfrac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\dfrac{0{,}625F_D M_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\dfrac{0{,}625M_{WH}}{I_Z}y\right\rvert 10^{-3}$
$\dfrac{\lvert\gamma_{S1}M_{SW,S} + 0{,}625\gamma_{W1}C_{FV}M_{WV,S}\rvert}{\gamma_{S1}M_{SW,H} + 0{,}625\gamma_{W1}C_{FV}M_{WV,H}} < 1$	$\left\lvert\dfrac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\dfrac{0{,}625M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 4 : Combination factors C_{FV}, C_{FH} and $C_{F\Omega}$

Load case	C_{FV}	C_{FH}	$C_{F\Omega}$
"a"	1,0	0	0
"b"	1,0	0	0
"c"	0,4	1,0	1,0
"d"	0,4	1,0	0
Flooding	0,6	0	0

3.2.7 In-plane hull girder shear stresses

The in-plane hull girder shear stresses to be considered for the strength check of plating which contributes to the longitudinal strength are obtained, in N/mm^2, from the following formula:

$\tau_1 = \gamma_{S1}\,\tau_{S1} + 0{,}625\,C_{FV}\,\gamma_{W1}\,\tau_{W1}$

where:

τ_{S1} : Absolute value of the hull girder shear stresses, in N/mm^2, induced by the maximum still water hull girder vertical shear force

τ_{W1} : Absolute value of the hull girder shear stresses, in N/mm², induced by the maximum wave hull girder vertical shear force

C_{FV} : Combination factor defined in Tab 4.

τ_{S1} and τ_{W1} may be calculated as indicated in Tab 5 where, at a preliminary design stage, the still water hull girder vertical shear force is not defined.

Table 5 : Hull girder shear stresses

Structural element	τ_{S1}, τ_{W1} in N/mm²
Bottom, bilge, inner bottom and decks (excluding possible longitudinal sloping plates)	0
Side, inner side and longitudinal bulkheads (including possible longitudinal sloping plates):	
• $0 \le z \le 0,25\ D$	$\tau_0\left(0,5 + 2\frac{z}{D}\right)$
• $0,25\ D < z \le 0,75\ D$	τ_0
• $0,75\ D < z \le D$	$\tau_0\left(2,5 - 2\frac{z}{D}\right)$
Note 1: $\tau_0 = \frac{47}{k}\left\{1 - \frac{6,3}{\sqrt{L_1}}\right\}$ N/mm² where: L_1 : Length, in m, defined in Ch 1, Sec 2, [2.1.1]	

3.3 Longitudinally framed plating contributing to the hull girder longitudinal strength

3.3.1 General

The net thickness of laterally loaded plate panels subjected to in-plane normal stress acting on the shorter sides is to be not less than the value obtained, in mm, from the following formula:

$$t = 14,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda_L R_y}}$$

where:

- for bottom, bilge, inner bottom and decks (excluding possible longitudinal sloping plates):

$$\lambda_L = \sqrt{1 - 0,95\left(\gamma_m \frac{\sigma_{x1}}{R_y}\right)^2} - 0,225\gamma_m \frac{\sigma_{x1}}{R_y}$$

- for side, inner side and longitudinal bulkheads (including possible longitudinal sloping plates):

$$\lambda_L = \sqrt{1 - 3\left(\gamma_m \frac{\tau_1}{R_y}\right)^2 - 0,95\left(\gamma_m \frac{\sigma_{x1}}{R_y}\right)^2} - 0,225\gamma_m \frac{\sigma_{x1}}{R_y}$$

3.3.2 Flooding conditions

The plating of structural watertight elements which constitute boundaries intended to stop vertical and horizontal flooding as per Internal Watertight Plan is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{\lambda_L R_y}}$$

where λ_L is defined in [3.3.1].

3.3.3 Testing conditions

The plating of compartments or structures as defined in Ch 5, Sec 6, Tab 10 is to be checked in testing conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_T}{R_y}}$$

3.4 Transversely framed plating contributing to the hull girder longitudinal strength

3.4.1 General

The net thickness of laterally loaded plate panels subjected to in-plane normal stress acting on the longer sides is to be not less than the value obtained, in mm, from the following formula:

$$t = C_T c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda_T R_y}}$$

where:

- for bottom, bilge, inner bottom and decks (excluding possible longitudinal sloping plates):

  C_T : Coefficient equal to 17,2

  $$\lambda_T = 1 - 0,89 \gamma_m \frac{\sigma_{x1}}{R_y}$$

- for side, inner side and longitudinal bulkheads (including possible longitudinal sloping plates):

  C_T : Coefficient equal to:

  17,2 for side

  14,9 for inner side and longitudinal bulkheads (including possible longitudinal sloping plates)

  $$\lambda_T = \sqrt{1 - 3\left(\gamma_m \frac{\tau_1}{R_y}\right)^2} - 0,89 \gamma_m \frac{\sigma_{x1}}{R_y}$$

3.4.2 Flooding conditions

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 17,2 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{\lambda_T R_y}}$$

where λ_T is defined in [3.4.1].

3.4.3 Testing conditions

The plating of compartments or structures as defined in Ch 5, Sec 6, Tab 10 is to be checked in testing conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{ST}}{R_y}}$$

3.5 Plating not contributing to the hull girder longitudinal strength

3.5.1 General

The net thickness of plate panels subjected to lateral pressure is to be not less than the value obtained, in mm, from the following formula:

$$t = 14,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$$

3.5.2 Flooding conditions

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y}}$$

3.5.3 Testing conditions

The plating of compartments or structures as defined in Ch 5, Sec 6, Tab 10 is to be checked in testing conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{ST}}{R_y}}$$

4 Strength check of plating subjected to wheeled loads

4.1 General

4.1.1 The requirements of this Article apply for the strength check of plating subjected to wheeled loads.

4.2 Load model

4.2.1 General

The still water and inertial forces induced by the sea and the various types of wheeled vehicles are to be considered, depending on the location of the plating.

The inertial forces induced by the sea are to be calculated in load case "b", as defined in Ch 5, Sec 4.

4.2.2 Wheeled forces

The wheeled force applied by one wheel is constituted by still water force and inertial force.

Still water force is the vertical force (F_S) defined in Ch 5, Sec 6, [4.1].

Inertial force is the vertical force ($F_{W,Z}$) defined in Ch 5, Sec 6, [4.1], for load case "b", with the acceleration a_{Z1} calculated at x = 0,5L.

4.3 Plating

4.3.1 The net thickness of plate panels subjected to wheeled loads is to be not less than the value obtained, in mm, from the following formula:

$$t = 0,9\, C_{WL} \sqrt{\frac{n P_0 k}{\lambda}}$$

where:

C_{WL} : Coefficient to be taken equal to:

$$C_{WL} = 2,15 - 0,05\frac{\ell}{s} + 0,02\left(4 - \frac{\ell}{s}\right)\alpha^{0,5} - 1,75\alpha^{0,25}$$

where ℓ/s is to be taken not greater than 3

$$\alpha = \frac{A_T}{\ell s}$$

A_T : Tyre print area, in m^2. In the case of double or triple wheels, A_T is the print area of the group of wheels. A_T is not to be taken greater than the value given in [4.3.2]

ℓ, s : Lengths, in m, of, respectively, the longer and the shorter sides of the plate panel

n : Number of wheels on the plate panel, taken equal to:

- 1 in the case of a single wheel
- the number of wheels in a group of wheels in the case of double or triple wheels

P_0 : Wheeled force, in kN, taken equal to:

$$P_0 = \gamma_{S2} F_S + \gamma_{W2} F_{W,Z}$$

λ : Coefficient taken equal to:

- for longitudinally framed plating:
  $\lambda = \lambda_L$ as defined in [3.3.1]
- for transversely framed plating:
  $\lambda = \lambda_T$ as defined in [3.4.1].

4.3.2 When the tyre print area is not known, it may be taken equal to:

$$A_T = 9,81\frac{n Q_A}{n_W p_T}$$

where:

n : Number of wheels on the plate panel, defined in [4.3.1]

Q_A : Axle load, in t

n_W : Number of wheels for the axle considered

p_T : Tyre pressure, in kN/m^2. When the tyre pressure is not indicated by the designer, it may be taken as defined in Tab 6.

Table 6 : Tyre pressures p_T for vehicles

Vehicle type	Tyre pressure p_T, in kN/m²	
	Pneumatic tyres	Solid rubber tyres
Private cars	250	not applicable
Trucks and trailers	800	not applicable
Handling machines	1100	1600

4.3.3 For vehicles with the four wheels of the axle located on a plate panel as shown in Fig 1, the net thickness of deck plating is to be not less than the greater of the values obtained, in mm, from the following formulae:

$t = t_1$

$t = t_2 (1 + \beta_2 + \beta_3 + \beta_4)^{0,5}$

where:

t_1 : Net thickness obtained from [4.3.1] for n = 2, considering one group of two wheels located on the plate panel

t_2 : Net thickness obtained from [4.3.1] for n = 1, considering one wheel located on the plate panel

β_2 , β_3 , β_4 : Coefficients obtained from the following formula, by replacing i by 2, 3 and 4, respectively (see Fig 1):

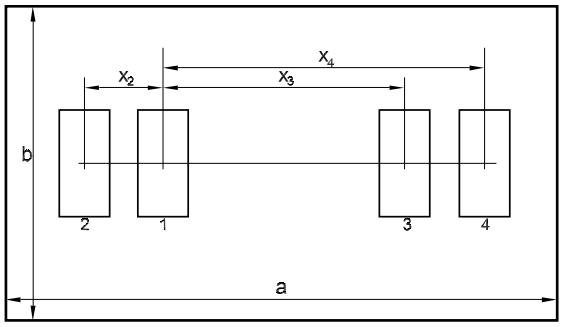
- for $x_i / b < 2$: $\beta_i = 0,8 (1,2 - 2,02 \alpha_i + 1,17 \alpha_i^2 - 0,23 \alpha_i^3)$
- for $x_i / b \geq 2$: $\beta_i = 0$

x_i : Distance, in m, from the wheel considered to the reference wheel (see Fig 1)

b : Dimension, in m, of the plate panel side perpendicular to the axle

$$\alpha_i = \frac{x_i}{b}$$

Figure 1 : Four wheel axle located on a plate panel



5 Buckling check

5.1 General

5.1.1 Application

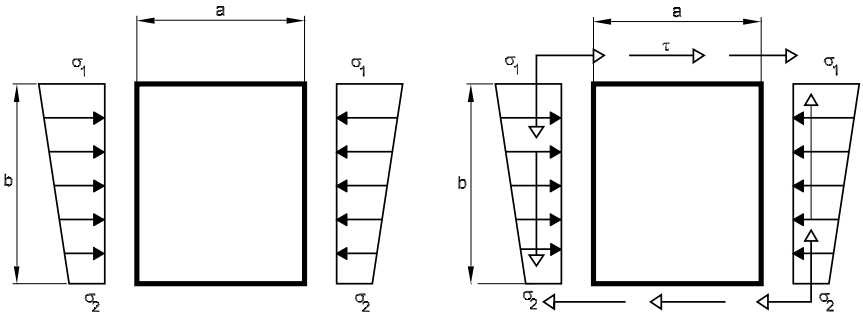
The requirements of this Article apply for the buckling check of plating subjected to in-plane compression stresses, acting on one or two sides, or to shear stress.

Rectangular plate panels are considered as being simply supported. For specific designs, other boundary conditions may be considered, at the Society's discretion, provided that the necessary information is submitted for review.

5.1.2 Compression and bending with or without shear

For plate panels subjected to compression and bending along one side, with or without shear, as shown in Fig 2, side "b" is to be taken as the loaded side. In such case, the compression stress varies linearly from σ_1 to $\sigma_2 = \psi \sigma_1$ (with $\psi \leq 1$) along edge "b".

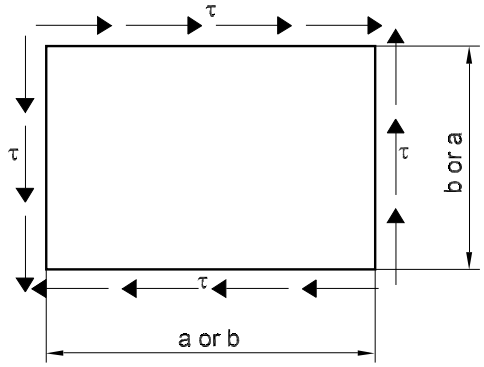
Figure 2 : Buckling of a simply supported rectangular plate panel subjected to compression and bending, with and without shear



5.1.3 Shear

For plate panels subjected to shear, as shown in Fig 3, side "b" may be taken as either the longer or the shorter side of the panel.

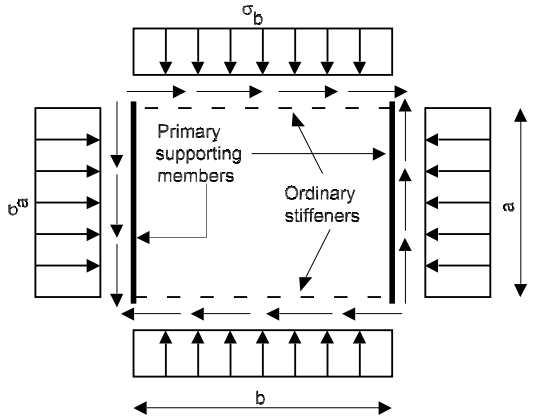
Figure 3 : Buckling of a simply supported rectangular plate panel subjected to shear



5.1.4 Bi-axial compression and shear

For plate panels subjected to bi-axial compression along sides "a" and "b", and to shear, as shown in Fig 4, side "a" is to be taken as the side in the direction of the primary supporting members.

Figure 4 : Buckling of a simply supported rectangular plate panel subjected to bi-axial compression and shear



5.2 Load model

5.2.1 Sign convention for normal stresses

The sign convention for normal stresses is as follows:

- tension: positive
- compression: negative.

5.2.2 In-plane hull girder compression normal stresses

The in-plane hull girder compression normal stresses to be considered for the buckling check of plating contributing to the longitudinal strength are obtained, in N/mm^2, from the following formula:

$$\sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1})$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 7

C_{FV}, C_{FH} : Combination factors defined in Tab 4.

σ_{X1} is to be taken as the maximum compression stress on the plate panel considered.

When the ship in still water is always in hogging condition, σ_{X1} may be evaluated by means of direct calculations when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

Table 7 : Hull girder normal compression stresses

Condition	σ_{S1} in N/mm² **(1)**	σ_{WV1} in N/mm²	σ_{WH1} in N/mm²
$z \geq N$	$\frac{M_{SW,S}}{I_Y}(z-N)10^{-3}$	$\frac{0,625F_D M_{WV,S}}{I_Y}(z-N)10^{-3}$	$-\left\lvert\frac{0,625M_{WH}}{I_Z}y\right\rvert 10^{-3}$
$z < N$	$\frac{M_{SW,H}}{I_Y}(z-N)10^{-3}$	$\frac{0,625M_{WV,H}}{I_Y}(z-N)10^{-3}$	

(1) When the ship in still water is always in hogging condition, σ_{S1} for $z \geq N$ is to be obtained, in N/mm², from the following formula, unless σ_{X1} is evaluated by means of direct calculations (see [5.2.2]):

$$\sigma_{S1} = \frac{M_{SW,Hmin}}{I_Y}(z-N)10^{-3}$$

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

5.2.3 In-plane hull girder shear stresses

The in-plane hull girder shear stresses to be considered for the buckling check of plating are obtained as specified in [3.2.7] for the strength check of plating subjected to lateral pressure, which contributes to the longitudinal strength.

5.2.4 Combined in-plane hull girder and local compression normal stresses

The combined in-plane compression normal stresses to be considered for the buckling check of plating are to take into account the hull girder stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis using the design loads given in Part B, Chapter 5.

With respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10], the combined stresses in x and y direction are obtained, in N/mm², from the following formulae:

$$\sigma_X = \sigma_{X1} + \gamma_{S2}\sigma_{X2,S} + \gamma_{W2}\sigma_{X2,W}$$

$$\sigma_Y = \gamma_{S2}\sigma_{Y2,S} + \gamma_{W2}\sigma_{Y2,W}$$

where:

σ_{X1} : Compression normal stress, in N/mm², induced by the hull girder still water and wave loads, defined in [5.2.2]

$\sigma_{X2,S}$,$\sigma_{Y2,S}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the still water design loads given in Part B, Chapter 5

$\sigma_{X2,W}$,$\sigma_{Y2,W}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the wave design loads given in Part B, Chapter 5.

5.2.5 Combined in-plane hull girder and local shear stresses

The combined in-plane shear stresses to be considered for the buckling check of plating are to take into account the hull girder stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis using the design loads given in Part B, Chapter 5.

The combined stresses are obtained, in N/mm², from the following formula:

$$\tau = \tau_1 + \gamma_{S2}\tau_{2,S} + \gamma_{W2}\tau_{2,W}$$

where:

τ_1 : Shear stress, in N/mm², induced by the hull girder still water and wave loads, defined in [5.2.3]

$\tau_{2,S}$: Shear stress, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the still water design loads given in Part B, Chapter 5

$\tau_{2,W}$: Shear stress, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the wave design loads given in Part B, Chapter 5.

5.3 Critical stresses

5.3.1 Compression and bending for plane panel

The critical buckling stress is to be obtained, in N/mm², from the following formulae:

$\sigma_c = \sigma_E$ for $\sigma_E \leq \frac{R_{eH}}{2}$

$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right)$ for $\sigma_E > \frac{R_{eH}}{2}$

where:

σ_E : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_1 \varepsilon 10^{-6}$$

K_1 : Buckling factor defined in Tab 8

ε : Coefficient to be taken equal to:

- $\varepsilon = 1$ for $\alpha \geq 1$
- $\varepsilon = 1,05$ for $\alpha < 1$ and side "b" stiffened by flat bar
- $\varepsilon = 1,10$ for $\alpha < 1$ and side "b" stiffened by bulb section
- $\varepsilon = 1,21$ for $\alpha < 1$ and side "b" stiffened by angle or T-section
- $\varepsilon = 1,30$ for $\alpha < 1$ and side "b" stiffened by primary supporting members.

where $\alpha = a / b$

Table 8 : Buckling factor K_1 for plate panels

Load pattern	Aspect ratio	Buckling factor K_1
$0 \leq \psi \leq 1$	$\alpha \geq 1$	$\frac{8,4}{\psi + 1,1}$
	$\alpha < 1$	$\left(\alpha + \frac{1}{\alpha}\right)^2 \frac{2,1}{\psi + 1,1}$
$-1 < \psi < 0$		$(1+\psi)K_1' - \psi K_1'' + 10\psi(1+\psi)$
$\psi \leq -1$	$\alpha\frac{1-\psi}{2} \geq \frac{2}{3}$	$23,9\left(\frac{1-\psi}{2}\right)^2$
	$\alpha\frac{1-\psi}{2} < \frac{2}{3}$	$\left(15,87 + \frac{1,87}{\left(\alpha\frac{1-\psi}{2}\right)^2} + 8,6\left(\alpha\frac{1-\psi}{2}\right)^2\right)\left(\frac{1-\psi}{2}\right)^2$

Note 1:

$\psi = \frac{\sigma_2}{\sigma_1}$

K_1' : Value of K_1 calculated for $\psi = 0$

K_1'' : Value of K_1 calculated for $\psi = -1$

5.3.2 Shear for plane panel

The critical shear buckling stress is to be obtained, in N/mm², from the following formulae:

$\tau_c = \tau_E$ for $\tau_E \leq \frac{R_{eH}}{2\sqrt{3}}$

$\tau_c = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\tau_E}\right)$ for $\tau_E > \frac{R_{eH}}{2\sqrt{3}}$

where:

τ_E : Euler shear buckling stress, to be obtained, in N/mm², from the following formula:

$$\tau_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_2 10^{-6}$$

K_2 : Buckling factor to be taken equal to:

$K_2 = 5,34 + \frac{4}{\alpha^2}$ for $\alpha > 1$

$K_2 = \frac{5,34}{\alpha^2} + 4$ for $\alpha \leq 1$

α : Coefficient defined in [5.3.1].

5.3.3 Bi-axial compression and shear for plane panel

The critical buckling stress $\sigma_{c,a}$ for compression on side "a" of the panel is to be obtained, in N/mm^2, from the following formula:

$$\sigma_{c,a} = \left(\frac{2,25}{\beta} - \frac{1,25}{\beta^2}\right) R_{eH}$$

where:

β : Slenderness of the panel, to be taken equal to:

$$\beta = 10^3 \frac{a}{t_{net}} \sqrt{\frac{R_{eH}}{E}}$$

without being taken less than 1,25.

The critical buckling stress $\sigma_{c,b}$ for compression on side "b" of the panel is to be obtained, in N/mm^2, from the formulae in [5.3.1].

The critical shear buckling stress is to be obtained, in N/mm^2, from the formulae in [5.3.2].

5.3.4 Compression and shear for curved panels

The critical buckling stress of curved panels subjected to compression on curved edges is to be obtained, in N/mm^2, from the following formulae:

$$\sigma_c = \sigma_E \qquad \text{for } \sigma_E \leq \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \text{ for } \sigma_E > \frac{R_{eH}}{2}$$

where:

σ_E : Euler buckling stress, to be obtained, in N/mm^2, from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_3$$

b : Width of curved panel, in mm, measured on arc

K_3 : Buckling factor defined in Tab 9.

The critical shear buckling stress is to be obtained, in N/mm^2, from the following formulae:

$$\tau_c = \tau_E \qquad \text{for } \tau_E \leq \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_c = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\tau_E}\right) \text{ for } \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

where:

τ_E : Euler shear buckling stress, to be obtained, in N/mm^2, from the following formula:

$$\tau_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_4$$

K_4 : Buckling factor to be taken equal to:

$$K_4 = \frac{12(1-\nu^2)}{\pi^2}\left(5 + 0,1\frac{b^2}{r t_{net}}\right)$$

b, r : Defined above.

Table 9 : Buckling factor K_3 for curved panels

Load	Buckling factor K_3
Compression stress perpendicular to the curved edges	$2\left[1 + \sqrt{1 + \frac{12(1-\nu^2)}{\pi^4}\frac{b^4}{r^2 t_{net}^2}}\right]$
Note 1: r : Radius of curvature, in mm.	

5.3.5 Compression for corrugation flanges

The critical buckling stress is to be obtained, in N/mm^2, from the following formulae:

$$\sigma_c = \sigma_E \qquad \text{for } \sigma_E \leq \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \text{ for } \sigma_E > \frac{R_{eH}}{2}$$

where:

σ_E : Euler buckling stress, to be obtained, in N/mm^2, from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_f}{V}\right)^2 K_5$$

K_5 : Buckling factor to be taken equal to:

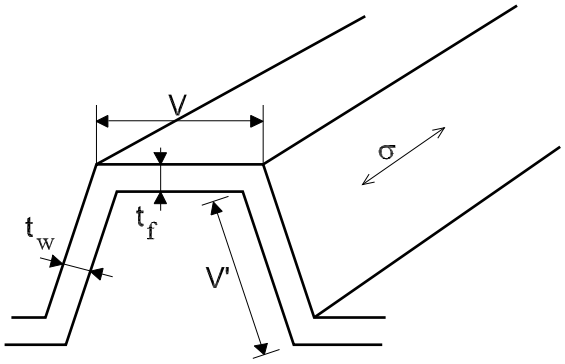
$$K_5 = \left(1 + \frac{t_w}{t_f}\right)\left\{3 + 0{,}5\frac{V'}{V} - 0{,}33\left(\frac{V'}{V}\right)^2\right\}$$

t_f : Net thickness, in mm, of the corrugation flange

t_w : Net thickness, in mm, of the corrugation web

V, V′ : Dimensions of a corrugation, in mm, shown in Fig 5.

Figure 5 : Dimensions of a corrugation



5.4 Checking criteria

5.4.1 Acceptance of results

The net thickness of plate panels is to be such as to satisfy the buckling check, as indicated in [5.4.2] to [5.4.5] depending on the type of stresses acting on the plate panel considered. When the buckling criteria is exceeded, the scantlings may still be considered as acceptable, provided that the stiffeners located on the plate panel satisfy the buckling and the ultimate strength checks as specified in Ch 7, Sec 2, [4] and Ch 7, Sec 2, [5].

5.4.2 Compression and bending

For plate panels subjected to compression and bending on one side, the critical buckling stress is to comply with the following formula:

$$\frac{\sigma_c}{\gamma_R \gamma_m} \geq |\sigma_b|$$

where:

σ_c : Critical buckling stress, in N/mm^2, defined in [5.3.1], [5.3.4] or [5.3.5], as the case may be

σ_b : Compression stress, in N/mm^2, acting on side “b” of the plate panel, to be calculated, as specified in [5.2.2] or [5.2.4], as the case may be.

5.4.3 Shear

For plate panels subjected to shear, the critical shear buckling stress is to comply with the following formula:

$$\frac{\tau_c}{\gamma_R \gamma_m} \geq |\tau_b|$$

where:

τ_c : Critical shear buckling stress, in N/mm^2, defined in [5.3.2] or [5.3.4], as the case may be

τ_b : Shear stress, in N/mm^2, acting on the plate panel, to be calculated as specified in [5.2.3] or [5.2.5], as the case may be.

5.4.4 Compression, bending and shear

For plate panels subjected to compression, bending and shear, the combined critical stress is to comply with the following formulae:

$$F \le 1 \qquad \text{for } \frac{\sigma_{comb}}{F} \le \frac{R_{eH}}{2\gamma_R\gamma_m}$$

$$F \le \frac{4\sigma_{comb}}{R_{eH}/\gamma_R\gamma_m}\left(1 - \frac{\sigma_{comb}}{R_{eH}/\gamma_R\gamma_m}\right) \qquad \text{for } \frac{\sigma_{comb}}{F} > \frac{R_{eH}}{2\gamma_R\gamma_m}$$

where:

$$\sigma_{comb} = \sqrt{\sigma_1^2 + 3\tau^2}$$

$$F = \gamma_R\gamma_m\left[\frac{1+\psi}{4}\frac{|\sigma_1|}{\sigma_E} + \sqrt{\left(\frac{3-\psi}{4}\right)^2\left(\frac{\sigma_1}{\sigma_E}\right)^2 + \left(\frac{\tau}{\tau_E}\right)^2}\right]$$

σ_E : Euler buckling stress, in N/mm^2, defined in [5.3.1], [5.3.4] or [5.3.5] as the case may be

τ_E : Euler shear buckling stress, in N/mm^2, defined in [5.3.2] or [5.3.4], as the case may be

$$\psi = \frac{\sigma_2}{\sigma_1}$$

σ_1, σ_2 and τ are defined in Fig 2 and are to be calculated, in N/mm^2, as specified in [5.2].

5.4.5 Bi-axial compression, taking account of shear stress

For plate panels subjected to bi-axial compression and shear, the critical buckling stresses are to comply with the following formula:

$$\left|\frac{\sigma_a}{\frac{\sigma_{c,a}}{\gamma_R\gamma_m}R_a}\right|^n + \left|\frac{\sigma_b}{\frac{\sigma_{c,b}}{\gamma_R\gamma_m}R_b}\right|^n \le 1$$

where:

$\sigma_{c,a}$: Critical buckling stress for compression on side "a", in N/mm^2, defined in [5.3.3]

$\sigma_{c,b}$: Critical buckling stress for compression on side "b", in N/mm^2, defined in [5.3.3]

σ_a : Compression stress acting on side "a", in N/mm^2, to be calculated as specified in [5.2.2] or [5.2.4], as the case may be

σ_b : Compression stress acting on side "b", in N/mm^2, to be calculated as specified in [5.2.2] or [5.2.4], as the case may be

n : Coefficient to be taken equal to:

$n = 1$ for $\alpha \ge 1/\sqrt{2}$

$n = 2$ for $\alpha < 1/\sqrt{2}$

$\alpha = a / b$

$$R_a = 1 - \left|\frac{\tau}{\tau_c}\right|^{n_a}$$

$$R_b = 1 - \left|\frac{\tau}{\tau_c}\right|^{n_b}$$

τ : Shear stress, in N/mm^2, to be calculated as specified in [5.2.3] or [5.2.5], as the case may be

τ_c : Critical shear buckling stress, in N/mm^2, defined in [5.3.2]

n_a : Coefficient to be taken equal to:

$n_a = 1 + 1/\alpha$ for $\alpha \ge 0,5$

$n_a = 3$ for $\alpha < 0,5$

n_b : Coefficient to be taken equal to:

$n_b = 1,9 + 0,1/\alpha$ for $\alpha \ge 0,5$

$n_b = 0,7(1 + 1/\alpha)$ for $\alpha < 0,5$

Section 2 Ordinary Stiffeners

Symbols

For the symbols not defined in this Section, refer to Ch 1, Sec 2, [2.1.1].

ν : Poisson's ratio. Unless otherwise specified, a value of 0,3 is to be taken into account

σ_{X1} : Hull girder normal stress, in N/mm^2, defined in:

- [3.3.7] for the yielding check of ordinary stiffeners
- [4.2.2] for the buckling check of ordinary stiffeners
- [5.3.3] for the ultimate strength check of ordinary stiffeners

ρ_S : Radius of gyration, in cm, of the stiffener with attached plating of width s

ρ_U : Radius of gyration, in cm, of the stiffener with attached plating of width b_U

A_e : Net sectional area, in cm^2, of the stiffener with attached plating of width b_e

A_S : Net sectional area, in cm^2, of the stiffener with attached plating of width s

A_{Sh} : Net shear sectional area, in cm^2, of the stiffener, to be calculated as specified in Ch 4, Sec 3, [3.4]

A_U : Net sectional area, in cm^2, of the stiffener with attached plating of width b_U

b_e : Width, in m, of the plating attached to the stiffener, for the buckling check, defined in [4.1]

b_f : Face plate width, in mm

b_p : Width, in m, of the plating attached to the stiffener, for the yielding check, defined in Ch 4, Sec 3, [3.3.1]

b_U : Width, in m, of the plating attached to the stiffener, for the ultimate strength check, defined in [5.2]

E : Young's modulus, in N/mm^2, to be taken equal to:

- for steels in general:
  $E = 2{,}06.10^5$ N/mm^2
- for stainless steels:
  $E = 1{,}95.10^5$ N/mm^2
- for aluminium alloys:
  $E = 7{,}0.10^4$ N/mm^2

F_S : Still water wheeled force, in kN (see [3.3.5])

$F_{W,Z}$: Inertial wheeled force, in kN (see [3.3.5]

h_w : Web height, in mm

I : Net moment of inertia, in cm^4, of the stiffener without attached plating, about its neutral axis parallel to the plating (see Ch 4, Sec 3, Tab 1)

I_e : Net moment of inertia, in cm^4, of the stiffener with attached shell plating of width b_e, about its neutral axis parallel to the plating

I_S : Net moment of inertia, in cm^4, of the stiffener with attached shell plating of width s, about its neutral axis parallel to the plating

I_U : Net moment of inertia, in cm^4, of the stiffener with attached shell plating of width b_U, about its neutral axis parallel to the plating

I_Y : Net moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings

I_Z : Net moment of inertia, in m^4, of the hull transverse section around its vertical neutral axis, to be calculated according to Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings

k : Material factor, defined in:

- Ch 4, Sec 1, [2.3], for steel
- Ch 4, Sec 1, [4.4], for aluminium alloys

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members (see Ch 4, Sec 3, [3.2]

m : Boundary coefficient, to be taken equal to:

- m = 12 for stiffeners clamped at both ends, whose end connections comply with the requirements in [3.2.2]
- m = 8 for stiffeners clamped at one end and simply supported at the other end, with the clamped end connection complying with the requirements in [3.2.2]
- m = 8 for stiffeners simply supported at both ends.

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.2]

$M_{SW,H}$: Design still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [2.2]

$M_{SW,Hmin}$: Minimum still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, without being taken greater than $0,3M_{WV,S}$

$M_{SW,S}$: Design still water bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [2.2]

M_{WT} : Wave torque, in kN.m, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.3]

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1]

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1]

N : Z co-ordinate, in m, with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6], of the centre of gravity of the hull transverse section constituted by members contributing to the hull girder longitudinal strength considered as having their net scantlings (see Ch 6, Sec 1, [2])

p_S : Still water pressure, in kN/m^2 (see [3.3.2] and [5.3.2]

p_{SF}, p_{WF} : Still water and wave pressures, in kN/m^2, in flooding conditions, defined in Ch 5, Sec 6, [7]

p_W : Wave pressure and, if necessary, dynamic pressures, according to the criteria in Ch 5, Sec 5, [2] and Ch 5, Sec 6, [2], in kN/m^2 (see [3.3.2] and [5.3.2])

$R_{eH,P}$: Minimum yield stress, in N/mm^2, of the plating material, defined in Ch 4, Sec 1, [2]

$R_{eH,S}$: Minimum yield stress, in N/mm^2, of the stiffener material, defined in Ch 4, Sec 1, [2]

R_y : Minimum yield stress, in N/mm^2, of the material to be taken equal to 235/k N/mm^2, unless otherwise specified

s : Spacing, in m, of ordinary stiffeners

t_f : Net face plate thickness, in mm

t_w : Net web thickness, in mm

t_p : Net thickness, in mm, of the attached plating

w : Net section modulus, in cm^3, of the stiffener, with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [3.4]

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6].

1 General

1.1 Net scantlings

1.1.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.2 Partial safety factors

1.2.1 The partial safety factors to be considered for the checking of ordinary stiffeners are specified in Tab 1.

Table 1 : Ordinary stiffeners - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check			Buckling check	Ultimate strength check
		General	Flooding pressure	Testing check		
		(see [3.3] to [3.7])	(see [3.8])	(see [3.9])	(see [4])	(see [5])
Still water hull girder loads	γ_{S1}	1,00	1,00	Not applicable	1,00	1,00
Wave hull girder loads	γ_{W1}	1,15	1,15	Not applicable	1,15	1,30
Still water pressure	γ_{S2}	1,00	1,00	1,00	Not applicable	1,00
Wave pressure	γ_{W2}	1,20	1,05	Not applicable	Not applicable	1,40
Material	γ_m	1,02	1,02	1,02	1,02	1,02
Resistance	γ_R	1,02 **(2)**	1,02 **(1)**	1,20 **(2)**	1,10	1,02

(1) For ordinary stiffeners of the collision bulkhead, γ_R =1,25. This requirement may be disregarded when damage stability considers at least two adjacent compartments flooded.

(2) For ordinary stiffeners of decks and side walls of ammunition storage, for assessment under flooding by fire-extinguishing system, γ_R = 1,02. This requirement may be disregarded when the extinguishing system used for ammunition storage is not by flooding of the compartment

1.3 Load point

1.3.1 Lateral pressure

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the ordinary stiffener considered.

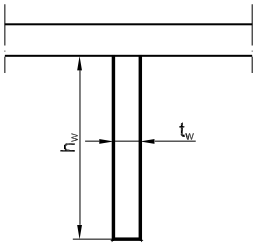
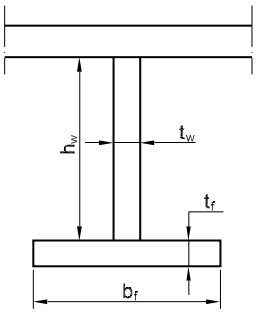
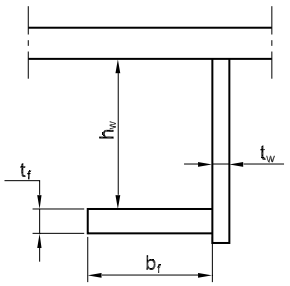
1.3.2 Hull girder stresses

For longitudinal ordinary stiffeners contributing to the hull girder longitudinal strength, the hull girder normal stresses are to be calculated in way of the neutral axis of the stiffener considered.

1.4 Net dimensions of ordinary stiffeners

1.4.1 The net dimensions of a flat bar ordinary stiffener, T-section ordinary stiffener and angle ordinary stiffener are to comply with the following requirement of Tab 2.

Table 2 : Net dimensions of ordinary stiffeners

Flat bar:	T-section ordinary stiffener:	Angle ordinary stiffener:
$\frac{h_w}{t_w} \le 20\sqrt{k}$ 	$\frac{h_w}{t_w} \le 55\sqrt{k}$ $\frac{b_f}{t_f} \le 33\sqrt{k}$ $b_f t_f \ge \frac{h_w t_w}{6}$ 	$\frac{h_w}{t_w} \le 55\sqrt{k}$ $\frac{b_f}{t_f} \le 16{,}5\sqrt{k}$ $b_f t_f \ge \frac{h_w t_w}{6}$ 

2 General requirements

2.1 General

2.1.1 The requirements in [2.2] are to be applied to ordinary stiffeners in addition to the requirements from Articles [3] to [5].

2.2 Struts of open floors

2.2.1 The sectional area A_{ST}, in cm^2, and the moment of inertia I_{ST} about the main axes, in cm^4, of struts of open floors are to be not less than the values obtained from the following formulae:

$$A_{ST} = \frac{p_{ST} s \ell}{20}$$

$$I_{ST} = \frac{0{,}75 s \ell (p_{STB} + p_{STU}) A_{AST} \ell_{ST}^2}{47{,}2 A_{AST} - s \ell (p_{STB} + p_{STU})}$$

where:

p_{ST} : Pressure to be taken equal to the greater of the values obtained, in kN/m^2, from the following formulae:

$p_{ST} = 0{,}5\ (p_{STB} + p_{STU})$

$p_{ST} = p_{STD}$

p_{STB} : Sea pressure, in kN/m^2, acting on the bottom in way of the strut, equal to:

$p_{STB} = \gamma_{S2}\ p_S + \gamma_{W2}\ p_W$

p_{STU} : Pressure, in kN/m^2, acting on the inner bottom in way of the strut due to the load in the tank or hold above, equal to:

$p_{STU} = \gamma_{S2}\ p_S + \gamma_{W2}\ p_W$

p_{STD} : Pressure, in kN/m^2, in double bottom at mid-span of the strut, equal to:

$p_{STD} = \gamma_{S2}\ p_S + \gamma_{W2}\ p_W$

ℓ : Span, in m, of the transverse ordinary stiffeners constituting the open floor (see Ch 4, Sec 3, [3.2.2])

ℓ_{ST} : Length, in m, of the strut

A_{AST} : Actual net sectional area, in cm^2, of the strut.

3 Yielding check

3.1 General

3.1.1 The requirements of this Article apply for the yielding check of ordinary stiffeners subjected to lateral pressure, wheeled loads or weapon firing dynamic loads and, for ordinary stiffeners contributing to the hull girder longitudinal strength, to hull girder normal stresses.

3.1.2 The yielding check is also to be carried out for ordinary stiffeners subjected to specific loads, such as concentrated loads.

3.2 Structural model

3.2.1 Boundary conditions

The requirements in [3.4], [3.7.3], [3.7.4], [3.8] and [3.9] apply to stiffeners considered either:

- clamped at both ends, whose end connections comply with the requirements in [3.2.2].
- clamped at one end and simply supported at the other end with the clamped end connection complying with the requirements in [3.2.2]
- simply supported at both ends

The requirements in [3.5] and [3.7.5] and [3.7.6] apply to stiffeners considered as simply supported at both ends. Other boundary conditions may be considered by the Society on a case-by-case basis, depending on the distribution of wheeled loads or weapon firing loads, as the case may be.

For other boundary conditions, the yielding check is to be considered on a case-by-case basis.

3.2.2 Bracket arrangement

The requirements of this Article apply to ordinary stiffeners without end brackets, with a bracket at one end or with two equal end brackets, where the bracket length is not greater than 0,2 ℓ.

In the case of ordinary stiffeners with two different end brackets of length not greater than 0,2 ℓ, the determination of normal and shear stresses due to design loads and the required section modulus and shear sectional area are considered by the Society on a case-by-case basis. In general, an acceptable solution consists in applying the criteria for equal brackets, considering both brackets as having the length of the smaller one.

In the case of ordinary stiffeners with end brackets of length greater than 0,2 ℓ, the determination of normal and shear stresses due to design loads and the required section modulus and shear sectional area are considered by the Society on a case-by-case basis.

3.3 Load model

3.3.1 General

The still water and wave lateral loads induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the ordinary stiffener under consideration and the type of compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

Ordinary stiffeners located on platings below the deepest equilibrium waterline (excluding those on side shell platings) which constitute boundaries intended to stop vertical and horizontal flooding are to be subjected to lateral pressure in flooding conditions.

The wave lateral loads and hull girder loads are to be calculated in the mutually exclusive load cases “a”, “b”, “c” and “d” in Ch 5, Sec 4.

3.3.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure p_S includes:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave pressure p_W includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case “a”, “b”, “c” and “d”
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case “a”, “b”, “c” and “d”
- the dynamic pressures, according to the criteria in Ch 5, Sec 6, [2].

3.3.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and wave pressure p_{WF} defined in Ch 5, Sec 6, [7].

3.3.4 Lateral pressure in testing conditions

The lateral pressure p_T in testing conditions is taken equal to:

- $p_{ST} - p_S$ for bottom shell plating and side shell plating
- p_{ST} otherwise

where:

p_{ST} : Still water pressure defined in Ch 5, Sec 6, Tab 10

p_S : Still water sea pressure defined in Ch 5, Sec 5, [1.1.1] for the draught T_1 at which the testing is carried out.

If the draught T_1 is not defined by the Designer, it may be taken equal to the light ballast draught T_B defined in Ch 5, Sec 1, [2.4.3].

3.3.5 Wheeled forces

The wheeled force applied by one wheel is constituted by still water force and inertial force:

- still water force is the vertical force F_S defined in Ch 5, Sec 6, [4.1]
- inertial force is the vertical force $F_{W,Z}$ defined in Ch 5, Sec 6, [4.1], for load case "b".

3.3.6 Weapons firing dynamic loads

- missile blast dynamic pressure
- accidental missile ignition dynamic pressure
- gun blast dynamic pressure.

3.3.7 Hull girder normal stresses

The hull girder normal stresses to be considered for the yielding check of ordinary stiffeners are obtained, in N/mm^2, from the following formulae:

- for longitudinal stiffeners contributing to the hull girder longitudinal strength and subjected to lateral pressure:
  $\sigma_{X1} = \gamma_{S1}\,\sigma_{S1} + \gamma_{W1}\,(C_{FV}\,\sigma_{WV1} + C_{FH}\,\sigma_{WH1} + C_{F\Omega}\,\sigma_{\Omega})$
- for longitudinal stiffeners contributing to the hull girder longitudinal strength and subjected to wheeled loads:
  $\sigma_{X1,Wh} = \text{Max}\,(\sigma_{X1H}\,;\,\sigma_{X1S})$
- for longitudinal stiffeners not contributing to the hull girder longitudinal strength:
  $\sigma_{X1} = 0$
- for transverse stiffeners:
  $\sigma_{X1} = 0$

where:

σ_Ω : Absolute value of the warping stress, in N/mm^2, induced by the torque 0,625 M_{WT} and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6]

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm^2, defined in Tab 3

σ_{X1H}, σ_{X1S} : Hull girder normal stresses, in N/mm^2, respectively in hogging and in sagging, defined in Tab 5

C_{FV}, C_{FH}, $C_{F\Omega}$: Combination factors defined in Tab 4.

Table 3 : Hull girder normal stresses - Ordinary stiffeners subjected to lateral pressure

Condition	σ_{S1}, in N/mm^2 **(1)**	σ_{WV1}, in N/mm^2	σ_{WH1}, in N/mm^2
Lateral pressure applied on the side opposite to the ordinary stiffener, with respect to the plating:			$\left\lvert\frac{0,625 M_{WH}}{I_Z} y\right\rvert 10^{-3}$
• $z \geq N$ in general • $z < N$ for stiffeners simply supported at both ends	$\left\lvert\frac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625 F_D M_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	
• $z < N$ in general • $z \geq N$ for stiffeners simply supported at both ends	$\left\lvert\frac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625 M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	
Lateral pressure applied on the same side as the ordinary stiffener:			
• $z \geq N$ in general • $z < N$ for stiffeners simply supported at both ends	$\left\lvert\frac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625 M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	
• $z < N$ in general • $z \geq N$ for stiffeners simply supported at both ends	$\left\lvert\frac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625 F_D M_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4.2].

Table 4 : Combination factors C_{FV}, C_{FH} and $C_{F\Omega}$

Load case	C_{FV}	C_{FH}	$C_{F\Omega}$
"a"	1,0	0	0
"b"	1,0	0	0
"c"	0,4	1,0	1,0
"d"	0,4	1,0	0
Flooding	0,6	0	0

Table 5 : Hull girder normal stresses - Ordinary stiffeners subjected to wheeled loads

Condition	Hull girder normal stresses, in N/mm²
• Hogging	$\sigma_{X1H} = \left\lvert \gamma_{S1}\frac{M_{SW,H}}{I_Y}(z-N)10^{-3} + \gamma_{W1}\left(C_{FV}\frac{0{,}625M_{WV,H}}{I_Y}(z-N)10^{-3} + C_{FH}\frac{0{,}625M_{WH}}{I_Z}y10^{-3} + C_{F\Omega}\sigma_\Omega\right)\right\rvert$
• Sagging**(1)**	$\sigma_{X1S} = \left\lvert \gamma_{S1}\frac{M_{SW,S}}{I_Y}(z-N)10^{-3} + \gamma_{W1}\left(C_{FV}\frac{0{,}625F_DM_{WV,S}}{I_Y}(z-N)10^{-3} + C_{FH}\frac{0{,}625M_{WH}}{I_Z}y10^{-3} + C_{F\Omega}\sigma_\Omega\right)\right\rvert$

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4.2].

3.4 Normal and shear stresses due to lateral pressure in intact conditions

3.4.1 General

Normal and shear stresses, induced by lateral pressures, in ordinary stiffeners are to be obtained from the formulae in:

- [3.4.2] in the case of single span longitudinal and transverse stiffeners
- [3.4.3] in the case of single span vertical stiffeners
- [3.4.4] in the case of multispan vertical stiffeners.

3.4.2 Single span longitudinal and transverse ordinary stiffeners

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_b\frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{mw}\left(1-\frac{s}{2\ell}\right)s\ell^2 10^3 + \sigma_{X1}$$

$$\tau = 5\beta_s\frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{A_{Sh}}\left(1-\frac{s}{2\ell}\right)s\ell$$

where:

β_b, β_s : Coefficients defined in Tab 6.

Table 6 : Coefficients β_b and β_s

Brackets at ends	Bracket lengths	β_b	β_s
0	–	1	1
1	ℓ_b	$\left(1-\frac{\ell_b}{2\ell}\right)^2$	$1-\frac{\ell_b}{2\ell}$
2	ℓ_{b1} ; ℓ_{b2}	$\left(1-\frac{\ell_{b1}}{2\ell}-\frac{\ell_{b2}}{2\ell}\right)^2$	$1-\frac{\ell_{b1}}{2\ell}-\frac{\ell_{b2}}{2\ell}$

3.4.3 Single span vertical ordinary stiffeners

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \lambda_b\beta_b\frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{mw}\left(1-\frac{s}{2\ell}\right)s\ell^2 10^3$$

$$\tau = 5\lambda_s\beta_s\frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{A_{Sh}}\left(1-\frac{s}{2\ell}\right)s\ell$$

where:

β_b , β_s : Coefficients defined in Tab 6

λ_b : Coefficient taken equal to the greater of the following values:

$$\lambda_b = 1 + 0{,}2\frac{\gamma_{S2}(p_{Sd} - p_{Su}) + \gamma_{W2}(p_{Wd} - p_{Wu})}{\gamma_{S2}(p_{Sd} + p_{Su}) + \gamma_{W2}(p_{Wd} + p_{Wu})}$$

$$\lambda_b = 1 - 0{,}2\frac{\gamma_{S2}(p_{Sd} - p_{Su}) + \gamma_{W2}(p_{Wd} - p_{Wu})}{\gamma_{S2}(p_{Sd} + p_{Su}) + \gamma_{W2}(p_{Wd} + p_{Wu})}$$

λ_s : Coefficient taken equal to the greater of the following values:

$$\lambda_s = 1 + 0{,}4\frac{\gamma_{S2}(p_{Sd} - p_{Su}) + \gamma_{W2}(p_{Wd} - p_{Wu})}{\gamma_{S2}(p_{Sd} + p_{Su}) + \gamma_{W2}(p_{Wd} + p_{Wu})}$$

$$\lambda_s = 1 - 0{,}4\frac{\gamma_{S2}(p_{Sd} - p_{Su}) + \gamma_{W2}(p_{Wd} - p_{Wu})}{\gamma_{S2}(p_{Sd} + p_{Su}) + \gamma_{W2}(p_{Wd} + p_{Wu})}$$

p_{Sd} : Still water pressure, in kN/m^2, at the lower end of the ordinary stiffener considered

p_{Su} : Still water pressure, in kN/m^2, at the upper end of the ordinary stiffener considered

p_{Wd} : Wave pressure, in kN/m^2, at the lower end of the ordinary stiffener considered

p_{Wu} : Wave pressure, in kN/m^2, at the upper end of the ordinary stiffener considered.

3.4.4 Multispan ordinary stiffeners

The maximum normal stress σ and shear stress τ in a multispan ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water and wave pressure and forces, to be determined on the basis of the criteria specified in Ch 5, Sec 5 and Ch 5, Sec 6
- the number and position of intermediate supports (decks, girders, etc.)
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

3.5 Normal and shear stresses due to wheeled loads

3.5.1 General

Normal and shear stresses, induced by the wheeled loads, in ordinary stiffeners are to be obtained from the formulae in:

- [3.5.2] in the case of single span longitudinal and transverse stiffeners
- [3.5.3] in the case of multispan stiffeners.

3.5.2 Single span longitudinal and transverse ordinary stiffeners subjected to wheeled loads

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm^2, from the following formulae:

$$\sigma = \alpha_W K_S \frac{P_0 \ell}{6w} 10^3 + \sigma_{X1,Wh}$$

$$\tau = \alpha_W K_T \frac{10 P_0}{A_{Sh}}$$

where:

P_0 : Wheeled force, in kN, taken equal to: $P_0 = \gamma_{S2} F_S + \gamma_{W2} F_{W,Z}$

α_W : Coefficient taking account of the number of wheels per axle considered as acting on the stiffener, defined in Tab 7

K_S , K_T : Coefficients taking account of the number of axles considered as acting on the stiffener, defined in Tab 8.

Table 7 : Wheeled loads - Coefficients α_W

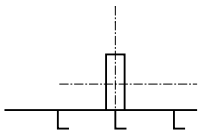
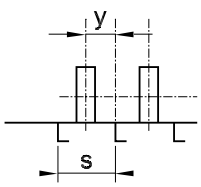
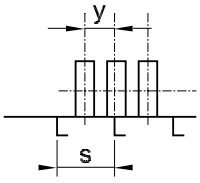
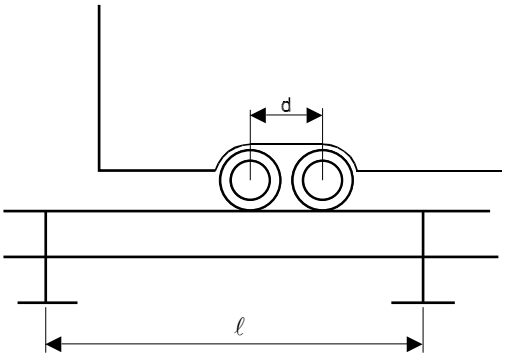
Single wheel	Double wheels	Triple wheels
$\alpha_W = 1$	$\alpha_W = 2\left(1 - \frac{y}{s}\right)$	$\alpha_W = 3 - 2\frac{y}{s}$
		
Note 1: y: Distance, in m, from the external wheel of a group of wheels to the stiffener under consideration, to be taken equal to the distance from the external wheel to the centre of the group of wheels.		

Table 8 : Wheeled loads - Coefficients K_S and K_T

		K_S	K_T
Single axle		$K_S = 1$	$K_T = 1$
Double axles	if $d \le \ell/\sqrt{3}$:	$K_S = \frac{172}{81} - \frac{4d}{3\ell} - \frac{d^2}{\ell^2} + \frac{d^4}{\ell^4}$	$K_T = 2 - \frac{d}{2\ell} - \frac{3d^2}{2\ell^2} + \frac{d^3}{\ell^3}$
	if $d > \ell/\sqrt{3}$:	$K_S = \frac{4}{3} - \frac{4d}{3\ell} + \frac{3d^2}{\ell^2} - \frac{8d^3}{3\ell^3}$	
Note 1: d : Distance, in m, between two axles (see Fig 1).			

Figure 1 : Wheeled load on stiffeners - Double axles



3.5.3 Multispan ordinary stiffeners subjected to wheeled loads

The maximum normal stress σ and shear stress τ in a multispan ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water forces and inertial forces applying on the stiffener, to be determined according to [3.3.5]
- the number and position of intermediate supports (girders, bulkheads, etc.)
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

3.6 Checking criteria

3.6.1 General

It is to be checked that the normal stress σ and the shear stress τ, calculated according to [3.4] and [3.5], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \ge \sigma$$

$$0{,}5\frac{R_y}{\gamma_R \gamma_m} \ge \tau$$

3.7 Net section modulus and net shear sectional area of ordinary stiffeners, complying with the checking criteria

3.7.1 General

The requirements in [3.7.3] and [3.7.4] provide the minimum net section modulus and net shear sectional area of single span ordinary stiffeners subjected to lateral pressure in intact conditions, complying with the checking criteria indicated in [3.6].

The requirements in [3.7.5] provide the minimum net section modulus and net shear sectional area of single span ordinary stiffeners subjected to wheeled loads, complying with the checking criteria indicated in [3.6].

The requirements in [3.7.6] provide the minimum net section modulus and net shear sectional area of single span ordinary stiffeners subjected to weapon firing dynamic loads.

3.7.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.7.1] is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90% of the maximum required value.

The same applies for the minimum net shear sectional area.

3.7.3 Single span longitudinal and transverse ordinary stiffeners subjected to lateral pressure

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of longitudinal or transverse ordinary stiffeners subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 6.

3.7.4 Single span vertical ordinary stiffeners subjected to lateral pressure

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of vertical ordinary stiffeners subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m R_y} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 6

λ_b, λ_s : Coefficients defined in [3.4.3].

3.7.5 Single span ordinary stiffeners subjected to wheeled loads

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of ordinary stiffeners subjected to wheeled loads are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \frac{\alpha_W K_S P_0 \ell}{6(R_y - \gamma_R \gamma_m \sigma_{X1,Wh})} 10^3$$

$$A_{Sh} = 20 \gamma_R \gamma_m \frac{\alpha_W K_T P_0}{R_y}$$

where:

P_0 : Wheeled force, in kN, defined in [3.5.2]

α_W, K_S, K_T :Coefficients defined in [3.5.2].

3.7.6 Single span ordinary stiffeners subjected to weapon firing dynamic loads

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of ordinary stiffeners subjected to weapon firing dynamic loads are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{W2} p_W}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 6

p_w : Weapon firing dynamic pressure defined in Ch 5, Sec 6, [9].

3.7.7 Multispan ordinary stiffeners

The minimum net section modulus and the net shear sectional area of multispan ordinary stiffeners are to be obtained from [3.4.4] or [3.5.3], as applicable, taking account of the checking criteria indicated in [3.6].

3.8 Net section modulus and net shear sectional area of ordinary stiffeners subjected to lateral pressure in flooding conditions

3.8.1 General

The requirements in [3.8.1] to [3.8.5] provide the minimum net section modulus and net shear sectional area of ordinary stiffeners located on structural watertight elements which constitute boundaries intended to stop vertical and horizontal flooding.

These ordinary stiffeners are to be checked in flooding conditions as specified in [3.8.3] to [3.8.5], depending on the type of stiffener.

3.8.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.8.1] is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90% of the maximum required value.

The same applies for the minimum net shear sectional area.

3.8.3 Single span longitudinal and transverse ordinary stiffeners

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of longitudinal or transverse ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 6.

3.8.4 Single span vertical ordinary stiffeners

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of vertical ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{m R_y} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 6

λ_b : Coefficient taken equal to the greater of the following values:

$$\lambda_b = 1 + 0{,}2 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

$$\lambda_b = 1 - 0{,}2 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

λ_s : Coefficient taken equal to the greater of the following values:

$$\lambda_s = 1 + 0{,}4 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

$$\lambda_s = 1 - 0{,}4 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

p_{SFd} : Still water pressure, in kN/m^2, in flooding conditions, at the lower end of the ordinary stiffener considered

p_{SFu} : Still water pressure, in kN/m^2, in flooding conditions, at the upper end of the ordinary stiffener considered

p_{WFd} : Wave pressure, in kN/m^2, in flooding conditions, at the lower end of the ordinary stiffener considered

p_{WFu} : Wave pressure, in kN/m^2, in flooding conditions, at the upper end of the ordinary stiffener considered.

3.8.5 Multispan ordinary stiffeners

The minimum net section modulus and the net shear sectional area of multispan ordinary stiffeners are to be obtained from [3.4.4], considering the still water pressure p_{SF} and wave pressure p_{WF} in flooding conditions, and taking account of the checking criteria indicated in [3.6].

3.9 Net section modulus and net shear sectional area of ordinary stiffeners subjected to lateral pressure in testing conditions

3.9.1 General

The requirements in [3.9.3] to [3.9.5] provide the minimum net section modulus and net shear sectional area of ordinary stiffeners of compartments subject to testing conditions.

3.9.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.9.1] is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90% of the maximum required value.

The same applies for the minimum net shear sectional area.

3.9.3 Single span longitudinal and transverse ordinary stiffeners

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of longitudinal or transverse ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_T}{m R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_T}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 6.

3.9.4 Single span vertical ordinary stiffeners

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of vertical ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_T}{m R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_T}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 6

λ_b : Coefficient taken equal to the greater of the following values:

$$\lambda_b = 1 + 0{,}2 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

$$\lambda_b = 1 - 0{,}2 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

λ_s : Coefficient taken equal to the greater of the following values:

$$\lambda_s = 1 + 0{,}4 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

$$\lambda_s = 1 - 0{,}4 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

p_{Td} : Still water pressure, in kN/m², in testing conditions, at the lower end of the ordinary stiffener considered

p_{Tu} : Still water pressure, in kN/m², in testing conditions, at the upper end of the ordinary stiffener considered.

3.9.5 Multispan ordinary stiffeners

The minimum net section modulus and the net shear sectional area of multispan ordinary stiffeners are to be obtained from [3.4.4], considering the pressure in testing conditions and taking account of the checking criteria indicated in [3.6].

4 Buckling check

4.1 Width of attached plating

4.1.1 The width of the attached plating to be considered for the buckling check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where no local buckling occurs on the attached plating (see Ch 7, Sec 1, [5.4.1]):

  $b_e = s$

- where local buckling occurs on the attached plating (see Ch 7, Sec 1, [5.4.1]):

  $$b_e = \left(\frac{2{,}25}{\beta_e} - \frac{1{,}25}{\beta_e^2}\right) s$$

  to be taken not greater than s

where:

$$\beta_e = \frac{s}{t_p}\sqrt{\frac{\sigma_b}{E}} 10^3$$

σ_b : Compression stress σ_X or σ_Y, in N/mm², acting on the plate panel, defined in Ch 7, Sec 1, [5.2.4], according to the direction x or y considered.

4.2 Load model

4.2.1 Sign convention for normal stresses

The sign convention for normal stresses is as follows:

- tension: positive
- compression: negative.

4.2.2 Hull girder compression normal stresses

The hull girder compression normal stresses to be considered for the buckling check of ordinary stiffeners contributing to the hull girder longitudinal strength are obtained, in N/mm^2, from the following formula:

$$\sigma_{X1} = \gamma_{S1}\,\sigma_{S1} + \gamma_{W1}\,(C_{FV}\,\sigma_{WV1} + C_{FH}\,\sigma_{WH1} + C_{F\Omega}\,\sigma_{\Omega})$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1}: Hull girder normal stresses, in N/mm^2, defined in Tab 9.

σ_{Ω} : Compression warping stress, in N/mm^2, induced by the torque 0,625 M_{WT} and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6]

C_{FV}, C_{FH}, $C_{F\Omega}$: Combination factors defined in Tab 4.

For longitudinal stiffeners, σ_{X1} is to be taken as the maximum compression stress on the stiffener considered.

When the ship in still water is always in hogging condition, σ_{X1} may be evaluated by means of direct calculations when justified on the basis of the ship characteristics and intended service. The calculations are to be submitted to the Society for approval.

Table 9 : Hull girder normal compression stresses

Condition	σ_{S1} in N/mm^2 **(1)**	σ_{WV1} in N/mm^2	σ_{WH1} in N/mm^2
• $z \geq N$	$\frac{M_{SW,S}}{I_Y}(z-N)10^{-3}$	$\frac{0,625F_D M_{WV,S}}{I_Y}(z-N)10^{-3}$	$-\left\lvert\frac{0,625M_{WH}}{I_Z}y\right\rvert 10^{-3}$
• $z < N$	$\frac{M_{SW,H}}{I_Y}(z-N)10^{-3}$	$\frac{0,625M_{WV,H}}{I_Y}(z-N)10^{-3}$	

(1) When the ship in still water is always in hogging condition, σ_{S1} for $z \geq N$ is to be obtained, in N/mm^2, from the following formula, unless σ_{X1} is evaluated by means of direct calculations (see [4.2.2]):

$$\sigma_{S1} = \frac{M_{SW,Hmin}}{I_Y}(z-N)10^{-3}$$

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

4.2.3 Combined hull girder and local compression normal stresses

The combined compression normal stresses to be considered for the buckling check of ordinary stiffeners are to take into account the hull girder stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis using the design loads as given in Part B, Chapter 5.

With respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10.1], the combined stresses in x and y direction are obtained, in N/mm^2, from the following formulae:

$$\sigma_X = \sigma_{X1} + \gamma_{S2}\sigma_{X2,S} + \gamma_{W2}\sigma_{X2,W}$$

$$\sigma_Y = \gamma_{S2}\sigma_{Y2,S} + \gamma_{W2}\sigma_{Y2,W}$$

where:

σ_{X1} : Compression normal stress, in N/mm^2, induced by the hull girder still water and wave loads, defined in [4.2.2]

$\sigma_{X2,S}$, $\sigma_{Y2,S}$: Compression normal stress in x and y direction, respectively, in N/mm^2, induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the still water design loads as given in Part B, Chapter 5

$\sigma_{X2,W}$, $\sigma_{Y2,W}$: Compression normal stress in x and y direction, respectively, in N/mm^2, induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the wave design loads as given in Part B, Chapter 5.

4.3 Critical stress

4.3.1 General

The critical buckling stress is to be obtained, in N/mm^2, from the following formulae:

$$\sigma_c = \sigma_E \qquad \text{for } \sigma_E \leq \frac{R_{eH,S}}{2}$$

$$\sigma_c = R_{eH,S}\left(1 - \frac{R_{eH,S}}{4\sigma_E}\right) \qquad \text{for } \sigma_E > \frac{R_{eH,S}}{2}$$

where:

σ_E = Min (σ_{E1} ; σ_{E2} ; σ_{E3})

σ_{E1} : Euler column buckling stress, in N/mm^2, given in [4.3.2]

σ_{E2} : Euler torsional buckling stress, in N/mm^2, given in [4.3.3]

σ_{E3} : Euler web buckling stress, in N/mm^2, given in [4.3.4].

4.3.2 Column buckling of axially loaded stiffeners

The Euler column buckling stress is obtained, in N/mm^2, from the following formula:

$$\sigma_E = \pi^2 E \frac{I_e}{A_e \ell^2} 10^{-4}$$

4.3.3 Torsional buckling of axially loaded stiffeners

The Euler torsional buckling stresses is obtained, in N/mm^2, from the following formula:

$$\sigma_E = \frac{\pi^2 E I_w}{10^4 I_p \ell^2}\left(\frac{K_C}{m^2} + m^2\right) + 0{,}385 E \frac{I_t}{I_p}$$

where:

I_w : Net sectorial moment of inertia, in cm^6, of the stiffener about its connection to the attached plating:

- for flat bars:

$$I_w = \frac{h_w^3 t_w^3}{36} 10^{-6}$$

- for T-sections:

$$I_w = \frac{t_f b_f^3 h_w^2}{12} 10^{-6}$$

- for angles and bulb sections:

$$I_w = \frac{b_f^3 h_w^2}{12(b_f + h_w)^2}[t_f(b_f^2 + 2b_f h_w + 4h_w^2) + 3t_w b_f h_w]\, 10^{-6}$$

I_p : Net polar moment of inertia, in cm^4, of the stiffener about its connection to the attached plating:

- for flat bars:

$$I_p = \frac{h_w^3 t_w}{3} 10^{-4}$$

- for stiffeners with face plate:

$$I_p = \left(\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f\right) 10^{-4}$$

I_t : St. Venant's net moment of inertia, in cm^4, of the stiffener without attached plating:

- for flat bars:

$$I_t = \frac{h_w t_w^3}{3} 10^{-4}$$

- for stiffeners with face plate:

$$I_t = \frac{1}{3}\left[h_w t_w^3 + b_f t_f^3\left(1 - 0{,}63\frac{t_f}{b_f}\right)\right] 10^{-4}$$

m : Number of half waves, to be taken equal to the integer number such that (see also Tab 10):

$$m^2(m-1)^2 \leq K_C < m^2(m+1)^2$$

$$K_C = \frac{C_0 \ell^4}{\pi^4 E I_w} 10^6$$

C_0 : Spring stiffness of the attached plating:

$$C_0 = \frac{E t_p^3}{2{,}73 s} 10^{-3}$$

Table 10 : Torsional buckling of axially loaded stiffeners Number m of half waves

K_C	$0 \le K_C < 4$	$4 \le K_C < 36$	$36 \le K_C < 144$
m	1	2	3

4.3.4 Web buckling of axially loaded stiffeners

The Euler buckling stress of the stiffener web is obtained, in N/mm², from the following formulae:

- for flat bars:

$$\sigma_E = 16\left(\frac{t_W}{h_W}\right)^2 10^4$$

- for stiffeners with face plate:

$$\sigma_E = 78\left(\frac{t_W}{h_W}\right)^2 10^4$$

4.4 Checking criteria

4.4.1 Stiffeners parallel to the direction of compression

The critical buckling stress of the ordinary stiffener is to comply with the following formula:

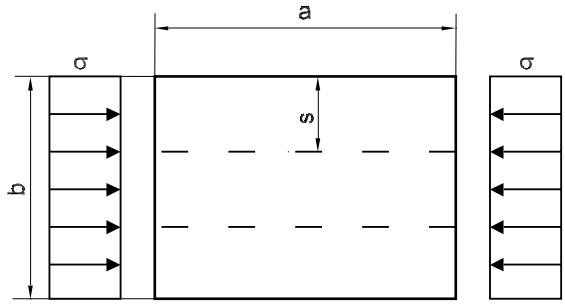
$$\frac{\sigma_c}{\gamma_R \gamma_m} \ge |\sigma_b|$$

where:

σ_c : Critical buckling stress, in N/mm², as calculated in [4.3.1]

σ_b : Compression stress σ_{xb} or σ_{yb}, in N/mm², in the stiffener, as calculated in [4.2.2] or [4.2.3].

Figure 2 : Buckling of stiffeners parallel to the direction of compression



4.4.2 Stiffeners perpendicular to the direction of compression

The net moment of inertia of stiffeners, in cm⁴, is to be not less than the greatest value obtained from the following formulae:

- $I = 360\ \ell^2$
- for $\sigma \le R_{eH,P} / 2$:

$$I = \frac{st_p^3}{485}\left[\frac{\left(\frac{\ell}{s}\right)^4 - 4}{\sigma_{E,1} - \sigma_{E,0}}\right](\sigma - \sigma_{E,0})$$

- for $\sigma > R_{eH,P} / 2$:

$$I = \frac{st_p^3}{485}\left[\frac{\left(\frac{\ell}{s}\right)^4 - 4}{\sigma_{E,1} - \sigma_{E,0}}\right]\left[\frac{R_{eH,P}}{4\left(1 - \frac{\sigma}{R_{eH,P}}\right)} - \sigma_{E,0}\right]$$

where:

ℓ/s : Ratio to be taken not less than 1,41

$\sigma_{E,0}$: Euler buckling stress, in N/mm², of the unstiffened plate taken equal to:

$$\sigma_{E,0} = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{\ell}\right)^2 \varepsilon K_{1,0} 10^{-6}$$

$K_{1,0}$: Coefficient defined in Ch 7, Sec 1, Tab 8 for:
$0 \le \Psi \le 1$ and $\alpha = a / \ell$

ε : Coefficient defined in Ch 7, Sec 1, [5.3.1]

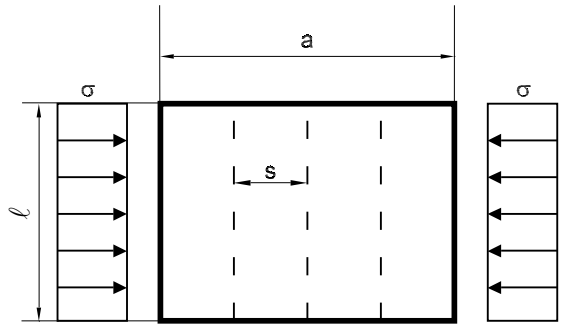
$\sigma_{E,1}$: Euler buckling stress, in N/mm^2, of the plate panel taken equal to:

$$\sigma_{E,1} = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{\ell}\right)^2 \varepsilon K_{1,1} 10^{-6}$$

$K_{1,1}$: Coefficient defined in Ch 7, Sec 1, Tab 8 for:

$0 \leq \Psi \leq 1$ and $\alpha = s/\ell$

Figure 3 : Buckling of stiffeners perpendicular to the direction of compression

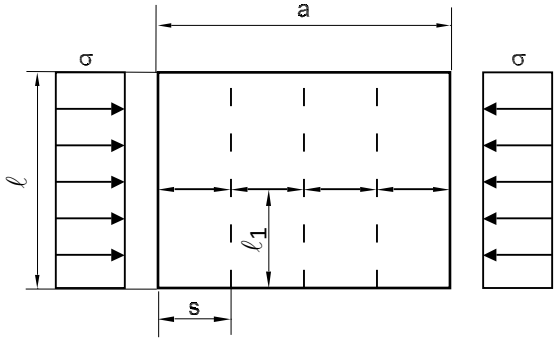


Where intercostal stiffeners are fitted, as shown in Fig 4, the check of the moment of inertia of stiffeners perpendicular to the direction of compression is to be carried out with the equivalent net thickness $t_{eq,net}$, in mm, obtained from the following formula:

$$t_{eq,net} = \frac{1+\left(\frac{s}{\ell_1}\right)^2}{1+\left(\frac{s}{\ell}\right)^2} t_{net}$$

where ℓ_1 is to be taken not less than s.

Figure 4 : Buckling of stiffeners perpendicular to the direction of compression (intercostal stiffeners)



5 Ultimate strength check of ordinary stiffeners contributing to the hull girder longitudinal strength

5.1 Application

5.1.1 The requirements of this Article apply to ships equal to or greater than 90 m in length. For such ships, the ultimate strength of stiffeners subjected to lateral pressure and to hull girder normal stresses is to be checked.

5.2 Width of attached plating

5.2.1 The width of the attached plating to be considered for the ultimate strength check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- if $\beta_U \leq 1,25$:

  $b_U = s$

- if $\beta_U > 1,25$:

$$b_U = \left(\frac{2,25}{\beta_U} - \frac{1,25}{\beta_U^2}\right) s$$

where:

$$\beta_U = \frac{s}{t_p}\sqrt{\frac{\sigma_{X1E}}{E}}10^3$$

σ_{X1E} : Stress defined in Tab 11.

Table 11 : Ultimate strength stress

Symbol	Resultant load pressure acting on the side opposite to the ordinary stiffener, with respect to the plating, in N/mm²	Resultant load pressure acting on the same side as the ordinary stiffener, in N/mm²
σ_U	$f\frac{A_U}{A_S}\left(1-\frac{s}{10b_U}\right)R_{eH,P}$	$R_{eH,S}\,f$
f	$\frac{\zeta}{2}-\sqrt{\frac{\zeta^2}{4}-\frac{1-\mu}{(1+\eta_P)\lambda_U^2}}$	
ζ	$\frac{1-\mu}{1+\eta_P}+\frac{1+\eta_P+\eta}{(1+\eta_P)\lambda_U^2}$	
μ	$\frac{125ps\ell^2 d_{P,U}}{R_{eH,P}I_U\left(1-\frac{s}{10b_U}\right)}$	$\frac{41,7ps\ell^2 d_{F,S}}{R_{eH,S}I_S}$
η	$\left(\delta_0+\frac{13ps\ell^4}{E_T I_S}10^4\right)\frac{d_{P,U}}{\rho_U^2}$	$\left(0,577\delta_0+\frac{1,5ps\ell^4}{E_T I_S}10^4\right)\frac{d_{F,S}}{\rho_S^2}$
η_P	$d_P A\left(\frac{1}{A_U}-\frac{1}{A_S}\right)\frac{d_{P,U}}{\rho_U^2}$	0
λ_U	$\frac{31,8\ell}{\rho_U}\sqrt{\frac{R_{eH,P}}{E_T}\left(1-\frac{s}{10b_U}\right)}$	$\frac{18,4\ell}{\rho_S}\sqrt{\frac{R_{eH,S}}{E_T}}$

Note 1:

$d_{P,U}$: Distance, in cm, between the neutral axis of the cross-section of the stiffener with attached plating of width b_U and the fibre at half-thickness of the plating

$d_{F,S}$: Distance, in cm, between the neutral axis of the cross-section of the stiffener with attached plating of width s and the fibre at half-thickness of the face plate of the stiffener

d_P : Distance, in cm, between the neutral axis of the ordinary stiffener without attached plating and the fibre at half-thickness of the attached plating

A : Net sectional area, in cm², of the stiffener without attached plating

p : Lateral pressure acting on the stiffener, equal to: $p = \gamma_{S2}\,p_S + \gamma_{W2U}\,p_W$

δ_0 : Pre-deformation, in cm, of the ordinary stiffener, to be assumed, in the absence of more accurate evaluation: $\delta_0 = 0,2\,\ell$

E_T : Structural tangent modulus, equal to:

$$E_T = 4E\frac{\sigma_{X1E}}{R_{eH,P}}\left(1-\frac{\sigma_{X1E}}{R_{eH,P}}\right) \quad \text{for } \sigma_{X1E} > 0,5R_{eH,P}$$

$$E_T = E \quad \text{for } \sigma_{X1E} \le 0,5R_{eH,P}$$

σ_{X1E} : Stress to be obtained, in N/mm², from the following formulae:

$$\text{if } \alpha > \frac{1,25}{\sqrt{|\sigma_{X1}|}}: \quad \sigma_{X1E} = \left\{\frac{-\frac{22,5st_P}{\alpha}+\sqrt{\left(\frac{22,5st_P}{\alpha}\right)^2+4A\left[(A_S+10st_P)\sigma_{X1}+\frac{12,5st_P}{\alpha^2}\right]}}{2A}\right\}^2$$

$$\text{if } \alpha \le \frac{1,25}{\sqrt{|\sigma_{X1}|}}: \quad \sigma_{X1E} = \sigma_{X1}$$

$$\alpha = 1000\frac{s}{t_p\sqrt{E}}$$

σ_{X1} : Compression stress, in N/mm², acting on the stiffener, as defined in [5.3.3].

5.3 Load model

5.3.1 General

The still water and wave lateral pressures induced by the sea and the various types of weights and ballast in intact conditions are to be considered, depending on the location of the ordinary stiffener under consideration and the type of compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

The wave lateral pressures and hull girder loads are to be calculated in the mutually exclusive load cases “a”, “b”, “c” and “d” in Ch 5, Sec 4.

5.3.2 Lateral pressure

Lateral pressure is constituted by still water pressure and wave pressure.

Still water pressure p_S includes:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for minimum operational condition.

Wave induced pressure p_W includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case “a”, “b”, “c” and “d”
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for minimum operational condition, and for each load case “a”, “b”, “c” and “d”.

5.3.3 Hull girder compression normal stresses

The hull girder compression normal stresses σ_{X1} to be considered for the ultimate strength check of stiffeners contributing to the longitudinal strength are those given in [4.2.2], where the partial safety factors are those specified in Tab 1 for the ultimate strength check.

5.4 Ultimate strength stress

5.4.1 The ultimate strength stress σ_U is to be obtained, in N/mm^2, from the formulae in Tab 11, for resultant lateral pressure acting either on the side opposite to the ordinary stiffener, with respect to the plating, or on the same side as the ordinary stiffener.

5.5 Checking criteria

5.5.1 The ultimate strength stress of the ordinary stiffener is to comply with the following formula:

$$\frac{\sigma_U}{\gamma_R \gamma_m} \geq |\sigma_{X1}|$$

where:

σ_U : Ultimate strength stress, in N/mm^2, as calculated in [5.4.1]

σ_{X1} : Compression stress, in N/mm^2, as calculated in [5.3.3].

Section 3 Primary Supporting Members

Symbols

For the symbols not defined in this Section, refer to Ch 1, Sec 2, [2.1.1].

σ_N : Normal stress, in N/mm^2, defined in [2.4.6]

σ_{X1} : Hull girder normal stress, in N/mm^2, defined in [2.4.6]

A_{Sh} : Net shear sectional area, in cm^2, of the primary supporting member, to be calculated as specified in Ch 4, Sec 3, [4.3]

b_p : Width, in m, of the plating attached to the primary supporting member, for the yielding check, defined in Ch 4, Sec 3, [4.2]

E : Young's modulus, in N/mm^2, to be taken equal to:

- for steels in general:
  E = 2,06.10^5 N/mm^2
- for stainless steels:
  E = 1,95.10^5 N/mm^2
- for aluminium alloys:
  E = 7,0.10^4 N/mm^2

I_Y : Net moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings

I_Z : Net moment of inertia, in m^4, of the hull transverse section around its vertical neutral axis, to be calculated according to Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings

k : Material factor, defined in:

- Ch 4, Sec 1, [2.3], for steel
- Ch 4, Sec 1, [4.4], for aluminium alloys

ℓ : Span, in m, of primary supporting members, measured between the supporting elements, see Ch 4, Sec 3, [4.1]

ℓ_b : Length, in m, of one bracket, see [2.2] and Ch 4, Sec 3, [4.4]

m : Boundary coefficient, to be taken equal to:

- m = 10 in general
- m = 12 for bottom and side girders

$M_{SW,H}$: Design still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [2.2]

$M_{SW,S}$: Design still water bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [2.2]

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.2]

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1]

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1]

N : Z co-ordinate, in m, with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6], of the centre of gravity of the hull transverse section constituted by members contributing to the hull girder longitudinal strength considered as having their net scantlings (see Ch 6, Sec 1, [2])

p_S : Still water pressure, in kN/m^2, see [2.4.2] and [2.4.4]

p_{SF}, p_{WF} : Still water and wave pressures, in kN/m^2, in flooding conditions, defined in Ch 5, Sec 6, [7]

p_W : Wave pressure, in kN/m^2, see [2.4.2] and [2.4.4]

R_{eH} : Minimum guaranteed yield stress, in N/mm^2, of the primary supporting member material defined in Ch 4, Sec 1, [2]

R_y : Minimum yield stress, in N/mm^2, of the material to be taken equal to 235/k N/mm^2, unless otherwise specified

s : Spacing, in m, of primary supporting members

w : Net section modulus, in cm^3, of the primary supporting member, with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [4.3]

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6].

1 General

1.1 Application

1.1.1 Analysis criteria

The requirements of this Section apply for the yielding and buckling checks of primary supporting members.

Depending on their arrangement, primary supporting members are to be analysed through one of the following models:

- an isolated beam structural model
- a three-dimensional structural model
- a complete ship structural model.

1.1.2 Structural models

Depending on the length, primary structural models are to be adopted as specified in Tab 1.

Table 1 : Selection of structural models

Ship length, in m	Calculation model
L < 90	Isolated beam model, or three-dimensional beam model for grillage or complex arrangements
L ≥ 90	Three-dimensional beam model **(1)**
(1) A three-dimensional finite element model or a complete ship model may also be used.	

1.1.3 Yielding check

The yielding check is to be carried out according to:

- [2] for primary supporting members analysed through isolated beam models
- [3] for primary supporting members analysed through three-dimensional models
- [4] for primary supporting members analysed through complete ship models.

1.1.4 Buckling check

The buckling check is to be carried out according to [5], on the basis of the stresses in primary supporting members calculated according to Articles [2], [3] or [4], depending on the structural model adopted.

1.1.5 Normal mode analysis

A normal mode analysis of primary supporting members may be required by the Society to be carried out, when deemed necessary on the basis of the expected frequency of cyclic loads.

1.2 Net scantlings

1.2.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.3 Partial safety factors

1.3.1 The partial safety factors to be considered for checking primary supporting members are specified in:

- Tab 2 for analyses based on isolated beam models
- Tab 3 for analyses based on three-dimensional models
- Tab 4 for analyses based on complete ship models.

Table 2 : Primary supporting members analysed through isolated beam models - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check		Buckling check	
		General (see [2.4] to [2.7])	Flooding **(1)** (see [2.8])	Plate panels (see [5.1])	Pillars (see [5.2] and [5.3])
Still water hull girder loads	γ_{S1}	1,00	1,00	1,00	1,00
Wave hull girder loads	γ_{W1}	1,15	1,15	1,15	1,15
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,05	1,20	1,20
(1) Applies only to primary supporting members to be checked in flooding conditions. **(2)** For primary supporting members of the collision bulkhead, γ_R = 1,25. This requirement may be disregarded when damaged stability considers at least two adjacent compartments flooded.					

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check		Buckling check	
		General (see [2.4] to [2.7])	Flooding **(1)** (see [2.8])	Plate panels (see [5.1])	Pillars (see [5.2] and [5.3])
Material	γ_m	1,02	1,02	1,02	1,02
Resistance	γ_R	• 1,02 in general • 1,15 for bottom and side girders	1,02 **(2)**	1,10	for [5.2]: see Tab 12 for [5.3]: 1,15

(1) Applies only to primary supporting members to be checked in flooding conditions.

(2) For primary supporting members of the collision bulkhead, γ_R = 1,25. This requirement may be disregarded when damaged stability considers at least two adjacent compartments flooded.

Table 3 : Primary supporting members analysed through three-dimensional models - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check (see [3])		Buckling check	
		General	Flooding **(1)**	Plate panels (see [5.1])	Pillars (see [5.2] and [5.3])
Still water hull girder loads	γ_{S1}	1,00	1,00	1,00	1,00
Wave hull girder loads	γ_{W1}	1,05	1,05	1,05	1,05
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10	1,10	1,10
Material	γ_m	1,02	1,02	1,02	1,02
Resistance	γ_R	Defined in Tab 5 and Tab 6	Defined in Tab 5 and Tab 6 **(2)**	1,02	for [5.2]: see Tab 12 for [5.3]: 1,15

(1) Applies only to primary supporting members to be checked in flooding conditions.

(2) For primary supporting members of the collision bulkhead, γ_R = 1,25. This requirement may be disregarded when damaged stability considers at least two adjacent compartments flooded.

Table 4 : Primary supporting members analysed through complete ship models - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check (see [4])	Buckling check	
			Plate panels (see [5.1])	Pillars (see [5.2] and [5.3])
Still water hull girder loads	γ_{S1}	1,00	1,00	1,00
Wave hull girder loads	γ_{W1}	1,10	1,10	1,10
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10	1,10
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	Defined in Tab 5 and Tab 6	1,02	for [5.2]: see Tab 12 for [5.3]: 1,15

Table 5 : Primary supporting members analysed through three-dimensional or complete ship models - Resistance partial safety factor

Type of three-dimensional model (see Ch 7, App 1)	Resistance partial safety factor γ_R (see [3.3.1] and [4.3.1])	
	General	Watertight bulkhead primary supporting members
Beam model	1,20	1,02
Coarse mesh finite element model	1,20	1,02
Fine mesh finite element model	1,10	1,02

Table 6 : Additional criteria for analyses based on fine mesh finite element models - Resistance partial safety factor

Symbol	Resistance partial safety factor (see [3.3.2] and [4.3.2])	
	General	Watertight bulkhead primary supporting members
γ_R	1,10	1,02

2 Yielding check of primary supporting members analysed through an isolated beam structural model

2.1 General

2.1.1 The requirements of this Article apply for the yielding check of primary supporting members subjected to lateral pressure, wheeled loads or weapon firing dynamic loads and, for primary supporting members contributing to the hull girder longitudinal strength, to hull girder normal stresses, which are to be analysed through an isolated beam model, according to [1.1.2].

2.1.2 The yielding check is also to be carried out for primary supporting members subjected to specific loads, such as concentrated loads.

2.2 Bracket arrangement

2.2.1 The requirements of this Article apply to primary supporting members with brackets at both ends of length not greater than 0,2 ℓ.

In the case of a significantly different bracket arrangement, the determination of normal and shear stresses due to design loads and the required section modulus and shear sectional area are considered by the Society on a case-by-case basis.

2.3 Load point

2.3.1 Lateral pressure

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the primary supporting member considered.

2.3.2 Hull girder normal stresses

For longitudinal primary supporting members contributing to the hull girder longitudinal strength, the hull girder normal stresses are to be calculated in way of the face plate of the primary supporting member considered.

2.4 Load model

2.4.1 General

The still water and wave lateral pressures induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the primary supporting member under consideration and the type of compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

Primary supporting members of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids are to be subjected to the lateral pressure in flooding conditions.

The wave lateral pressures and hull girder loads are to be calculated in the mutually exclusive load cases “a”, “b”, “c” and “d” in Ch 5, Sec 4.

2.4.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure p_S includes:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave pressure p_W includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case “a”, “b”, “c” and “d”
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case “a”, “b”, “c” and “d”.

2.4.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and the wave pressure p_{WF} defined in Ch 5, Sec 6, [7].

2.4.4 Wheeled loads

For primary supporting members subjected to wheeled loads, the yielding check may be carried out according to [2.5] to [2.7] considering uniform pressures equivalent to the distribution of vertical concentrated forces, when such forces are closely located.

For the determination of the equivalent uniform pressures, the most unfavourable case, i.e. where the maximum number of axles are located on the same primary supporting member, according to Fig 1 to Fig 3, is to be considered.

The equivalent still water pressure and inertial pressure are indicated in Tab 7.

For arrangements different from those shown in Fig 1 to Fig 3, the yielding check of primary supporting members is to be carried out by a direct calculation, taking into account the distribution of concentrated loads induced by vehicle wheels.

Table 7 : Wheeled loads - Equivalent uniform still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water condition		$p_S = 10\ p_{eq}$
Upright condition	"a"	No inertial pressure
	"b"	$p_W = p_{eq}\ a_{Z1}$
Inclined condition	"c"	The inertial pressure may be disregarded
	"d"	$p_W = p_{eq}\ a_{Z2}$

Note 1:

$$p_{eq} = \frac{n_V Q_A}{\ell s}\left(3 - \frac{X_1 + X_2}{s}\right)$$

n_V : Maximum number of vehicles possible located on the primary supporting member
Q_A : Maximum axle load, in t, defined in Ch 5, Sec 6, Tab 5
X_1 : Minimum distance, in m, between two consecutive axles (see Fig 2 and Fig 3)
X_2 : Minimum distance, in m, between axles of two consecutive vehicles (see Fig 3).

Figure 1 : Wheeled loads - Distribution of vehicles on a primary supporting member

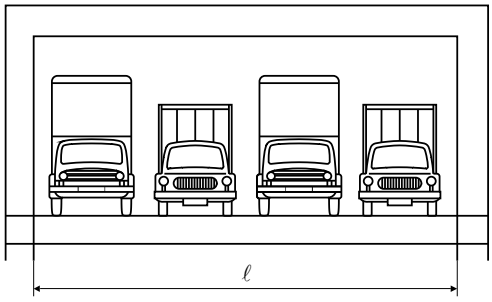


Figure 2 : Wheeled loads - Distance between two consecutive axles

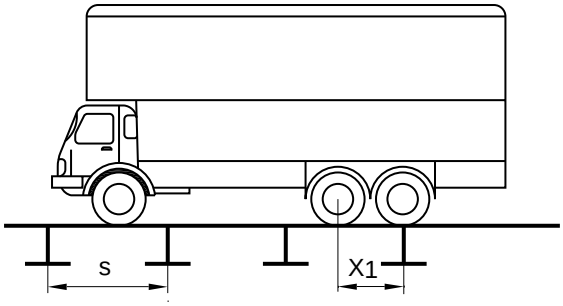
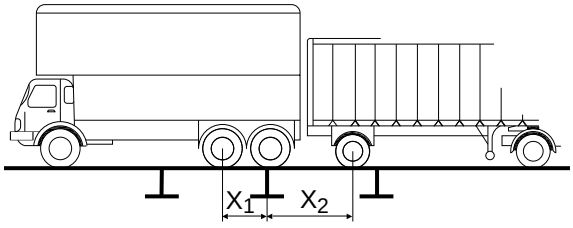


Figure 3 : Wheeled loads - Distance between axles of two consecutive vehicles



2.4.5 Weapon firing dynamic loads

For primary supporting members subjected to weapon firing dynamic loads, the yielding check may be carried out according to [2.7.4] considering uniform pressure distribution.

The pressure p_W is to be calculated according to the requirements specified in Ch 5, Sec 6, [9] for the following weapon firing dynamic loads:

- missile blast dynamic pressure
- accidental missile ignition dynamic pressure
- gun blast dynamic pressure.

For primary supporting members subjected to the gun recoil dynamic force and, in general, when the weapon firing dynamic loads cannot be considered as uniformly distributed, the yielding check is to be carried out taking into account the actual load distribution.

2.4.6 Normal stresses

The normal stresses to be considered for the yielding check of primary supporting members are obtained, in N/mm^2, from the following formulae:

- for longitudinal primary supporting members contributing to the hull girder longitudinal strength:

$$\sigma_N = \sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1})$$

- for longitudinal primary supporting members not contributing to the hull girder longitudinal strength and for transverse primary supporting members:

$$\sigma_N = 45/k \quad N/mm^2$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm^2, defined in:

- Tab 8 for primary supporting members subjected to lateral pressure,
- Tab 9 for primary supporting members subjected to wheeled loads

C_{FV}, C_{FH} : Combination factors defined in Tab 10.

Table 8 : Hull girder normal stresses - Primary supporting members subjected to lateral pressure

Condition		σ_{S1}, in N/mm^2 **(1)**	σ_{WV1}, in N/mm^2	σ_{WH1}, in N/mm^2
Lateral pressure applied on the side opposite to the primary supporting member, with respect to the plating:	• $z \geq N$	$\left\lvert\frac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625F_DM_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625M_{WH}}{I_Z}y\right\rvert 10^{-3}$
	• $z < N$	$\left\lvert\frac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	
Lateral pressure applied on the same side as the primary supporting member:	• $z \geq N$	$\left\lvert\frac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	
	• $z < N$	$\left\lvert\frac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625F_DM_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 9 : Hull girder normal stresses - Primary supporting members subjected to wheeled loads

Condition	σ_{S1} in N/mm^2 **(1)**	σ_{WV1} in N/mm^2	σ_{WH1} in N/mm^2
$z \geq N$	$\left\lvert\frac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625M_{WH}}{I_Z}y\right\rvert 10^{-3}$
$z < N$	$\left\lvert\frac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625F_DM_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 10 : Combination factors C_{FV} and C_{FH}

Load case	C_{FV}	C_{FH}
"a"	1,0	0
"b"	1,0	0
"c"	0,4	1,0
"d"	0,4	1,0
Flooding	0,6	0

2.5 Normal and shear stresses due to lateral pressure in intact conditions

2.5.1 General

Normal and shear stresses, induced by lateral pressures, in primary supporting members are to be determined from the formulae given in:

- [2.5.2] in the case of longitudinal and transverse primary supporting members
- [2.5.3] in the case of vertical primary supporting members.

2.5.2 Longitudinal and transverse primary supporting members

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm^2, from the following formulae:

$$\sigma = \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{mw} s \ell^2 10^3 + \sigma_N$$

$$\tau = 5 \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{A_{Sh}} s \ell$$

where:

$$\beta_b = \left(1 - \frac{\ell_{b1}}{2\ell} - \frac{\ell_{b2}}{2\ell}\right)^2$$

$$\beta_s = 1 - \frac{\ell_{b1}}{2\ell} - \frac{\ell_{b2}}{2\ell}$$

ℓ_{b1}, ℓ_{b2} : Lengths of the brackets at ends, in m.

2.5.3 Vertical primary supporting members

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm^2, from the following formulae:

$$\sigma = \beta_b \frac{\gamma_{S2} \lambda_{bS} p_S + \gamma_{W2} \lambda_{bW} p_W}{mw} s \ell^2 10^3 + \sigma_A$$

$$\tau = 5 \beta_s \frac{\gamma_{S2} \lambda_{sS} p_S + \gamma_{W2} \lambda_{sW} p_W}{A_{Sh}} s \ell$$

where:

β_b, β_s : Coefficients defined in [2.5.2]

$$\lambda_{bS} = 1 + 0{,}2 \frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{bW} = 1 + 0{,}2 \frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

$$\lambda_{sS} = 1 + 0{,}4 \frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{sW} = 1 + 0{,}4 \frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

p_{Sd} : Still water pressure, in kN/m^2, at the lower end of the primary supporting member considered

p_{Su} : Still water pressure, in kN/m^2, at the upper end of the primary supporting member considered

p_{Wd} : Wave pressure, in kN/m^2, at the lower end of the primary supporting member considered

p_{Wu} : Wave pressure, in kN/m^2, at the upper end of the primary supporting member considered

σ_A : Axial stress, to be obtained, in N/mm^2, from the following formula:

$$\sigma_A = 10 \frac{F_A}{A}$$

F_A : Axial load (still water and wave) transmitted to the vertical primary supporting members by the structures above. For multideck ships, the criteria in [5.2.1] for pillars are to be adopted

A : Net sectional area, in cm^2, of the vertical primary supporting members with attached plating of width b_p.

2.6 Checking criteria

2.6.1 General

It is to be checked that the normal stress σ and the shear stress τ, calculated according to [2.5], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0{,}5 \frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

2.7 Net section modulus and net sectional shear area complying with the checking criteria

2.7.1 General

The requirements in [2.7.2] and [2.7.3] provide the minimum net section modulus and net shear sectional area of primary supporting members subjected to lateral pressure in intact conditions, complying with the checking criteria indicated in [2.6].

The requirements in [2.7.4] provide the minimum net section modulus and net shear sectional area of primary supporting members subjected to weapon firing dynamic loads.

2.7.2 Longitudinal and transverse primary supporting members

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of longitudinal or transverse primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_N)} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

where β_b and β_s are the coefficients defined in [2.5.2].

2.7.3 Vertical primary supporting members

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of vertical primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} \lambda_{bS} p_S + \gamma_{W2} \lambda_{bW} p_W}{m(R_y - \gamma_R \gamma_m \sigma_A)} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} \lambda_{sS} p_S + \gamma_{W2} \lambda_{sW} p_W}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [2.5.2]

λ_{bs}, λ_{bW}, λ_{sS}, λ_{sW} : Coefficients defined in [2.5.3]

σ_A : Defined in [2.5.3].

2.7.4 Primary supporting members subjected to weapon firing dynamic loads

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of primary supporting members subjected to weapon firing dynamic loads are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{W2} p_W s \ell^2}{8 R_y} 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{W2} p_W s \ell^2}{R_y}$$

where:

β_b, β_s : Coefficients defined in [2.5.2]

p_w : Weapon firing dynamic pressure defined in Ch 5, Sec 6, [9].

2.8 Net section modulus and net shear sectional area of primary supporting members subjected to lateral pressure in flooding conditions

2.8.1 General

The requirements in [2.8.1] to [2.8.3] apply to primary supporting members located on structural watertight elements as per Internal Watertight Plan which constitute boundaries intended to stop vertical and horizontal flooding.

These primary supporting members are to be checked in flooding conditions as specified in [2.8.2] and [2.8.3], depending on the type of member.

2.8.2 Longitudinal and transverse primary supporting members

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of longitudinal or transverse primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{m(R_y - \gamma_R \gamma_m \sigma_N)} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [2.5.2].

2.8.3 Vertical primary supporting members

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of vertical primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} \lambda_{bS} p_{SF} + \gamma_{W2} \lambda_{bW} p_{WF}}{m R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} \lambda_{sS} p_{SF} + \gamma_{W2} \lambda_{sW} p_{WF}}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [2.5.2]

$$\lambda_{bS} = 1 + 0,2 \frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{bW} = 1 + 0,2 \frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

$$\lambda_{sS} = 1 + 0,4 \frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{sW} = 1 + 0,4 \frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

p_{SFd} : Still water pressure, in kN/m^2, in flooding conditions, at the lower end of the primary supporting member considered

p_{SFu} : Still water pressure, in kN/m^2, in flooding conditions, at the upper end of the primary supporting member considered

p_{WFd} : Wave pressure, in kN/m^2, in flooding conditions, at the lower end of the primary supporting member considered

p_{WFu} : Wave pressure, in kN/m^2, in flooding conditions, at the upper end of the primary supporting member considered.

3 Yielding check of primary supporting members analysed through a three-dimensional structural model

3.1 General

3.1.1 The requirements of this Article apply for the yielding check of primary supporting members subjected to lateral pressure, wheeled loads or weapon firing dynamic loads and, for those contributing to the hull girder longitudinal strength, to hull girder normal stresses, which are to be analysed through a three-dimensional structural model, according to [1.1.2].

3.1.2 The yielding check is also to be carried out for primary supporting members subjected to specific loads, such as concentrated loads.

3.2 Analysis criteria

3.2.1 The analysis of primary supporting members based on three-dimensional models is to be carried out according to:

- the requirements in Ch 7, App 1 for primary supporting members subjected to lateral pressure or weapon firing dynamic loads
- the requirements in Ch 7, App 2 for primary supporting members subjected to wheeled loads.

These requirements apply for:

- the structural modelling
- the load modelling
- the stress calculation.

3.3 Checking criteria

3.3.1 General

For all types of analysis (see Ch 7, App 1, [2]), it is to be checked that the equivalent stress σ_{VM}, calculated according to Ch 7, App 1, [5] is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

3.3.2 Additional criteria for analyses based on fine mesh finite element models

Fine mesh finite element models are defined with reference to Ch 7, App 1, [3.4].

For all the elements of the fine mesh models, it is to be checked that the normal stresses σ_1 and σ_2 and the shear stress τ_{12}, calculated according to Ch 7, App 1, [5], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \text{Max}\,(\sigma_1;\sigma_2)$$

$$0{,}5\,\frac{R_y}{\gamma_R \gamma_m} \geq \tau_{12}$$

3.3.3 Specific case of primary supporting members subjected to wheeled loads

For all types of analysis (see Ch 7, App 2, [2]), it is to be checked that the equivalent stress σ_{VM}, calculated according to Ch 7, App 2, [5] is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

4 Yielding check of primary supporting members analysed through a complete ship structural model

4.1 General

4.1.1 The requirements of this Article apply for the yielding check of primary supporting members which are to be analysed through a complete ship structural model.

4.1.2 A complete ship structural model is to be carried out, when deemed necessary by the Society, to analyse primary supporting members of ships with one or more of the following characteristics:

- ships having large deck openings
- ships having large space arrangements
- multideck ships having series of openings in side or longitudinal bulkheads, when the stresses due to the different contribution of each deck to the hull girder strength are to be taken into account.

4.2 Analysis criteria

4.2.1 The analysis of primary supporting members based on complete ship models is to be carried out according to Ch 7, App 3.

These requirements apply for:

- the structural modelling
- the load modelling
- the stress calculation.

4.3 Checking criteria

4.3.1 General

It is to be checked that the equivalent stress σ_{VM}, calculated according to Ch 7, App 3, [4] is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

4.3.2 Additional criteria for elements modelled with fine meshes

Fine meshes are defined with reference to Ch 7, App 3, [2.4].

For all the elements modelled with fine meshes, it is to be checked that the normal stresses σ_1 and σ_2 and the shear stress τ_{12}, calculated according to Ch 7, App 3, [4], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \text{Max}\,(\sigma_1;\sigma_2)$$

$$0{,}5\,\frac{R_y}{\gamma_R \gamma_m} \geq \tau_{12}$$

5 Buckling check

5.1 Local buckling of plate panels

5.1.1 A local buckling check is to be carried out, according to Ch 7, Sec 1, [5], for plate panels which constitute primary supporting members.

In carrying out this check, the stresses in the plate panels are to be calculated according to [2], [3] or [4], depending on the structural model adopted for the analysis of primary supporting members.

5.2 Buckling of pillars subjected to compression axial load

5.2.1 Compression axial load

The compression axial load in the pillar is to be obtained, in kN, from the following formula:

$$F_A = A_D(\gamma_{S2}p_S + \gamma_{W2}p_W) + \sum_i r(\gamma_{S2}Q_{i,S} + \gamma_{W2}Q_{i,W})$$

where:

A_D : Area, in m^2, of the portion of the deck or the platform supported by the pillar considered

r : Coefficient which depends on the relative position of each pillar above the one considered, to be taken equal to:

- r = 1,0 for the pillar considered
- r = 0,9 for the pillar immediately above that considered
- $r = 0,9^i$ for the i^{th} pillar of the line above the pillar considered, to be taken not less than 0,478

$Q_{i,S}$, $Q_{i,W}$: Still water and wave load, respectively, in kN, from the i^{th} pillar of the line above the pillar considered, if any.

5.2.2 Critical column buckling stress of pillars

The critical column buckling stress of pillars is to be obtained, in N/mm^2, from the following formulae:

$$\sigma_{cB} = \sigma_{E1} \quad \text{for} \quad \sigma_{E1} \le \frac{R_{eH}}{2}$$

$$\sigma_{cB} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E1}}\right) \quad \text{for} \quad \sigma_{E1} > \frac{R_{eH}}{2}$$

where:

σ_{E1} : Euler column buckling stress, to be obtained, in N/mm^2, from the following formula:

$$\sigma_{E1} = \pi^2 E \frac{I}{A(f\ell)^2} 10^{-4}$$

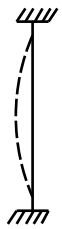
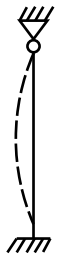
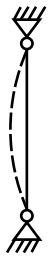
I : Minimum net moment of inertia, in cm^4, of the pillar

A : Net cross-sectional area, in cm^2, of the pillar

ℓ : Span, in m, of the pillar

f : Coefficient, to be obtained from Tab 11.

Table 11 : Coefficient f

	Both ends fixed	One end fixed, one end pinned	Both ends pinned
Boundary conditions of the pillar			
Coefficient f	f = 0,5	$f = \frac{\sqrt{2}}{2}$	f = 1,0

5.2.3 Critical torsional buckling stress of built-up pillars

The critical torsional buckling stress of built-up pillars is to be obtained, in N/mm^2, from the following formulae:

$$\sigma_{cT} = \sigma_{E2} \quad \text{for} \quad \sigma_{E2} \le \frac{R_{eH}}{2}$$

$$\sigma_{cT} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E2}}\right) \quad \text{for} \quad \sigma_{E2} > \frac{R_{eH}}{2}$$

where:

σ_{E2} : Euler torsional buckling stress, to be obtained, in N/mm^2, from the following formula:

$$\sigma_{E2} = \frac{\pi^2 E I_w}{10^4 I_p \ell^2} + 0,41 E \frac{I_t}{I_p}$$

I_w : Net sectorial moment of inertia of the pillar, to be obtained, in cm^6, from the following formula:

$$I_w = \frac{t_f b_f^3 h_w^2}{24} 10^{-6}$$

h_W : Web height of built-up section, in mm

t_W : Net web thickness of built-up section, in mm

b_F : Face plate width of built-up section, in mm

t_F : Net face plate thickness of built-up section, in mm

I_p : Net polar moment of inertia of the pillar, to be obtained, in cm^4, from the following formula:

$I_P = I_{XX} + I_{YY}$

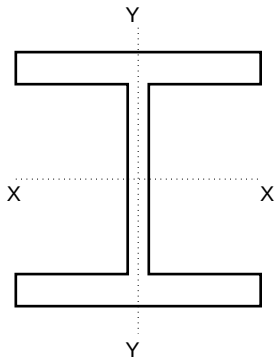
I_{XX} : Net moment of inertia about the XX axis of the pillar section (see Fig 4)

I_{YY} : Net moment of inertia about the YY axis of the pillar section (see Fig 4)

I_t : St. Venant's net moment of inertia of the pillar, to be obtained, in cm^4, from the following formula:

$$I_t = \frac{1}{3}[h_w t_w^3 + 2 b_f t_f^3] 10^{-4}$$

Figure 4 : Reference axes for the calculationof the moments of inertia of a built-up section



5.2.4 Critical local buckling stress of built-up pillars

The critical local buckling stress of built-up pillars is to be obtained, in N/mm^2, from the following formulae:

$$\sigma_{cL} = \sigma_{E3} \quad \text{for} \quad \sigma_{E3} \le \frac{R_{eH}}{2}$$

$$\sigma_{cL} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E3}}\right) \quad \text{for} \quad \sigma_{E3} > \frac{R_{eH}}{2}$$

where:

σ_{E3} : Euler local buckling stress, to be taken equal to the lesser of the values obtained, in N/mm^2, from the following formulae:

$$\sigma_{E3} = 78\left(\frac{E}{206000}\right)\left(\frac{t_W}{h_W}\right)^2 10^4$$

$$\sigma_{E3} = 32\left(\frac{E}{206000}\right)\left(\frac{t_F}{b_F}\right)^2 10^4$$

t_W, h_W, t_F, b_F : Dimensions, in mm, of the built-up section, defined in [5.2.3].

5.2.5 Critical local buckling stress of pillars having hollow rectangular section

The critical local buckling stress of pillars having hollow rectangular section is to be obtained, in N/mm^2, from the following formulae:

$$\sigma_{cL} = \sigma_{E4} \quad \text{for} \quad \sigma_{E4} \le \frac{R_{eH}}{2}$$

$$\sigma_{cL} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E4}}\right) \quad \text{for} \quad \sigma_{E4} > \frac{R_{eH}}{2}$$

where:

σ_{E4} : Euler local buckling stress, to be taken equal to the lesser of the values obtained, in N/mm^2, from the following formulae:

$$\sigma_{E4} = 78\left(\frac{E}{206000}\right)\left(\frac{t_2}{b}\right)^2 10^4$$

$$\sigma_{E4} = 78\left(\frac{E}{206000}\right)\left(\frac{t_1}{h}\right)^2 10^4$$

b : Length, in mm, of the shorter side of the section

t_2 : Net web thickness, in mm, of the shorter side of the section

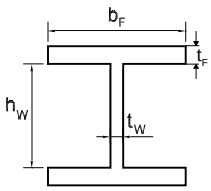
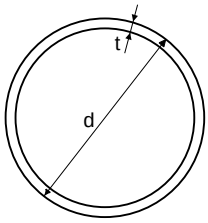
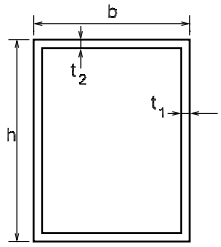
h : Length, in mm, of the longer side of the section

t_1 : Net web thickness, in mm, of the longer side of the section.

5.2.6 Checking criteria

The net scantlings of the pillar loaded by the compression axial stress F_A defined in [5.2.1] are to comply with the formulae in Tab 12.

Table 12 : Buckling check of pillars subject to compression axial load

Pillar cross-section	Column buckling check	Torsional buckling check	Local buckling check	Geometric condition
Built-up 	$\frac{\sigma_{cB}}{\gamma_R\gamma_m} \geq 10\frac{F_A}{A}$	$\frac{\sigma_{cT}}{\gamma_R\gamma_m} \geq 10\frac{F_A}{A}$	$\frac{\sigma_{cL}}{\gamma_R\gamma_m} \geq 10\frac{F_A}{A}$	$\frac{b_F}{t_F} \leq 40$
Hollow tubular 	$\frac{\sigma_{cB}}{\gamma_R\gamma_m} \geq 10\frac{F_A}{A}$	Not required	Not required	$\frac{d}{t} \leq 55$ $t \geq 5,5$ mm
Hollow rectangular 	$\frac{\sigma_{cB}}{\gamma_R\gamma_m} \geq 10\frac{F_A}{A}$	Not required	$\frac{\sigma_{cL}}{\gamma_R\gamma_m} \geq 10\frac{F_A}{A}$	$\frac{b}{t_2} \leq 55$ $\frac{h}{t_1} \leq 55$ $t_1 \geq 5,5$ mm $t_2 \geq 5,5$ mm

Note 1:

σ_{cB} : Critical column buckling stress, in N/mm², defined in [5.2.2]

σ_{cT} : Critical torsional buckling stress, in N/mm², defined in [5.2.3]

σ_{cL} : Critical local buckling stress, in N/mm², defined in [5.2.4] for built-up section or in [5.2.5] for hollow rectangular section

γ_R : Resistance partial safety factor, to be taken equal to:

- 1,15 for column buckling
- 1,05 for torsional and local buckling

F_A : compression axial load in the pillar, in kN, defined in [5.2.1]

A : Net sectional area, in cm², of the pillar.

5.2.7 Contact pressure

At connections between pillars and decks, it is to be checked that the contact pressure σ_C, in N/mm2, complies with the following criteria:

$\sigma_c \leq 0,8\ R_{eH}$

where:

$\sigma_c = 10F_A/A_C$

with:

F_A : Compression axial load in the pillar, in kN

A_C : Contact area between the pillar and the deck structural members, in cm²

R_{eH} : Smallest of the assembled elements yield stress, in N/mm².

5.3 Buckling of pillars subjected to compression axial load and bending moments

5.3.1 Checking criteria

In addition to the requirements in [5.2], the net scantlings of the pillar loaded by the compression axial load and bending moments are to comply with the following formula:

$$10F\left(\frac{1}{A}+\frac{\Phi e}{w_P}\right)+\left(10^3\frac{M_{max}}{w_P}\right)\leq\frac{R_{eH}}{\gamma_R\gamma_m}$$

where:

F : Compression load, in kN, acting on the pillar

A : Net cross-sectional area, in cm^2, of the pillar

e : Eccentricity, in cm, of the compression load with respect to the centre of gravity of the cross-section

$$\Phi=\frac{1}{1-\frac{10F}{\sigma_{E1}A}}$$

σ_{E1} : Euler column buckling stress, in N/mm^2, defined in [5.2.2]

w_P : Minimum net section modulus, in cm^3, of the cross-section of the pillar

$M_{max} = Max\ (M_1\ ;\ M_2\ ;\ M_0)$

M_1 : Bending moment, in kN.m, at the upper end of the pillar

M_2 : Bending moment, in kN.m, at the lower end of the pillar

$$M_0=\frac{0{,}5(\sqrt{1+t^2})(M_1+M_2)}{\cos(u)}$$

$$u=0{,}5\pi\sqrt{\frac{10F}{\sigma_{E1}A}}$$

$$t=\frac{1}{\tan(u)}\left(\frac{M_2-M_1}{M_2+M_1}\right)$$

provided that:

$$-\tan^2 u\leq\frac{M_2-M_1}{M_2+M_1}\leq\tan^2 u$$

6 Dynamic analysis of main weapon mount supporting structure

6.1 Application

6.1.1 The requirements of this Article apply for the dynamic analysis of main weapon mount supporting structure subjected to dynamic loads.

6.2 Dynamic analysis

6.2.1 Analysis criteria

The dynamic analysis of main weapon mount supporting structure is to be based on direct calculations performed through three-dimensional models.

The criteria adopted for structural modelling are to comply with the requirements specified in Ch 7, App 1.

In any case, the mesh accuracy is to be such that the stiffness and the mass distribution of the model elements of the mount supporting structure and of the surrounding hull structure properly represent those of the actual structure.

Dynamic analysis of special weapons, such as vertical missile launching system (VLS) and rocket or missile launching system with elevation and slewing capabilities, are to be considered by the Society on a case-by-case basis. When deemed necessary, the Society may also require that finite element model transient analyses be performed.

6.2.2 Normal mode analysis

It is to be checked that each normal mode frequency f_{Ni}, in Hz, of the weapon mount supporting structure is in compliance with one of the following formulae:

$f_{Ni} < 0{,}8\ f_{E,MIN}$

$f_{Ni} > 1{,}2\ f_{E,MAX}$

where:

$F_{E,MIN}$, $F_{E,MAX}$: The lesser and the greater values, in Hz, respectively, among the possible excitations frequencies due to the weapon (e.g. hail) or the propulsion system.

The normal mode calculation method and the number of normal modes to be taken into account are considered by the Society on a case-by-case basis.

When at least one of the normal mode frequencies does not comply with the above formulae, a dynamic analysis is to be carried out according to the requirements in [6.2.3].

6.2.3 Dynamic analysis

It is to be checked that the dynamic effects induced in the weapon mounting supporting structure by the weapon or the propulsion system are within allowable limits, when this is required according to [6.2.2].

The dynamic effects are to be calculated by means of a dynamic analysis aiming at evaluating:

- the response of the weapon system in the time domain to possible excitations due to the weapon (e.g. hail)
- the response amplitude operators (RAOs) of the weapon system versus possible excitations due to the propulsion system.

When the dynamic analysis is based on normal models, their number is, in general, to be such that the modal effective mass is not less than 95% of the mass of the system constituted by the weapon and its mounting supporting structure.

The modal effective mass is defined as:

$$\sum_{i=1}^{N} \gamma_i^2$$

where γ_i is the i^{th} modal participation factor and N is the number of the considered normal modes.

The dynamic analysis criteria and the relevant allowable limits are considered by the Society on a case-by-case basis.

Section 4 Fatigue Check of Structural Details

Symbols

For the symbols not defined in this Section, refer to Ch 1, Sec 2, [2.1.1].

$\Delta\sigma_{P0}$: Allowable stress range, defined in Article [4].

ℓ : Span, in m, of primary supporting members, measured between the supporting elements, see Ch 4, Sec 3, [4.1]

ℓ_b : Length, in m, of one bracket, see Ch 7, Sec 3, [2.2] and Ch 4, Sec 3, [4.4]

K_F : Fatigue notch factor, defined in [4.3.1]

K_h, $K\ell$: Stress concentration factors, defined in Ch 11, Sec 2 for the special structural details there specified

K_m : Stress concentration factor, taking account of misalignment, defined in [4.3.1]

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 4, Sec 3, [3.2]

I_Y : Net moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings

I_Z : Net moment of inertia, in m^4, of the hull transverse section around its vertical neutral axis, to be calculated according to Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.2]

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1]

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1]

N : Z co-ordinate, in m, with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6], of the centre of gravity of the hull transverse section constituted by members contributing to the hull girder longitudinal strength considered as having their net scantlings (see Ch 6, Sec 1, [2])

p_W : Wave pressure, in kN/m^2 (see [2.2])

s : Spacing, in m, of ordinary stiffeners

T_1 : Draught, in m, corresponding to the loading condition considered.

w : Net section modulus, in cm^3, of the stiffener, with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [3.4]

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6].

1 General

1.1 Net scantlings

1.1.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.2 Application

1.2.1 Structural details to be checked

The requirements of this Section apply for the fatigue check of special structural details, according to Ch 11, Sec 2.

The Society may require other details to be checked, when deemed necessary on the basis of the detail geometry, tolerances and stress level, in agreement with the Designer.

1.2.2 Categorisation of details

With respect to the method to be adopted to calculate the stresses acting on structural members, the details for which the fatigue check is to be carried out may be grouped as follows:

- details where the stresses are to be calculated through a three-dimensional structural model (e.g. connections between primary supporting members)
- details located at ends of ordinary stiffeners, for which an isolated structural model can be adopted.

1.2.3 Details where the stresses are to be calculated through a three-dimensional structural model

The requirements of Ch 7, App 1, [6] apply, in addition to those from Articles [1] to [5] of this Section.

1.2.4 Details located at ends of ordinary stiffeners

The requirements from Articles [1] to [6] of this Section apply.

1.2.5 Other details

In general, for details other than those in [1.2.2], the stresses are to be calculated through a method agreed by the Society on a case-by-case basis, using the load model defined in Article [2].

The checking criterion in Article [5] is generally to be applied.

1.3 Definitions

1.3.1 Hot spots

Hot spots are the locations where fatigue cracking may occur. They are indicated in the relevant figures of special structural details in Ch 11, Sec 2.

1.3.2 Nominal stress

Nominal stress is the stress in a structural component taking into account macro-geometric effects but disregarding the stress concentration due to structural discontinuities and to the presence of welds (see Fig 1).

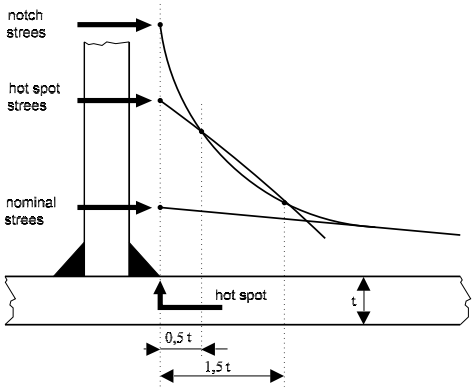
1.3.3 Hot spot stress

Hot spot stress is a local stress at the hot spot taking into account the influence of structural discontinuities due to the geometry of the detail, but excluding the effects of welds (see Fig 1).

1.3.4 Notch stress

Notch stress is a peak stress in a notch such as the root of a weld or the edge of a cut-out. This peak stress takes into account the stress concentrations due to the presence of notches (see Fig 1).

Figure 1 : Nominal, hot spot and notch stresses



1.3.5 Elementary stress range

Elementary stress range is the stress range determined for one of the load cases “a”, “b”, “c” or “d” (see Ch 5, Sec 4, [2]) and for either of the loading conditions (see Ch 5, Sec 1, [2.4] and Ch 5, Sec 1, [2.5]).

1.3.6 Equivalent stress range

Equivalent stress range is a stress range obtained from a combination of elementary stress ranges, as indicated in [4.3.1] for notch stress and [2.3.1] for hull girder nominal stress.

1.4 Partial safety factors

1.4.1 The partial safety factors to be considered for the fatigue check of structural details are specified in Tab 1.

Table 1 : Fatigue check - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Value	
		General	Details at ends of ordinary stiffeners
Still water hull girder loads	γ_{S1}	1,00	1,00
Wave hull girder loads	γ_{W1}	1,05	1,15
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,20
Resistance	γ_{R}	1,02	1,02

2 Load model

2.1 General

2.1.1 Load point

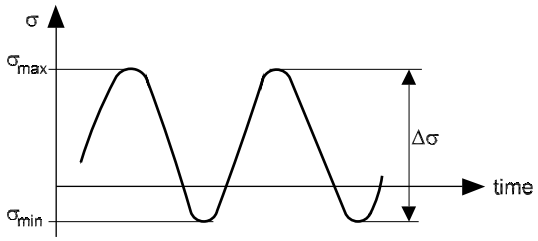
Unless otherwise specified, design loads are to be determined at points defined in:

- Ch 7, Sec 2, [1.3] for ordinary stiffeners
- Ch 7, Sec 3, [1] for primary supporting members.

2.1.2 Local and hull girder loads

The fatigue check is based on the stress range induced at the hot spot by the time variation of local and hull girder loads in each load case "a", "b", "c" and "d" defined in [2.2] for the loading conditions defined in [2.1.4] and [2.1.3] (see Fig 2).

Figure 2 : Stress range



2.1.3 Loading conditions for details where the stresses are to be calculated through a three-dimensional structural model

The most severe full load and operational load conditions for the detail concerned are to be considered in accordance with Ch 5, Sec 1, [2.5].

2.1.4 Loading conditions for details located at ends of ordinary stiffeners

The load distribution is to be considered in accordance with Ch 5, Sec 1, [2.4].

2.1.5 Spectral fatigue analysis

For ships with non-conventional shapes or with restricted navigation, the Society may require a spectral fatigue analysis to be carried out.

In this analysis, the loads and stresses are to be evaluated through long-term stochastic analysis taking into account the characteristics of the ship and the navigation notation.

The load calculations and fatigue analysis are to be submitted to the Society for approval.

2.2 Local lateral pressures

2.2.1 General

The still water and wave lateral pressures induced by the sea, various types of loads and ballast are to be considered.

Lateral pressure is constituted by still water pressure and wave pressure.

2.2.2 Load cases "a-max" and "a-min", in upright ship condition

The still water sea pressure (p_S) is defined in Ch 5, Sec 5, [1.1.1].

The wave pressure p_W is defined in Tab 2.

No internal inertial pressures are considered.

Table 2 : Wave pressure in load case "a"

Location	Wave pressure p_W, in kN/m²	
	a-max	a-min
Bottom and sides below the waterline ($z \le T_1$)	$\alpha^{1/4}\frac{\rho g h_1}{2}\left[\frac{T_1 + z}{T_1}\right]$	$-\alpha^{1/4}\frac{\rho g h_1}{2}\left[\frac{T_1 + z}{T_1}\right]$ without being taken less than $\frac{\gamma_S}{\gamma_W}\rho g(z - T_1)$
Sides above the waterline ($z > T_1$)	$\rho g(T_1 + \alpha^{1/4} h_1 - z)$	0,0
Note 1: α : Coefficient equal to T_1/T, but not to be taken greater than 1		

2.2.3 Load cases “b-max” and “b-min”, in upright ship condition

Still water pressures p_S includes:

- the still water sea pressure defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of loads and for ballast.

Dynamic pressure p_W is constituted by internal inertial pressures defined in Tab 4.

No sea wave dynamic pressures are considered.

2.2.4 Load cases “c-max” and “c-min”, in inclined ship condition

Still water pressures p_S includes:

- the still water sea pressure defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of loads and for ballast.

Wave pressure p_W includes:

- the wave pressure obtained from Tab 3
- the inertial pressure obtained from Tab 4 for the various types of loads and ballast.

2.2.5 Load cases “d-max” and “d-min”, in inclined ship condition

Still water pressures p_S includes:

- the still water sea pressure defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of loads and for ballast.

Wave pressure p_W includes:

- the wave pressure obtained from Tab 3
- the inertial pressure obtained from Tab 4 for the various types of loads and ballast.

Table 3 : Wave pressure in inclined ship conditions (load cases “c” and “d”)

Location		Wave pressure p_W, in kN/m² **(1)**	
		c-max / d-max	c-min / d-min
Bottom and sides below the waterline ($z \le T_1$)	$y \ge 0$	$C_{F2}\alpha^{1/4}\rho g h_2 \frac{\lvert y\rvert}{B_W}\left[\frac{T_1+z}{T_1}\right]$	$-C_{F2}\alpha^{1/4}\rho g h_2 \frac{\lvert y\rvert}{B_W}\left[\frac{T_1+z}{T_1}\right]$ without being taken less than $\frac{\gamma_S}{\gamma_W}\rho g(z-T_1)$
	$y < 0$	$-C_{F2}\alpha^{1/4}\rho g h_2 \frac{\lvert y\rvert}{B_W}\left[\frac{T_1+z}{T_1}\right]$ without being taken less than $\frac{\gamma_S}{\gamma_W}\rho g(z-T_1)$	$C_{F2}\alpha^{1/4}\rho g h_2 \frac{\lvert y\rvert}{B_W}\left[\frac{T_1+z}{T_1}\right]$
Sides above the waterline ($z > T_1$)	$y \ge 0$	$\rho g\left[T_1 + 2C_{F2}\alpha^{1/4}\frac{\lvert y\rvert}{B_W}h_2 - z\right]$	0,0
	$y < 0$	0,0	$\rho g\left[T_1 + 2C_{F2}\alpha^{1/4}\frac{\lvert y\rvert}{B_W}h_2 - z\right]$

(1) In the formulae giving the wave pressure p_W, the ratio $|y| / B_W$ is not to be taken greater than 0,5.

Note 1:

α : Coefficient equal to T_1/T, but not to be taken greater than 1

C_{F2} : Combination factor, to be taken equal to:
- $C_{F2} = 1,0$ for load case “c”
- $C_{F2} = 0,5$ for load case “d”

B_W : Moulded breadth, in m, measured at the waterline at draught T_1, at the hull transverse section considered

h_2 : Reference value, in m, of the relative motion in the inclined ship condition, defined in Ch 5, Sec 3, [3.3.2] and not to be taken greater than the minimum of T_1 and $(D - 0,9\ T_1)$.

Table 4 : Inertial pressures

Loads	Load case	Inertial pressures, in kN/m² **(1)**
Liquids	b-max	$p_W = \rho_L[-0,5a_{X1}\ell_B - a_{Z1}(z_{TOP} - z)]$
	b-min	$p_W = \rho_L[0,5a_{X1}\ell_B + a_{Z1}(z_{TOP} - z)]$
	c-max d-max	$p_W = \rho_L[0,7C_{FA}a_{Y2}(y - y_H) + (-0,7C_{FA}a_{Z2} - g)(z - z_H) + g(z - z_{TOP})]$
	c-min d-min	$p_W = \rho_L[-0,7C_{FA}a_{Y2}(y - y_H) + (0,7C_{FA}a_{Z2} - g) + g(z - z_{TOP})]$

(1) The symbols used in the formulae of inertial pressures are defined in Ch 5, Sec 6.

Note 1:

C_{FA} : Combination factor, to be taken equal to:

$C_{FA} = 0,7$ for load case "c"

$C_{FA} = 1,0$ for load case "d"

2.3 Nominal hull girder normal stresses

2.3.1 The nominal hull girder normal stresses are obtained, in N/mm², from the following formulae:

- for members contributing to the hull girder longitudinal strength:

$$\sigma_h = \gamma_{S1}\sigma_{SW} + \gamma_{W1}(C_{FV}\sigma_{WV} + C_{FH}\sigma_{WH})$$

- for members not contributing to the hull girder longitudinal strength:

$$\sigma_h = 0$$

where:

σ_{SW} : Still water hull girder normal stresses, in N/mm², taken equal to:

$$\sigma_{SW} = \frac{M_{SW}}{I_Y}(z - N)10^{-3}$$

M_{SW} : Still water bending moment for the loading condition considered

σ_{WV}, σ_{WH}: Hull girder normal stresses, in N/mm², defined in Tab 5

C_{FV}, C_{FH} : Combination factors defined in Tab 6.

Table 5 : Nominal hull girder normal stresses

Load case	σ_{WV}, in N/mm²	σ_{WH}, in N/mm²
a-max	$\frac{0,625M_{WV,H}}{I_Y}(z - N)10^{-3}$	0
a-min	$\frac{0,625M_{WV,S}}{I_Y}(z - N)10^{-3}$	0
b-max b-min	0	0
c-max d-max	0	$-\frac{0,625M_{WH}}{I_Z}y10^{-3}$
c-min d-min	0	$\frac{0,625M_{WH}}{I_Z}y10^{-3}$

Table 6 : Combination factors C_{FV}, C_{FH} and $C_{F\Omega}$

Load case	C_{FV}	C_{FH}	$C_{F\Omega}$
"a"	1,0	0	0
"b"	1,0	0	0
"c"	0,4	1,0	1,0
"d"	0,4	1,0	0

3 Fatigue damage ratio

3.1 General

3.1.1 Elementary fatigue damage ratio

The elementary fatigue damage ratio is to be obtained from the following formula:

$$D_{ij} = \frac{N_t}{K_p}\frac{(\Delta\sigma_{N,ij})^3}{(-\ln p_R)^{3/\xi}}\,\mu_{ij}\,\Gamma_C\left[\frac{3}{\xi}+1\right]$$

where:

$\Delta\sigma_{N,ij}$: Elementary notch stress range, in N/mm², defined in [4.3.1]

$$\mu_{ij} = 1 - \frac{\Gamma_N\frac{3}{\xi}+1,\nu_{ij} - \Gamma_N\frac{5}{\xi}+1,\nu_{ij}\,\nu_{ij}^{-2/\xi}}{\Gamma_C\frac{3}{\xi}+1}$$

$$\xi = \xi_0\,K_2$$

$$\xi_0 = \frac{73-0,07L}{60} \text{ without being less than } 0,85$$

K_2 : For fatigue calculation in way of connection of longitudinals on transverses, K_2 is given below, without being taken less than 0,9:

$$K_2 = 1,04 - 0,14\frac{|z-T_1|}{D-T_1}$$

K_2 is to be taken equal to 1 for all other fatigue calculations

T_1 : Draught, in m, corresponding to the loading condition “Full load” or “Operational load”

$$\nu_{ij} = -\left(\frac{S_q}{\Delta\sigma_{N,ij}}\right)^{\xi}\ln p_R$$

$$S_q = (K_p 10^{-7})^{1/3}$$

$$K_p = 5,802\left(\frac{22}{t}\right)^{0,9}10^{12}$$

t : Net thickness, in mm, of the element under consideration not being taken less than 22 mm

N_t : Number of cycles corresponding to the design fatigue life T_{FL}, to be taken equal to:

$$N_t = \frac{31,55\cdot\alpha_0\cdot T_{FL}}{T_A}10^6$$

α_0 : Sailing factor, taken equal to 0,80, except if otherwise specified

T_A : Average period, in seconds, to be taken equal to: $T_A = 4 \log L$

T_{FL} : Increased design fatigue life, in years, having a value between 30 and 40

$p_R = 10^{-5}$

$\Gamma_N[X+1,\nu_{ij}]$: Incomplete Gamma function, calculated for $X = 3/\xi$ or $X = 5/\xi$ and equal to:

$$\Gamma_N[X+1,\nu_{ij}] = \int_0^{\nu_{ij}} t^X e^{-t}dt$$

Values of $\Gamma_N[X+1,\nu_{ij}]$ are also indicated in Tab 7. For intermediate values of X and ν_{ij}, Γ_N may be obtained by linear interpolation

$\Gamma_C[X+1]$: Complete Gamma function, calculated for $X = 3/\xi$, equal to:

$$\Gamma_C[X+1] = \int_0^{\infty} t^X e^{-t}dt$$

Values of $\Gamma_C[X+1]$ are also indicated in Tab 8. For intermediate values of X, Γ_C may be obtained by linear interpolation.

Table 7 : Function Γ_N [X+1, ν_{ij}]

X	ν_{ij} = 1,5	ν_{ij} = 2,0	ν_{ij} = 2,5	ν_{ij} = 3,0	ν_{ij} = 3,5	ν_{ij} = 4,0	ν_{ij} = 4,5
2,6	0,38	0,75	1,19	1,63	2,04	2,41	2,71
2,7	0,39	0,78	1,25	1,73	2,20	2,62	2,97
2,8	0,39	0,80	1,31	1,85	2,38	2,85	3,26
2,9	0,39	0,83	1,38	1,98	2,57	3,11	3,58
3,0	0,39	0,86	1,45	2,12	2,78	3,40	3,95
3,1	0,40	0,89	1,54	2,27	3,01	3,72	4,35
3,2	0,40	0,92	1,62	2,43	3,27	4,08	4,81
3,3	0,41	0,95	1,72	2,61	3,56	4,48	5,32
3,4	0,41	0,99	1,82	2,81	3,87	4,92	5,90
3,5	0,42	1,03	1,93	3,03	4,22	5,42	6,55
3,6	0,42	1,07	2,04	3,26	4,60	5,97	7,27
3,7	0,43	1,12	2,17	3,52	5,03	6,59	8,09
3,8	0,43	1,16	2,31	3,80	5,50	7,28	9,02
3,9	0,44	1,21	2,45	4,10	6,02	8,05	10,06
4,0	0,45	1,26	2,61	4,43	6,59	8,91	11,23
4,1	0,45	1,32	2,78	4,80	7,22	9,87	12,55
4,2	0,46	1,38	2,96	5,20	7,93	10,95	14,05
4,3	0,47	1,44	3,16	5,63	8,70	12,15	15,73
4,4	0,48	1,51	3,37	6,11	9,56	13,50	17,64
4,5	0,49	1,57	3,60	6,63	10,52	15,01	19,79
4,6	0,49	1,65	3,85	7,20	11,57	16,70	22,23
4,7	0,50	1,73	4,12	7,82	12,75	18,59	24,98
4,8	0,52	1,81	4,40	8,50	14,04	20,72	28,11
4,9	0,52	1,90	4,71	9,25	15,49	23,11	31,64
5,0	0,53	1,99	5,04	10,07	17,09	25,78	35,65
5,1	0,55	2,09	5,40	10,97	18,86	28,79	40,19
5,2	0,56	2,19	5,79	11,95	20,84	32,17	45,34
5,3	0,57	2,30	6,21	13,03	23,03	35,96	51,19
5,4	0,58	2,41	6,66	14,21	25,46	40,23	57,83
5,5	0,59	2,54	7,14	15,50	28,17	45,03	65,37
5,6	0,61	2,67	7,67	16,92	31,18	50,42	73,93
5,7	0,62	2,80	8,23	18,48	34,53	56,49	83,66
5,8	0,64	2,95	8,84	20,19	38,25	63,33	94,73
5,9	0,65	3,10	9,50	22,07	42,39	71,02	107,32
6,0	0,67	3,26	10,21	24,13	47,00	79,69	121,64
6,1	0,68	3,44	10,98	26,39	52,14	89,45	137,95
6,2	0,70	3,62	11,82	28,87	57,86	100,45	156,51
6,3	0,72	3,81	12,71	31,60	64,24	112,86	177,65
6,4	0,73	4,02	13,68	34,60	71,34	126,85	201,74
6,5	0,75	4,23	14,73	37,90	79,25	142,62	229,20
6,6	0,77	4,46	15,87	41,52	88,07	160,42	260,50

Table 8 : Function Γ_C [X+1]

X	Γ_C [X+1]	X	Γ_C [X+1]
2,6	3,717	3,4	10,136
2,7	4,171	3,5	11,632
2,8	4,694	3,6	13,381
2,9	5,299	3,7	15,431
3,0	6,000	3,8	17,838
3,1	6,813	3,9	20,667
3,2	7,757	4,0	24,000
3,3	8,855		

3.1.2 Cumulative damage ratio

The cumulative damage ratio is to be obtained from the following formula:

$D = K_{cor} [\alpha D_F + (1 - \alpha) D_B]$

where:

K_{cor} : Corrosion factor, taken equal to:

- $K_{cor} = 1,0$ for dry compartments
- $K_{cor} = 1,1$ for ballast tanks having an effective coating protection
- $K_{cor} = 1,5$ for cargo oil tanks

α : coefficient to be taken equal to 0,75

D_F : Cumulative damage ratio for ship in "Full load" condition, taken equal to:

$$D_F = \frac{1}{6}D_{aF} + \frac{1}{6}D_{bF} + \frac{1}{3}D_{cF} + \frac{1}{3}D_{dF}$$

D_B : Cumulative damage ratio for ship in "Operational load" condition, taken equal to:

$$D_B = \frac{1}{3}D_{aB} + \frac{1}{3}D_{bB} + \frac{1}{3}D_{cB}$$

D_{aF} , D_{bF} , D_{cF} , D_{dF} : Elementary damage ratios for load cases "a", "b", "c" and "d", respectively, in "Full load" condition, defined in [3.1.1]

D_{aB} , D_{bB} , D_{cB} : Elementary damage ratios for load cases "a", "b", and "c", respectively, in "Operational load" condition, defined in [3.1.1].

4 Stress range

4.1 General

4.1.1 Calculation point

Unless otherwise specified, stresses are to be determined at the hot spots indicated, for each detail, in the relevant figures in Ch 11, Sec 2.

4.1.2 Stress components

For the details in [1.2.2], the stresses to be used in the fatigue check are the normal stresses in the directions indicated, for each detail, in the relevant figures in Ch 11, Sec 2.

Where the fatigue check is required for details other than those in [1.2.2], the stresses to be used are the principal stresses at the hot spots which form the smallest angle with the crack rising surface.

4.2 Hot spot stress range

4.2.1 Elementary hot spot stress range

The elementary hot spot stress range $\Delta\sigma_{G,ij}$ is to be obtained, in N/mm^2, in accordance with:

- Ch 7, App 1, [6] for details where the stresses are to be calculated through a three-dimensional structural models
- [6.2] for details located at ends of ordinary stiffeners.

4.3 Notch stress range

4.3.1 Elementary notch stress range

The elementary notch stress range is to be obtained, in N/mm^2, from the following formula:

$\Delta\sigma_{N,ij} = K_{C,ij} \Delta\sigma_{N0,ij}$

with:

$\Delta\sigma_{N0,ij} = 0,7 K_F K_m \Delta\sigma_{G,ij}$

where:

K_F : Fatigue notch factor, equal to:

$$K_F = \lambda\sqrt{\frac{\theta}{30}}$$

for flame-cut edges, K_F may be taken equal to 2,0

λ : Coefficient depending on the weld configuration, and given in Tab 9

θ : Mean weld toe angle, in degrees, without being taken less than 30°. Unless otherwise specified, θ may be taken equal to:

- 30° for butt joints
- 45° for T joints or cruciform joints

K_m : Stress concentration factor, taking account of misalignment, defined in Tab 10, and to be taken not less than 1

$\Delta\sigma_{G,ij}$: Elementary hot spot stress range, defined in [4.2.1]

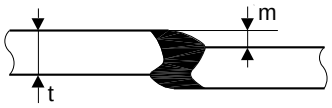
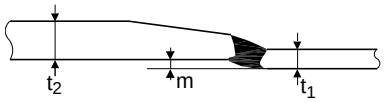
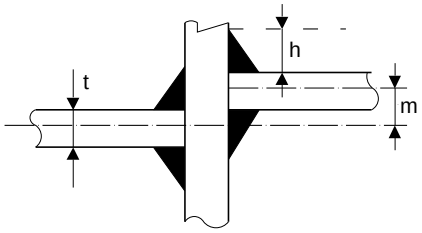
$$K_{C,ij} = \frac{0,4R_{eH}}{\Delta\sigma_{N0,ij}} + 0,6 \text{ with } 0,8 \leq K_{C,ij} \leq 1$$

Table 9 : Weld coefficient λ

Weld configuration			Grind welds	Other cases
Butt joints:	• Stresses parallel to weld axis	- full penetration	λ = 1,85	λ = 2,10
		- partial penetration	λ = 1,85	λ = 2,10
	• Stresses perpendicular to weld axis	- full penetration	λ = 2,10	λ = 2,40
		- partial penetration	λ = 3,95	λ = 4,50
T joints:	• Stresses parallel to weld axis; fillet weld and partial penetration		λ = 1,60	λ = 1,80
	• Stresses perpendicular to weld axis and in plane of continuous element (**1**); fillet weld and partial penetration		λ = 1,90	λ = 2,15
	• Stresses perpendicular to weld axis and in plane of welded element; fillet weld and partial penetration		λ = 3,95	λ = 4,50
Cruciform joints:	• Full penetration		λ = 1,85	λ = 2,10
	• Partial penetration		λ = 2,05	λ = 2,35

(1) This case includes the hot spots indicated in the sheets of special structural details in Ch 11, Sec 2 relevant to the connections of longitudinal ordinary stiffeners with transverse primary supporting members

Table 10 : Stress concentration factor K_m for misalignment

Axial misalignment between flat plates: $K_m = 1 + \frac{3(m - m_0)}{t}$	
Axial misalignment between flat plates of different thicknesses: $K_m = 1 + \frac{6(m - m_0)}{t_1} \frac{t_1^{3/2}}{t_1^{3/2} + t_2^{3/2}}$	
Axial misalignment in fillet welded cruciform joints: $K_m = 1 + \frac{m - m_0}{t + h}$	

Note 1:

m : Actual misalignment between two abutting members

m_0 : Permissible misalignment for the detail considered, given in Ch 11, Sec 2, or any other agreed document according to [1.2.1]

Note 2: When the actual misalignment m is lower than the permissible misalignment m_0, K_m is to be taken equal to 1

5 Checking criterion

5.1 Damage ratio

5.1.1 The cumulative damage ratio D, calculated according to [3.1.2], is to comply with the following criterion:

$$D \leq \frac{1}{\gamma_R}$$

6 Structural details located at ends of ordinary stiffeners

6.1 General

6.1.1 For the fatigue check of connections located at ends of ordinary stiffeners, the elementary hot spot stress range $\Delta\sigma_{G,ij}$ may be calculated as indicated in [6.2].

6.2 Determination of elementary hot spot stress range

6.2.1 Nominal local stress

For each load case "a", "b", "c" and "d", "-max" and "-min", the nominal local stress $\sigma\ell$ applied to the ordinary stiffener, is to be obtained, in N/mm^2, from the following formula:

$$\sigma_\ell = \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{12w}\left(1 - \frac{s}{2\ell}\right) s\ell^2 10^3$$

where:

w : Net section modulus, in cm^3, of the stiffener, with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [3.4]

s : Spacing, in m, of ordinary stiffeners

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 4, Sec 3, [3.2]

β_b : Coefficient to be taken as follows:

- $\beta_b = 1,0$ in the case of an ordinary stiffener without brackets at ends
- $\beta_b = \beta_{b1}$ defined in Ch 7, Sec 2, [3.4.3], in the case of an ordinary stiffener with a bracket of length not greater than 0,2 ℓ at one end
- $\beta_b = \beta_{b2}$ defined in Ch 7, Sec 2, [3.4.4], in the case of an ordinary stiffener with equal brackets of length not greater than 0,2 ℓ at ends.

6.2.2 Elementary hot spot stress range

For each load case "a", "b", "c" and "d", the elementary hot spot stress range $\Delta\sigma_{G,ij}$ is to be obtained, in N/mm^2, from the following formula:

$$\Delta\sigma_{G,ij} = |\sigma_{G\,(i\text{-}max)} - \sigma_{G\,(i\text{-}min)}| + K\ell\,\Delta\sigma_{DEF,ij}$$

where:

$$\sigma_{G\,(i\text{-}max)} = K_N\,(K_h\,\sigma_h + K\ell\,K_S\,\sigma\ell)_{(i\text{-}max)}$$

$$\sigma_{G\,(i\text{-}min)} = K_N\,(K_h\,\sigma_h + K\ell\,K_S\,\sigma\ell)_{(i\text{-}min)}$$

$\Delta\sigma_{DEF,ij}$: Nominal stress range due to the local deflection of the ordinary stiffener to be obtained, in N/mm^2, from the following formula:

$$\Delta\sigma_{DEF,ij} = \frac{4(\Delta\delta)EI}{w\ell^2}10^{-5}$$

σ_h : Nominal hull girder stress for the load case "i-max" or "i-min" considered, to be determined as indicated in [2.3.1]

$\sigma\ell$: Nominal local stress for the load case "i-max" or "i-min" considered, to be determined as indicated in [6.2.1]

K_N : Coefficient taking account of North Atlantic navigation, taken equal to 1

K_h, $K\ell$: Geometrical stress concentration factors for overall hull girder stress and local stress, as given in Pt B, Ch 11, App 2

K_S : Coefficient taking account of the stiffener section geometry, equal to:

$$K_S = 1 + \left[\frac{t_f(a^2 - b^2)}{2w_B}\right]\left[1 - \frac{b}{a+b}\left(1 + \frac{w_B}{w_A}\right)\right]10^{-3}$$

a, b : Eccentricities of the stiffener, in mm, defined in Fig 3

Bulb sections may be taken as equivalent to an angle profile, as defined in Ch 4, Sec 3, [3.1.2] with:

$a = 0,75\ b_f$

$b = 0,25\ b_f$

t_f : Face plate net thickness, in mm

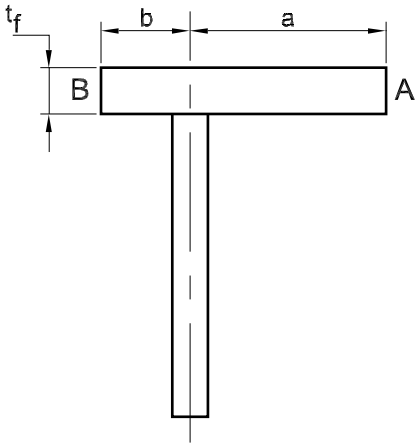
b_f : Face plate width, in mm

w_A, w_B : Net section moduli of the stiffener, in cm^3, in A and B, respectively, about its vertical axis and without attached plating

$\Delta\delta$: Local range of deflection, in mm, of the ordinary stiffener (total amplitude of vertical deflection between the two adjacent primary members supporting the ordinary stiffener under consideration)

I : Net moment of inertia, in cm^4, of the ordinary stiffener with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [3.4].

Figure 3 : Geometry of a stiffener section



Appendix 1 Analyses Based on Three-Dimensional Models

Symbols

For the symbols not defined in this Section, refer to Ch 1, Sec 2, [2.1.1].

$\alpha = \frac{T_1}{T}$

γ_{S1} , γ_{W1} : Partial safety factors, defined in Ch 7, Sec 3.

ρ : Sea water density, taken equal to 1,025 t/m^3

g : Gravity acceleration, in m/s^2: g = 9,81 m/s^2

h_1 : Reference values of the ship relative motions in the upright ship condition, defined in Ch 5, Sec 3, [3.3]

h_2 : Reference values of the ship relative motions in the inclined ship conditions, defined in Ch 5, Sec 3, [3.3]

M_{SW} : Still water bending moment, in kN.m, at the hull transverse section considered

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.2]

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1]

M_{WV} : Vertical wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1], having the same sign as M_{SW}

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1]

Q_{SW} : Still water shear force, in kN, at the hull transverse section considered

Q_{WV} : Vertical wave shear force, in kN, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.4], having:

- where M_{WV} is positive (hogging condition):
  - a positive sign for x < 0,5L
  - a negative sign for x ≥ 0,5L
- where M_{WV} is negative (sagging condition):
  - a negative sign for x < 0,5L
  - a positive sign for x ≥ 0,5L

T_1 : draught, in m, corresponding to the loading condition considered

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6].

1 General

1.1 Application

1.1.1 The requirements of this Appendix apply for the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members which are to be analysed through three-dimensional structural models, according to Ch 7, Sec 3.

The analysis application procedure is shown graphically in Fig 1.

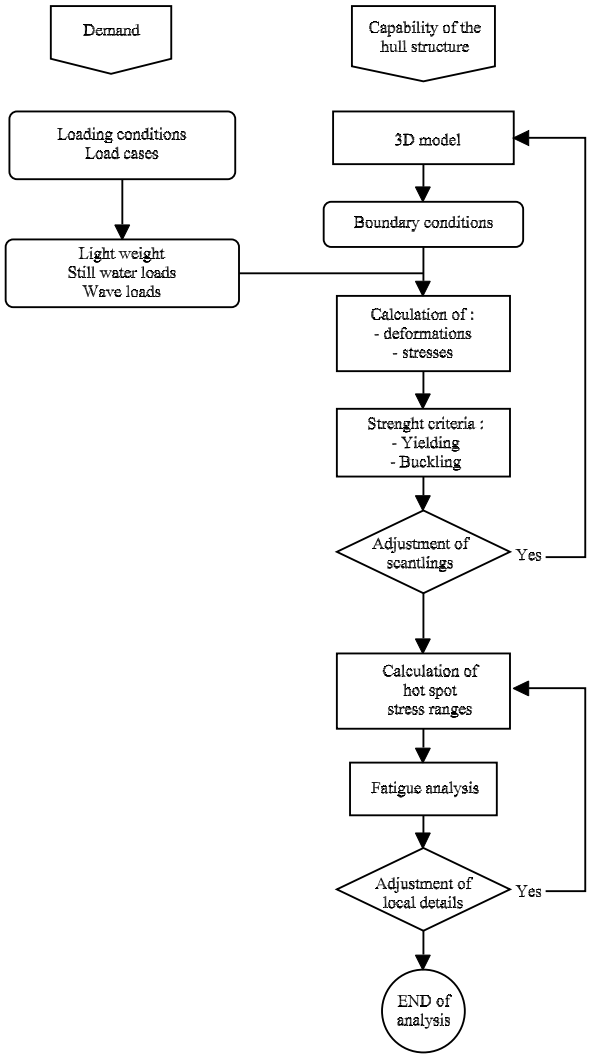
1.1.2 This Appendix deals with that part of the structural analysis which aims at calculating:

- the stresses in the primary supporting members in the midship area and, when necessary, in other areas, which are to be used in the yielding and buckling checks
- the hot spot stress ranges in the structural details which are to be used in the fatigue check.

1.1.3 The yielding and buckling checks of primary supporting members are to be carried out according to Ch 7, Sec 3.

The fatigue check of structural details is to be carried out according to Ch 7, Sec 4.

Figure 1 : Application procedure of the analyses based on three-dimensional models



1.2 Information required

1.2.1 The following information is necessary to perform these structural analyses:

- general arrangement
- capacity plan
- structural plans of the areas involved in the analysis
- longitudinal sections and decks.

2 Analysis criteria

2.1 General

2.1.1 All primary supporting members in the midship regions are normally to be included in the three-dimensional model, with the purpose of calculating their stress level and verifying their scantlings.

When the primary supporting member arrangement is such that the Society can accept that the results obtained for the midship region are extrapolated to other regions, no additional analyses are required. Otherwise, analyses of the other regions are to be carried out.

2.2 Finite element model analysis

2.2.1 For ships more than 150 m in length, finite element models, built according to [3.2] and [3.4], are generally to be adopted.

The analysis of primary supporting members is to be carried out on fine mesh models, as defined in [3.4.3].

2.3 Beam model analysis

2.3.1 Beam models may be adopted in lieu of the finite element models for cases specified in Ch 7, Sec 3, [1.1.2] provided that:

- primary supporting members are not so stout that the beam theory is deemed inapplicable by the Society
- their behaviour is not substantially influenced by the transmission of shear stresses through the shell plating.

In any case, finite element models may need to be adopted when deemed necessary by the Society on the basis of the ship structural arrangement.

2.4 Structural detail analysis

2.4.1 Structural details in Ch 7, Sec 4, [1.2.3], for which a fatigue analysis is to be carried out, are to be modelled as specified in [6].

3 Structural modelling of primary supporting members

3.1 Model construction

3.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected.

Ordinary stiffeners are also to be represented in the model in order to reproduce the stiffness and inertia of the actual hull girder structure. The way ordinary stiffeners are represented in the model depends on the type of model (beam or finite element), as specified in [3.4] and [3.5].

3.1.2 Net scantlings

All the elements in [3.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2, [1]. Therefore, also the hull girder stiffness and inertia to be reproduced by the model are those obtained by considering the net scantlings of the hull structures.

3.2 Model extension

3.2.1 The longitudinal extension of the structural model is to be such that:

- the hull girder stresses in the area to be analysed are properly taken into account in the structural analysis
- the results in the areas to be analysed are not influenced by the unavoidable inaccuracy in the modelling of the boundary conditions.

3.2.2 In the case of structural symmetry with respect to the ship centreline longitudinal plane, the hull structures may be modelled over half the ship breadth.

3.3 Finite element modelling criteria

3.3.1 Modelling of primary supporting members

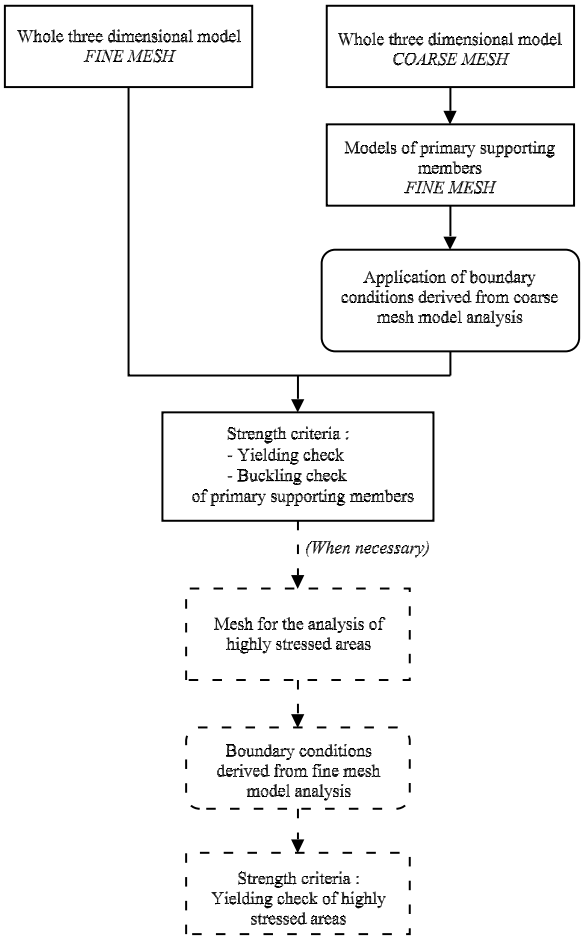
The analysis of primary supporting members based on fine mesh models, as defined in [3.4.3], is to be carried out by applying one of the following procedures (see Fig 2), depending on the computer resources:

- an analysis of the whole three-dimensional model based on a fine mesh
- an analysis of the whole three-dimensional model based on a coarse mesh, as defined in [3.4.2], from which the nodal displacements or forces are obtained to be used as boundary conditions for analyses based on fine mesh models of primary supporting members, e.g.:
  - transverse rings
  - double bottom girders
  - side girders
  - deck girders
  - primary supporting members of transverse bulkheads
  - primary supporting members which appear from the analysis of the whole model to be highly stressed.

3.3.2 Modelling of the most highly stressed areas

The areas which appear from the analyses based on fine mesh models to be highly stressed may be required to be further analysed, using the mesh accuracy specified in [3.4.4].

Figure 2 : Finite element modelling criteria



3.4 Finite element models

3.4.1 General

Finite element models are generally to be based on linear assumptions. The mesh is to be executed using membrane or shell elements, with or without mid-side nodes.

Meshing is to be carried out following uniformity criteria among the different elements.

In general, for some of the most common elements, the quadrilateral elements are to be such that the ratio between the longer side length and the shorter side length does not exceed 4 and, in any case, is less than 2 for most elements. Their angles are to be greater than 60° and less than 120°. The triangular element angles are to be greater than 30° and less than 120°.

Further modelling criteria depend on the accuracy level of the mesh, as specified in [3.4.2] to [3.4.4].

3.4.2 Coarse mesh

The number of nodes and elements is to be such that the stiffness and inertia of the model properly represent those of the actual hull girder structure, and the distribution of loads among the various load carrying members is correctly taken into account.

To this end, the structural model is to be built on the basis of the following criteria:

- ordinary stiffeners contributing to the hull girder longitudinal strength and which are not individually represented in the model are to be modelled by rod elements and grouped at regular intervals
- webs of primary supporting members may be modelled with only one element on their height
- face plates may be simulated with bars having the same cross-section
- the plating between two primary supporting members may be modelled with one element stripe
- holes for the passage of ordinary stiffeners or small pipes may be disregarded
- manholes (and similar discontinuities) in the webs of primary supporting members may be disregarded, but the element thickness is to be reduced in proportion to the hole height and the web height ratio.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

3.4.3 Fine mesh

The ship structure may be considered as finely meshed when each longitudinal ordinary stiffener is modelled; as a consequence, the standard size of finite elements used is based on the spacing of ordinary stiffeners.

The structural model is to be built on the basis of the following criteria:

- webs of primary members are to be modelled with at least three elements on their height
- the plating between two primary supporting members is to be modelled with at least two element stripes
- the ratio between the longer side and the shorter side of elements is to be less than 3 in the areas expected to be highly stressed
- the holes for the passage of ordinary stiffeners may be disregarded.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

3.4.4 Mesh for the analysis of structural details

The structural modelling is to be accurate; the mesh dimensions are to be such as to enable a faithful representation of the stress gradients. The use of membrane elements is only allowed when significant bending effects are not present; in other cases, elements with general behaviour are to be used.

3.5 Beam models

3.5.1 Beams representing primary supporting members

Primary supporting members are to be modelled by beam elements with shear strain, positioned on their neutral axes, whose inertia characteristics are to be calculated as specified in Ch 4, Sec 3, [4].

3.5.2 Torsional moments of inertia

Whenever the torsional effects of the modelling beams are to be taken into account (e.g. for modelling the double bottom, hopper tanks and lower stools), their net torsional moments of inertia are obtained, in cm^4, from the following formulae:

- for open section beams (see Fig 3):

$$I_T = \frac{1}{3}\sum_i (t_i^3 \ell_i) 10^{-4}$$

- for beams of double skin structures (see Fig 4):

$$I_T = \frac{t_1 t_2 (b_1 + b_2) H_D^2}{2(t_1 + t_2)} 10^{-4}$$

where:

Σi : Sum of all the profile segments that constitute the beam section

t_i, ℓ_i : Net thickness and length, respectively, in mm, of the i-th profile segment of the beam section

t_1, t_2 : Net thickness, in mm, of the inner and outer plating, respectively

b_1, b_2 : Distances, in mm, from the beam considered to the two adjacent beams

H_D : Height, in mm, of the double skin.

Figure 3 : Open section beams

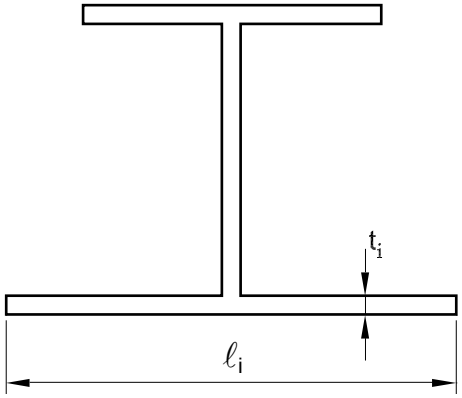
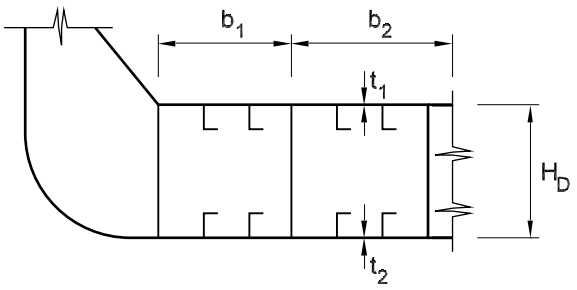


Figure 4 : Beams of double skin structures



3.5.3 Primary supporting members with variable cross-section

In the case of primary supporting members with variable cross-section, the inertia characteristics of the modelling beams may be assumed as a constant and equal to their average value along the length of the elements themselves.

3.5.4 Modelling of primary supporting member ends

The presence of end brackets may be disregarded; in such case their presence is also to be neglected for the evaluation of the beam inertia characteristics.

Rigid end beams are generally to be used to connect ends of the various primary supporting members, such as:

- floors and side vertical primary supporting members
- bottom girders and vertical primary supporting members of transverse bulkheads
- cross ties and side/longitudinal bulkhead primary supporting members.

3.5.5 Beams representing hull girder characteristics

The stiffness and inertia of the hull girder are to be taken into account by longitudinal beams positioned as follows:

- on deck and bottom in way of side shell and longitudinal bulkheads, if any, for modelling the hull girder bending strength
- on deck, side shell, longitudinal bulkheads, if any, and bottom for modelling the hull girder shear strength.

3.6 Boundary conditions of the whole three-dimensional model

3.6.1 Structural model extended over at least three cargo tank/hold lengths

The whole three-dimensional model is assumed to be fixed at its aft end, while shear forces and bending moments are applied at its fore end to ensure equilibrium (see Article [4]).

At the fore end section, rigid constraint conditions are to be applied to all nodes located on longitudinal members, in such a way that the transverse section remains plane after deformation.

When the hull structure is modelled over half the ship's breadth (see [3.2.2]), in way of the ship centreline longitudinal plane, symmetry or anti-symmetry boundary conditions as specified in Tab 1 are to be applied, depending on the loads applied to the model (symmetrical or anti-symmetrical, respectively).

Table 1 : Symmetry and anti-symmetry conditions in way of the ship centreline longitudinal plane

Boundary conditions	DISPLACEMENTS in directions**(1)**		
	X	Y	Z
Symmetry	free	fixed	free
Anti-symmetry	fixed	free	fixed

Boundary conditions	ROTATION around axes **(1)**		
	X	Y	Z
Symmetry	fixed	free	fixed
Anti-symmetry	free	fixed	free

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [10].

4 Load models of primary supporting members

4.1 General

4.1.1 Loading conditions and load cases in intact conditions

The still water and wave loads are to be calculated for the most severe loading conditions as given in the loading manual, with a view to maximizing the stresses in the longitudinal structure and primary supporting members.

The following loading conditions are generally to be considered:

- homogeneous loading conditions at draught T
- non-homogeneous loading conditions at draught T, when applicable
- partial loading conditions at the relevant draught
- ballast conditions at the relevant draught.

The wave local and hull girder loads are to be calculated in the mutually exclusive load cases “a”, “b”, “c” and “d” in Ch 5, Sec 4.

4.1.2 Loading conditions and load cases in flooding conditions

When applicable, the pressures in flooding conditions are to be calculated according to Ch 5, Sec 6, [7].

4.1.3 Lightweight

The lightweight of the modelled portion of the hull is to be uniformly distributed over the length of the model in order to obtain the actual longitudinal distribution of the still water bending moment.

4.1.4 Models extended over half breadth of ship

When the ship is symmetrical with respect to her centreline longitudinal plane and the hull structure is modelled over half the ship breadth, non-symmetrical loads are to be broken down into symmetrical and anti-symmetrical loads and applied separately to the model with symmetry and anti-symmetry boundary conditions in way of the ship centreline longitudinal plane (see [3.6]).

4.2 Local loads

4.2.1 General

Still water loads include:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal loads, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave loads include:

- the wave pressure, defined in [4.2.2] for each load case “a”, “b”, “c” and “d”
- the inertial loads, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case “a”, “b”, “c” and “d”.

4.2.2 Wave loads

The wave pressure at any point of the model is obtained from the formulae in Tab 2 for upright ship conditions (load cases “a” and “b”) and in Tab 3 for inclined ship conditions (load cases “c” and “d”).

Table 2 : Wave pressure in upright ship conditions (load cases “a” and “b”)

Location	Wave pressure p_W, in kN/m²	C_1	
		crest	trough **(1)**
Bottom and sides below the waterline with: $z \le T_1 - h$	$C_1 \rho g h e^{\frac{-2\pi(T_1 - z)}{\alpha L}}$	1,0	– 1,0
Sides below the waterline with: $T_1 - h < z \le T_1$	$C_1 \rho g h e^{\frac{-2\pi(T_1 - z)}{\alpha L}}$	1,0	$\frac{z - T_1}{h}$
Sides above the waterline: $z > T_1$	$C_1 \rho g (T_1 + h - z)$	1,0	0,0

(1) The wave pressure for load case “b, trough” is to be used only for the fatigue check of structural details.

Note 1:

$h = \alpha^{1/4} C_{F1} h_1$

C_{F1} : Combination factor, to be taken equal to:

- $C_{F1} = 1,0$ for load case “a”
- $C_{F1} = 0,5$ for load case “b”.

Table 3 : Wave pressure in inclined ship conditions (load cases “c” and “d”)

Location	Wave pressure p_W, in kN/m²	C_2 (negative roll angle)	
		$y \geq 0$	$y < 0$
Bottom and sides below the waterline with: $z \leq T_1 - h$	$C_2 C_{F2} \alpha^{1/4} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{\alpha L}} + A_R y e^{\frac{-\pi(T_1 - z)}{\alpha L}} \right]$	1,0	1,0
Sides below the waterline with: $T_1 - h < z \leq T_1$	$C_2 C_{F2} \alpha^{1/4} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{\alpha L}} + A_R y e^{\frac{-\pi(T_1 - z)}{\alpha L}} \right]$	1,0	$\frac{T_1 - z}{h}$
Sides above the waterline: $z > T_1$	$C_2 \rho g \left[T_1 + C_{F2} \alpha^{1/4} \left(\frac{y}{B_W} h_1 + A_R y \right) - z \right]$	1,0	0,0

Note 1:

$h = \alpha^{1/4} C_{F2} h_2$

C_{F2} : Combination factor, to be taken equal to:

- $C_{F2} = 1,0$ for load case “c”
- $C_{F2} = 0,5$ for load case “d”

B_W : Moulded breadth, in m, measured at the waterline at draught T_1, at the hull transverse section considered

A_R : Roll amplitude, defined in Ch 5, Sec 3, [2.4.1].

4.2.3 Distributed loads

Distributed loads are to be applied to the plating panels.

In the analyses carried out on the basis of membrane finite element models or beam models, the loads distributed perpendicularly to the plating panels are to be applied on the ordinary stiffeners proportionally to their areas of influence. When ordinary stiffeners are not modelled or are modelled with rod elements (see [3.4]), the distributed loads are to be applied to the primary supporting members actually supporting the ordinary stiffeners.

4.2.4 Concentrated loads

When the elements directly supporting the concentrated loads are not represented in the structural model, the loads are to be distributed on the adjacent structures according to the actual stiffness of the structures which transmit them.

In the analyses carried out on the basis of coarse mesh finite element models or beam models, concentrated loads applied in five or more points almost equally spaced inside the same span may be applied as equivalent linearly distributed loads.

4.2.5 Cargo in sacks, bales and similar packages

The vertical loads are comparable to distributed loads. The loads on vertical walls may be disregarded.

4.2.6 Other cargoes

The modelling of cargoes other than those mentioned under [4.2.3] to [4.2.5] will be considered by the Society on a case-by-case basis.

4.3 Hull girder loads

4.3.1 The hull girder loads are constituted by:

- the still water and wave vertical bending moments
- the horizontal wave bending moment
- the still water and wave vertical shear forces,

and are to be applied at the model fore end section. The shear forces are to be distributed on the plating according to the theory of bidimensional flow of shear stresses.

These loads are to be applied separately for the following two conditions:

- maximal bending moments at the middle of the central tank/hold: the hull girder loads applied at the fore end section are to be such that the values of the hull girder loads in Tab 4 are obtained
- maximal shear forces in way of the aft transverse bulkhead of the central tank/hold: the hull girder loads applied at the fore end section are to be such that the values of the hull girder loads in Tab 5 are obtained.

Table 4 : Hull girder loads - Maximal bending moments at the middle of the model

Ship condition	Load case	Vertical bending moments at the middle of the model		Horizontal wave bending moment at the middle of the model	Vertical shear forces at the middle of the model	
		Still water	Wave		Still water	Wave
Upright	"a" crest	$\gamma_{S1} M_{SW}$	$0,625\ \gamma_{W1} M_{WV,H}$	0	0	0
	"a" trough	$\gamma_{S1} M_{SW}$	$0,625\ \gamma_{W1} M_{WV,S}$	0	0	0
	"b"	$\gamma_{S1} M_{SW}$	$0,625\ \gamma_{W1} M_{WV,S}$	0	0	0
Inclined	"c"	$\gamma_{S1} M_{SW}$	$0,25\ \gamma_{W1} M_{WV}$	$0,625\ \gamma_{W1} M_{WH}$	$\gamma_{S1} Q_{SW}$	$0,25\ \gamma_{W1} Q_{WV}$
	"d"	$\gamma_{S1} M_{SW}$	$0,25\ \gamma_{W1} M_{WV}$	$0,625\ \gamma_{W1} M_{WH}$	$\gamma_{S1} Q_{SW}$	$0,25\ \gamma_{W1} Q_{WV}$
Note 1: Hull girder loads are to be calculated at the middle of the model.						

Table 5 : Hull girder loads - Maximal shear forces in way of the aft bulkhead of the model

Ship condition	Load case	Vertical bending moments in way of the aft bulkhead of the model		Vertical shear forces in way of the aft bulkhead of the model	
		Still water	Wave	Still water	Wave
Upright	"a" crest	$\gamma_{S1} M_{SW}$	$0,4\ \gamma_{W1} M_{WV}$	$\gamma_{S1} Q_{SW}$	$0,625\ \gamma_{W1} Q_{WV}$
	"a" trough	$\gamma_{S1} M_{SW}$	$0,4\ \gamma_{W1} M_{WV}$	$\gamma_{S1} Q_{SW}$	$0,625\ \gamma_{W1} Q_{WV}$
	"b"	$\gamma_{S1} M_{SW}$	$0,4\ \gamma_{W1} M_{WV}$	$\gamma_{S1} Q_{SW}$	$0,625\ \gamma_{W1} Q_{WV}$
Inclined	"c"	$\gamma_{S1} M_{SW}$	$0,4\ \gamma_{W1} M_{WV}$	$\gamma_{S1} Q_{SW}$	$0,25\ \gamma_{W1} Q_{WV}$
	"d"	$\gamma_{S1} M_{SW}$	$0,4\ \gamma_{W1} M_{WV}$	$\gamma_{S1} Q_{SW}$	$0,25\ \gamma_{W1} Q_{WV}$
Note 1: Hull girder loads are to be calculated in way of the aft bulkhead of the model.					

5 Stress calculation

5.1 Analysis based on finite element models

5.1.1 Stresses induced by local and hull girder loads

Both local and hull girder loads are to be directly applied to the model, as specified in [4.3.1] so that the stresses calculated by the finite element program include the contribution of both local and hull girder loads.

5.1.2 Stress components

Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 5. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 2, [10].

The following stress components are to be calculated at the centroid of each element:

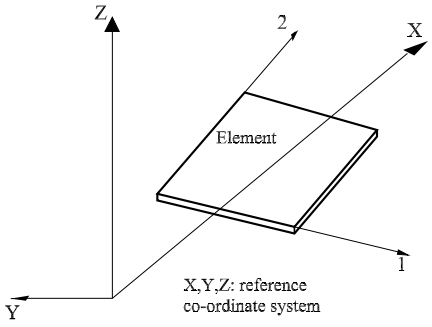
- the normal stresses σ_1 and σ_2 in the directions of the element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

5.1.3 Stress calculation points

Stresses are generally calculated by the computer programs for each element. The values of these stresses are to be used for carrying out the checks required.

Figure 5 : Reference and element co-ordinate systems



5.2 Analysis based on beam models

5.2.1 Stresses induced by local and hull girder loads

Since beam models generally have limited extension compared with the ship length, only local loads are directly applied to the structural model, as specified in [4.2]. Therefore, the stresses calculated by the beam program include the contribution of local loads only. Hull girder stresses are to be calculated separately and added to the stresses induced by local loads.

5.2.2 Stress components

The following stress components are to be calculated:

- the normal stress σ_1 in the direction of the beam axis
- the shear stress τ_{12} in the direction of the local loads applied to the beam
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + 3\tau_{12}^2}$$

5.2.3 Stress calculation points

Stresses are to be calculated at least in the following points of each primary supporting member:

- in the primary supporting member span where the maximum bending moment occurs
- at the connection of the primary supporting member with other structures, assuming as resistant section that formed by the member, the bracket (if any and if represented in the model) and the attached plating
- at the toe of the bracket (if any and if represented in the model) assuming as resistant section that formed by the member and the attached plating.

The values of the stresses are to be used for carrying out the checks required.

6 Fatigue analysis

6.1 Elementary hot spot stress range calculation

6.1.1 General

The requirements of this Article apply for calculating the elementary hot spot stress range for the fatigue check of structural details at the connections of primary supporting members analysed through a three-dimensional structural model. The fatigue check of these details is to be carried out in accordance with the general requirements of Ch 7, Sec 4, [1] to Ch 7, Sec 4, [5].

The definitions in Ch 7, Sec 4, [1.3] apply.

6.1.2 Net scantlings

The three-dimensional structural model is to be built considering all the structures with their net scantlings according to Ch 4, Sec 2, [1].

6.1.3 Hot spot stresses directly obtained through finite element analysis

Where the structural detail is analysed through a finite element analysis based on a very fine mesh, the elementary hot spot stress range may be obtained as the difference between the maximum and minimum stresses induced by the wave loads in the hot spot considered.

The requirements for:

- the finite element modelling, and
- the calculation of the hot spot stresses and the hot spot stress range

are specified in [6.2].

6.1.4 Hot spot stresses directly obtained through the calculation of nominal stresses

Where the structural detail is analysed through a finite element analysis based on a mesh less fine than that in [6.1.3], the elementary hot spot stress range may be obtained by multiplying the nominal stress range, obtained as the difference between the maximum and minimum nominal stresses induced by the wave loads in the vicinity of the hot spot considered, by the appropriate stress concentration factors.

The requirements for:

- the finite element modelling
- the calculation of the nominal stresses and the nominal stress range
- the stress concentration factors
- the calculation of the hot spot stresses and the hot spot stress range

are specified in [6.3].

6.2 Hot spot stresses directly obtained through finite element analysis

6.2.1 Finite element model

In general, the determination of hot spot stresses necessitates carrying out a very fine mesh finite element analysis, further to a coarser mesh finite element analysis. The boundary nodal displacements or forces obtained from the coarser mesh model are applied to the very fine mesh model as boundary conditions.

The model extension is to be such as to enable a faithful representation of the stress gradient in the vicinity of the hot spot and to avoid it being incorrectly affected by the application of the boundary conditions.

6.2.2 Finite element modelling criteria

The finite element model is to be built according to the following requirements:

- the detail may be considered as being realised with no misalignment
- the size of finite elements located in the vicinity of the hot spot is to be about twice to three times the thickness of the structural member. Where the details is the connection between two or more members of different thickness, the thickness to be considered is that of the thinnest member
- the centre of the first element adjacent to a weld toe is to be located between the weld toe and 0,4 times the thickness of the thinnest structural member connected by the weld
- plating, webs and face plates of primary and secondary members are to be modelled by 4-node thin shell or 8-node solid elements. In the case of a steep stress gradient, 8-node thin shell elements or 20-node solid elements are recommended
- when thin shell elements are used, the structure is to be modelled at mid-face of the plates
- the aspect ratio of elements is to be not greater than 3.

6.2.3 Calculation of hot spot stresses

The hot spot stresses are to be calculated at the centroid of the first element adjacent to the hot spot.

The stress components to be considered are those specified in Ch 7, Sec 4, [3.1.2]. They are to be calculated at the surface of the plate in order to take into account the plate bending moment, where relevant.

Where the detail is the free edge of an opening (e.g. a cutout for the passage of an ordinary stiffener through a primary supporting member), fictitious truss elements with minimal stiffness may needed to be fitted along the edge to calculate the hot spot stresses.

6.2.4 Calculation of the elementary hot spot stress range

The elementary hot spot stress range is to be obtained, in N/mm^2, from the following formula:

$$\Delta\sigma_{S,ij} = |\sigma_{S,ij,max} - \sigma_{S,ij,min}|$$

where:

$\sigma_{S,ij,max}$, $\sigma_{S,ij,min}$: Maximum and minimum values of the hot spot stress, induced by the maximum and minimum loads, defined in Ch 7, Sec 4, [2.2] and Ch 7, Sec 4, [2.3]

i : Denotes the load case

j : Denotes the loading condition.

6.3 Hot spot stresses directly obtained through calculation of nominal stresses

6.3.1 Finite element model

A finite element is to be adopted, to be built according to the requirements in [3.3] and [3.4]. The areas in the vicinity of the structural details are to be modelled with fine mesh models, as defined in [3.4.3].

6.3.2 Calculation of the elementary nominal stress range

The elementary nominal stress range is to be obtained, in N/mm^2, from the following formula:

$$\Delta\sigma_{n,ij} = |\sigma_{n,ij,max} - \sigma_{n,ij,min}|$$

where:

$\sigma_{n,ij,max}$, $\sigma_{n,ij,min}$: Maximum and minimum values of the nominal stress, induced by the maximum and minimum loads, defined in Ch 7, Sec 4, [2.2] and Ch 7, Sec 4, [2.3]

i : Denotes the load case

j : Denotes the loading condition.

6.3.3 Calculation of the elementary hot spot stress range

The elementary hot spot stress range is to be obtained, in N/mm^2, from the following formula:

$$\Delta\sigma_{S,ij} = K_S \, \Delta\sigma_{n,ij}$$

where:

K_S : Stress concentration factor, defined in Ch 11, Sec 2, [2] for the relevant detail configuration

$\Delta\sigma_{n,ij}$: Elementary nominal stress range, defined in [6.3.2].

Appendix 2 Analyses of Primary Supporting Members Subjected to Wheeled Loads

1 General

1.1 Scope

1.1.1 The requirements of this Appendix apply for the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members subjected to wheeled loads which are to be analysed through three-dimensional structural models, according to Ch 7, Sec 3.

1.1.2 The purpose of these structural analyses is to determine:

- the distribution of the forces induced by the vertical acceleration acting on wheeled cargoes, among the various primary supporting members of decks, sides and possible bulkheads
- the behaviour of the above primary supporting members under the racking effects due to the transverse forces induced by the transverse acceleration acting on wheeled cargoes, when the number or location of transverse bulkheads are not sufficient to avoid such effects,

and to calculate the stresses in primary supporting members.

The above calculated stresses are to be used in the yielding and buckling checks.

In addition, the results of these analyses may be used, where deemed necessary by the Society, to determine the boundary conditions for finer mesh analyses of the most highly stressed areas.

1.1.3 When the behaviour of primary supporting members under the racking effects, due to the transverse forces induced by the transverse acceleration, is not to be determined, the stresses in deck primary supporting members may be calculated according to the simplified analysis in [6], provided that the conditions for its application are fulfilled (see [6.1]).

1.1.4 The yielding and buckling checks of primary supporting members are to be carried out according to Ch 7, Sec 3.

1.2 Application

1.2.1 The requirements of this Appendix apply to ships whose structural arrangement is such that the following assumptions may be considered as being applicable:

- primary supporting members of side and possible bulkheads may be considered fixed in way of the double bottom (this is generally the case when the stiffness of floors is at least three times that of the side primary supporting members)
- under transverse inertial forces, decks behave as beams loaded in their plane and supported at the ship ends; their effect on the ship transverse rings (side primary supporting members and deck beams) may therefore be simulated by means of elastic supports in the transverse direction or transverse displacements assigned at the central point of each deck beam.

1.2.2 When the assumptions in [1.2.1] are considered by the Society as not being applicable, the analysis criteria are defined on a case-by-case basis, taking into account the ship structural arrangement and loading conditions. In such cases, the analysis is generally to be carried out on the basis of a finite element model of the whole ship, built according to the requirements in Ch 7, App 1, as far as applicable.

1.3 Information required

1.3.1 The following information is necessary to perform these structural analyses:

- general arrangement
- structural plans of the areas involved in the analysis
- longitudinal sections and decks
- characteristics of vehicles loaded: load per axles, arrangement of wheels on axles, tyre dimensions.

1.4 Lashing of vehicles

1.4.1 The presence of lashing for vehicles is generally to be disregarded, but may be given consideration by the Society, on a case-by-case basis, at the request of the interested parties.

2 Analysis criteria

2.1 Finite element model analysis

2.1.1 For ships greater than 200 m in length, finite element models, built according to Ch 7, App 1, [3.4], are generally to be adopted.

The analysis of primary supporting members is to be carried out on fine mesh models, as defined in Ch 7, App 1, [3.4.3].

2.1.2 Areas which appear, from the primary supporting member analysis, to be highly stressed may be required to be further analysed through appropriately meshed structural models, as defined in Ch 7, App 1, [3.4.4].

2.2 Beam model analysis

2.2.1 For ships less than 200 m in length, beam models, built according to Ch 7, App 1, [3.5], may be adopted in lieu of the finite element models in [2.1], provided that:

- primary supporting members are not so stout that the beam theory is deemed inapplicable by the Society
- their behaviour is not substantially influenced by the transmission of shear stresses through the shell plating.

2.2.2 In any case, finite element models may need to be adopted when deemed necessary by the Society on the basis of the ship structural arrangement.

3 Structural modelling of primary supporting members

3.1 Model construction

3.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected. In particular, the following primary supporting members are to be included in the model:

- deck beams
- side primary supporting members
- primary supporting members of longitudinal and transverse bulkheads, if any
- pillars
- deck beams, deck girders and pillars supporting ramps and deck openings, if any.

3.1.2 Net scantlings

All the elements in [3.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2, [1].

3.2 Model extension

3.2.1 The structural model is to represent a hull portion which includes the zone under examination and which is repeated along the hull. The non-modelled hull parts are to be considered through boundary conditions as specified in [3.3].

In addition, the longitudinal extension of the structural model is to be such that the results in the areas to be analysed are not influenced by the unavoidable inaccuracy in the modelling of the boundary conditions.

3.2.2 Double bottom structures are not required to be included in the model, based on the assumptions in [1.2.1].

3.3 Boundary conditions of the three-dimensional model

3.3.1 Boundary conditions at the lower ends of the model

The lower ends of the model (i.e. the lower ends of primary supporting members of side and possible bulkheads) are to be considered as being clamped in way of the inner bottom.

3.3.2 Boundary conditions at the fore and aft ends of the model

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 1.

Table 1 : Symmetry conditions at the model fore and aft ends

DISPLACEMENTS in directions **(1)**			ROTATION around axes **(1)**		
X	Y	Z	X	Y	Z
fixed	free	free	free	fixed	fixed
(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [10].					

3.3.3 Additional boundary conditions at the fore and aft ends of models subjected to transverse loads

When the model is subjected to transverse loads, i.e. when the loads in inclined ship conditions (as defined in Ch 5, Sec 4) are applied to the model, the transverse displacements of the deck beams are to be obtained by means of a racking analysis and applied at the fore and aft ends of the model, in way of each deck beam.

For ships with a traditional arrangement of fore and aft parts, a simplified approximation may be adopted, when deemed acceptable by the Society, defining the boundary conditions without taking into account the racking calculation and introducing springs, acting in the transverse direction, at the fore and aft ends of the model, in way of each deck beam (see Fig 1). Each spring, which simulates the effects of the deck in way of which it is modelled, has a stiffness obtained, in kN/m, from the following formula:

$$R_D = \frac{24 E J_D s_a 10^3}{2x^4 - 4L_D x^3 + L_D^2\left(x^2 + 15{,}6\frac{J_D}{A_D}\right) + L_D^3 x}$$

where:

J_D : Net moment of inertia, in m^4, of the average cross-section of the deck, with the attached side shell plating

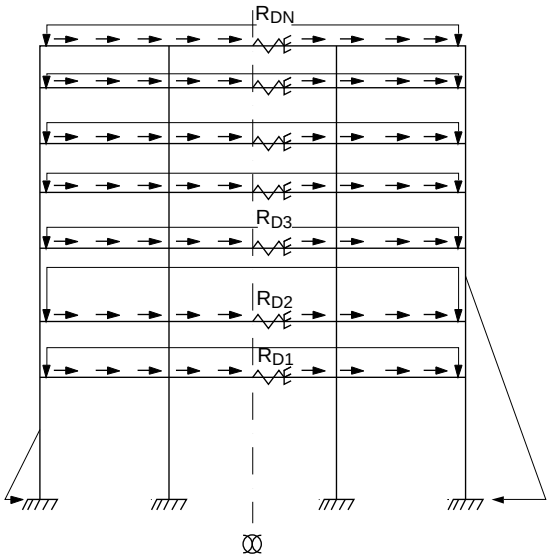
A_D : Net area, in m^2, of the average cross-section of deck plating

s_a : Spacing of side vertical primary supporting members, in m

x : Longitudinal distance, in m, measured from the transverse section at mid-length of the model to any deck end

L_D : Length of the deck, in m, to be taken equal to the ship length. Special cases in which such value may be reduced will be considered by the Society on a case-by-case basis.

Figure 1 : Springs at the fore and aft ends of models subjected to transverse loads



4 Load model

4.1 General

4.1.1 Hull girder and local loads

Only local loads are to be directly applied to the structural model.

The stresses induced by hull girder loads are to be calculated separately and added to the stresses induced by local loads.

4.1.2 Loading conditions and load cases: wheeled cargoes

The still water and wave loads are to be calculated for the most severe loading conditions as given in the loading manual, with a view to maximizing the stresses in primary supporting members.

The loads transmitted by vehicles are to be applied taking into account the most severe axle positions for the ship structures.

The wave local loads and hull girder loads are to be calculated in the mutually exclusive load cases “b” and “d” in Ch 5, Sec 4. Load cases “a” and “c” may be disregarded for the purposes of the structural analyses dealt with in this Appendix.

4.1.3 Loading conditions and load cases: dry uniform cargoes

When the ship decks are also designed to carry dry uniform cargoes, the loading conditions which envisage the transportation of such cargoes are also to be considered. The still water and wave loads induced by these cargoes are to be calculated for the most severe loading conditions, with a view to maximizing the stresses in primary supporting members.

The wave local loads and hull girder loads are to be calculated in the mutually exclusive load cases “b” and “d” in Ch 5, Sec 4. Load cases “a” and “c” may be disregarded for the purposes of the structural analyses dealt with in this Appendix.

4.2 Local loads

4.2.1 General

Still water loads include:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water forces induced by wheeled cargoes, defined in Ch 5, Sec 6, Tab 5.

Wave induced loads include:

- the wave pressure, defined in Ch 5, Sec 5, [2] for load cases “b” and “d”
- the inertial forces defined in Ch 5, Sec 6, Tab 5 for load cases “b” and “d”.

When the ship decks are also designed to carry dry uniform cargoes, local loads also include the still water and inertial pressures defined in Ch 5, Sec 6, [4]. Inertial pressures are to be calculated for load cases “b” and “d”.

4.2.2 Tyred vehicles

For the purpose of primary supporting members analyses, the forces transmitted through the tyres may be considered as concentrated loads in the tyre print centre.

The forces acting on primary supporting members are to be determined taking into account the area of influence of each member and the way ordinary stiffeners transfer the forces transmitted through the tyres.

4.2.3 Non-tyred vehicles

The requirements in [4.2.2] also apply to tracked vehicles. In this case, the print to be considered is that below each wheel or wheelwork.

For vehicles on rails, the loads transmitted are to be applied as concentrated loads.

4.2.4 Distributed loads

In the analyses carried out on the basis of beam models or membrane finite element models, the loads distributed perpendicularly to the plating panels are to be applied on the primary supporting members proportionally to their areas of influence.

4.3 Hull girder loads

4.3.1 The normal stresses induced by the hull girder loads in Tab 2 are to be added to the stresses induced in the primary supporting members by local loads.

Table 2 : Hull girder loads

Ship condition	Load case	Vertical bending moments at the middle of the model		Horizontal wave bending moment at the middle of the model
		Still water	Wave	
Upright	“b”	M_{SW}	0,625 $M_{WV,S}$	0
Inclined	“d”	M_{SW}	0,25 M_{WV}	0,625 M_{WH}

Note 1:

M_{SW} : Still water bending moment at the middle of the model, for the loading condition considered

$M_{WV,S}$: Sagging wave bending moments at the middle of the model, defined in Ch 5, Sec 2

M_{WV} : Wave bending moment at the middle of the model, defined in Ch 5, Sec 2, having the same sign as M_{SW}

M_{WH} : Horizontal wave bending moment at the middle of the model, defined in Ch 5, Sec 2.

Note 2: Lower values of wave bending moments may be considered on case-by-case basis, for wheeled loads applied only in specified limited sea states.

5 Stress calculation

5.1 Stresses induced by local and hull girder loads

5.1.1 Only local loads are directly applied to the structural model, as specified in [4.1.1]. Therefore, the stresses calculated by the program include the contribution of local loads only. Hull girder stresses are to be calculated separately and added to the stresses induced by local loads.

5.2 Analysis based on finite element models

5.2.1 Stress components

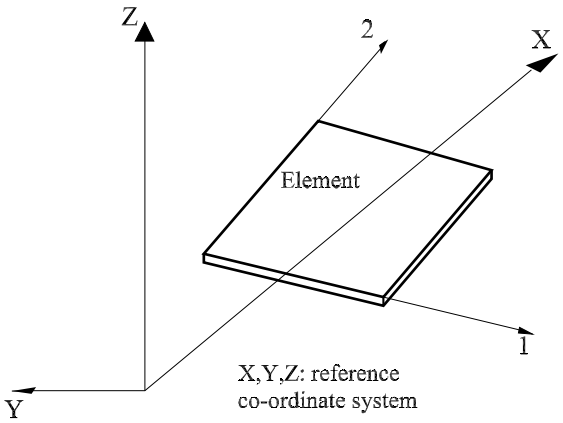
Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 2. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 2, [10].

The following stress components are to be calculated at the centroid of each element:

- the normal stresses σ_1 and σ_2 in the directions of element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

Figure 2 : Reference and element co-ordinate systems



5.2.2 Stress calculation points

Stresses are generally calculated by the computer programs for each element. The values of these stresses are to be used for carrying out the checks required.

5.3 Analysis based on beam models

5.3.1 Stress components

The following stress components are to be calculated:

- the normal stress σ_1 in the direction of the beam axis
- the shear stress τ_{12} in the direction of the local loads applied to the beam
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + 3\tau_{12}^2}$$

5.3.2 Stress calculation points

Stresses are to be calculated at least in the following points of each primary supporting member:

- in the primary supporting member span where the maximum bending moment occurs
- at the connection of the primary supporting member with other structures, assuming as resistant section that formed by the member, the bracket (if any and if represented in the model) and the attached plating
- at the toe of the bracket (if any and if represented in the model) assuming as resistant section that formed by the member and the attached plating.

The values of the stresses calculated in the above points are to be used for carrying out the checks required.

6 Grillage analysis of deck primary supporting members

6.1 Application

6.1.1 For the sole purpose of calculating the stresses in deck primary supporting members, due to the forces induced by the vertical accelerations acting on wheeled cargoes, these members may be subjected to the simplified two-dimensional analysis described in [6.2].

This analysis is generally considered as being acceptable for usual structural typology, where there are neither pillar lines, nor longitudinal bulkheads.

6.2 Analysis criteria

6.2.1 Structural model

The structural model used to represent the deck primary supporting members is a beam grillage model.

6.2.2 Model extension

The structural model is to represent a hull portion which includes the zone under examination and which is repeated along the hull. The non-modelled hull parts are to be considered through boundary conditions as specified in [3.3].

6.3 Boundary conditions

6.3.1 Boundary conditions at the fore and aft ends of the model

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 1.

6.3.2 Boundary conditions at the connections of deck beams with side vertical primary supporting members

Vertical supports are to be fitted at the nodes positioned in way of the connection of deck beams with side primary supporting members.

The contribution of flexural stiffness supplied by the side primary supporting members to the deck beams is to be simulated by springs, applied at their connections, having rotational stiffness, in the plane of the deck beam webs, obtained, in kN.m/rad, from the following formulae:

- for intermediate decks:

$$R_F = \frac{3E(J_1 + J_2)(\ell_1 + \ell_2)}{\ell_1^2 + \ell_2^2 - \ell_1 \ell_2} 10^{-5}$$

- for the uppermost deck:

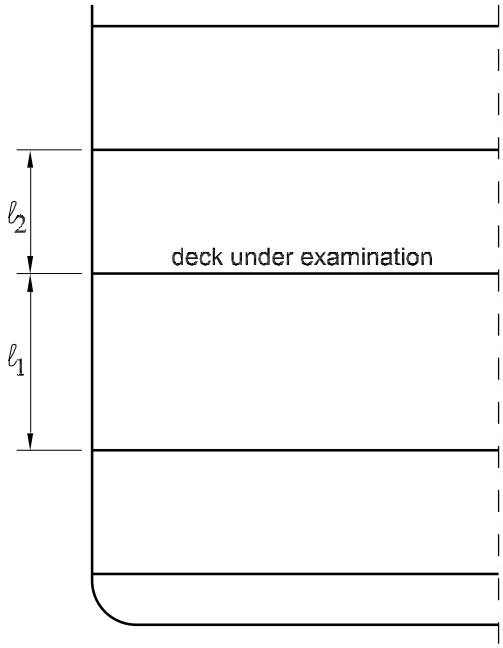
$$R_F = \frac{6EJ_1}{\ell_1} 10^{-5}$$

where:

ℓ_1, ℓ_2 : Heights of the 'tweendecks, in m, respectively below and above the deck under examination (see Fig 3)

J_1, J_2 : Net moments of inertia, in cm^4, of side primary supporting members with attached shell plating, relevant to the 'tweendecks, respectively below and above the deck under examination.

Figure 3 : 'Tweendeck heights for grillage analysis of deck primary supporting members



6.4 Load model

6.4.1 Hull girder and local loads are to be calculated and applied to the model according to Article [4].

Wave loads are to be calculated considering load case "b" only.

6.5 Stress calculation

6.5.1 Stress components are to be calculated according to [5.1] and [5.3].

Appendix 3 Analyses Based on Complete Ship Models

Symbols

γ_{S1} , γ_{W1} , γ_{S2} , γ_{W2} : Partial safety factors defined in Ch 7, Sec 3

Δ : Moulded displacement in seawater, in t

λ : Wave length, in m.

B_{WS} : Breadth at full load waterline, in m, defined in Ch 1, Sec 2, [4.4]

F : Froude number calculated at the maximum service speed, defined in Ch 5, Sec 2

g : Gravity acceleration, equal to 9,81 m/s^2

L : Rule length, in m

T_R : Roll period, in s, defined in Ch 5, Sec 3, [2.4.1]

1 General

1.1 Application

1.1.1 The requirements of this Appendix apply for the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members which are to be analysed through a complete ship model, according to Ch 7, Sec 3.

1.1.2 This Appendix deals with that part of the structural analysis which aims at calculating the stresses in the primary supporting members and more generally in the hull plating, to be used for yielding and buckling checks.

1.1.3 The yielding and buckling checks of primary supporting members are to be carried out according to Ch 7, Sec 3.

2 Structural modelling

2.1 Model construction

2.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected.

Ordinary stiffeners are also to be represented in the model in order to reproduce the stiffness and the inertia of the actual hull girder structure.

2.1.2 Net scantlings

All the elements in [2.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2. Therefore, also the hull girder stiffness and inertia to be reproduced by the model are those obtained by considering the net scantlings of the hull structures.

2.2 Model extension

2.2.1 Superstructures are to be modelled in order to reproduce the correct lightweight distribution.

Long superstructures are to be modelled in order to also reproduce the correct hull global strength, in particular the contribution of each superstructure deck to the hull girder longitudinal strength.

2.2.2 In the case of structural symmetry with respect to the ship centreline longitudinal plane, the hull structures may be modelled over half the ship breadth.

2.3 Finite element modelling criteria

2.3.1 Modelling of primary supporting members

The analyses of primary supporting members are to be based on fine mesh models, as defined in [2.4.3].

Such analyses may be carried out deriving the nodal displacements or forces, to be used as boundary conditions, from analyses of the complete ships based on coarse meshes, as defined in Ch 7, App 1, [3.4.2].

The areas for which analyses based on fine mesh models are to be carried out are the following:

- typical reinforced transverse rings
- typical deck girders
- areas of structural discontinuity (e.g. ramp areas)
- areas in way of typical side and deck openings
- areas of significant discontinuity in primary supporting, member arrangements (e.g. in way of large spaces).

Other areas may be required to be analysed through fine mesh models, where deemed necessary by the Society, depending on the ship structural arrangement and loading conditions as well as the results of the coarse mesh analysis.

2.3.2 Modelling of the most highly stressed areas

The areas which appear from the analyses based on fine mesh models to be highly stressed may be required to be further analysed, using the mesh accuracy specified in Ch 7, App 1, [3.4.4].

2.4 Finite element models

2.4.1 General

Finite element models are generally to be based on linear assumptions. The mesh is to be executed using membrane or shell elements, with or without mid-side nodes.

Meshing is to be carried out following uniformity criteria among the different elements.

In general, for some of the most common elements, the quadrilateral elements are to be such that the ratio between the longer side length and the shorter side length does not exceed 4 and, in any case, is less than 2 for most elements. Their angles are to be greater than 60° and less than 120°. The triangular element angles are to be greater than 30° and less than 120°.

Further modelling criteria depend on the accuracy level of the mesh, as specified from [2.4.2] to [2.4.4].

2.4.2 Coarse mesh

The number of nodes and elements is to be such that the stiffness and the inertia of the model represent properly those of the actual hull girder structure, and the distribution of loads among the various load carrying members is correctly taken into account.

To this end, the structural model is to be built on the basis of the following criteria:

- ordinary stiffeners contributing to the hull girder longitudinal strength and which are not individually represented in the model are to be modelled by rod elements and grouped at regular intervals
- webs of primary supporting members may be modelled with only one element on their height
- face plates may be simulated with bars having the same cross-section
- the plating between two primary supporting members may be modelled with one element stripe
- holes for the passage of ordinary stiffeners or small pipes may be disregarded
- manholes (and similar discontinuities) in the webs of primary supporting members may be disregarded, but the element thickness is to be reduced in proportion to the hole height and the web height ratio.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

2.4.3 Fine mesh

The ship structure may be considered as finely meshed when each longitudinal secondary stiffener is modelled; as a consequence, the standard size of finite elements used is based on the spacing of ordinary stiffeners.

The structural model is to be built on the basis of the following criteria:

- webs of primary members are to be modelled with at least three elements on their height
- the plating between two primary supporting members is to be modelled with at least two element stripes
- the ratio between the longer side and the shorter side of elements is to be less than 3 in the areas expected to be highly stressed
- holes for the passage of ordinary stiffeners may be disregarded.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

2.4.4 Mesh for the analysis of structural details

The structural modelling is to be accurate; the mesh dimensions are to be such as to enable a faithful representation of the stress gradients. The use of membrane elements is only allowed when significant bending effects are not present; in other cases, elements with general behaviour are to be used.

2.5 Boundary conditions of the model

2.5.1 In order to prevent rigid body motions of the overall model, the constraints specified in Tab 1 are to be applied.

2.5.2 When the hull structure is modelled over half the ship's breadth (see [2.2.2]), in way of the ship centreline longitudinal plane, symmetry or anti-symmetry boundary conditions as specified in Tab 2 are to be applied, depending on the loads applied to the model (respectively symmetrical or anti-symmetrical).

Table 1 : Boundary conditions to prevent rigid body motion of the model

Boundary conditions	DISPLACEMENTS in directions**(1)**		
	X	Y	Z
One node on the fore end of the ship	free	fixed	fixed
One node on the port side shell at aft end of the ship**(2)**	fixed	free	fixed
One node on the starboard side shell at aft end of the ship**(2)**	free	fixed	fixed

Boundary conditions	ROTATION around axes **(1)**		
	X	Y	Z
One node on the fore end of the ship	free	free	free
One node on the port side shell at aft end of the ship**(2)**	free	free	free
One node on the starboard side shell at aft end of the ship**(2)**	free	free	free

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [10].

(2) The nodes on the port side shell and that on the starboard side shell are to be symmetrical with respect to the ship longitudinal plane of symmetry.

Table 2 : Symmetry and anti-symmetry conditions in way of the ship centreline longitudinal plane

Boundary conditions	DISPLACEMENTS in directions**(1)**		
	X	Y	Z
Symmetry	free	fixed	free
Anti-symmetry	fixed	free	fixed

Boundary conditions	ROTATION around axes**(1)**		
	X	Y	Z
Symmetry	fixed	free	fixed
Anti-symmetry	free	fixed	free

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [10].

3 Load model

3.1 General

3.1.1 Design wave method

The various load components which occur simultaneously may be combined by setting the characteristics of regular waves that maximize the dominant load parameters given in Part B, Chapter 5.

Any other method may be used provided that relevant documentation is submitted to the Society for review.

A recommended procedure to compute the characteristics of the design wave is provided in [3.2].

3.1.2 Loads

Still water loads include:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal loads, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave loads, determined by mean of hydrodynamic calculations according to [3.2], include:

- the wave pressure
- the inertial loads.

3.1.3 Lightweight

The lightweight of the ship is to be uniformly distributed over the model length, in order to obtain the actual longitudinal distribution of the still water bending moment.

3.1.4 Models extended over half breadth of ship

When the ship is symmetrical with respect to her centreline longitudinal plane and the hull structure is modelled over half the ship breadth, non-symmetrical loads are to be broken down into symmetrical and anti-symmetrical loads and applied separately to the model with symmetry and anti-symmetry boundary conditions in way of the ship centreline longitudinal plane (see [2.5.2]).

3.2 Procedure for the selection of design waves

3.2.1 Summary of the loading procedure

Applicable cargo loading conditions given in Part D are analysed through:

- the computation of the characteristics of the finite element model under still water loads (see [3.3.1])
- the election of the load cases critical for the strength of the resistant structural members (see [3.3.2]).

The determination of the design wave characteristics for each load case includes the following steps:

- computation of the response operators (amplitude and phase) of the dominant load effect
- selection of the wave length and heading according to the guidelines in [3.3]
- computation of the wave amplitude corresponding to the design value of the dominant load effect
- determination of the wave phase such that the dominant load effect reaches its maximum.

3.2.2 Dominant load effects

Each critical load case maximizes the value of one of the following load effects having a dominant influence on the strength of some parts of the structure:

- vertical wave bending moment in hogging condition at midship section
- vertical wave bending moment in sagging condition at midship section
- vertical wave shear force on transverse bulkheads
- horizontal wave bending moment at midship section
- vertical acceleration at centreline in midship and fore body sections
- transverse acceleration at deck at sides at midship section
- vertical relative motion at sides in upright ship condition, at midship section
- vertical relative motion at sides in inclined ship condition, at midship section.

3.2.3 Response Amplitude Operators

The Response Amplitude Operators (RAO's) and associated phase characteristics are to be computed for wave periods between 4 and 22 seconds, using a seakeeping program, for the following motions and load effects:

- heave, pitch, roll and yaw motions
- vertical wave bending moment at 0,50 L
- vertical wave shear force at 0,25 L and 0,50 L
- horizontal wave bending moment at 0,50 L
- wave torque at 0,25 L, 0,50 L and 0,75 L (for ships with large deck openings).

The response amplitude operators are to be calculated for wave headings ranging from following seas (0 degree) to head seas (180 degrees) by increment of 15 degrees, using a ship speed of 60% of the maximum service speed.

The amplitude and phase of other dominant load effects may be computed at relevant wave period, using the RAO's listed above.

3.2.4 Design waves

For each load case, the ship is considered to encounter a regular wave, defined by its parameters (see Fig 1):

- wave length λ or period T
- heading angle α
- wave height (double amplitude)
- wave phase.

The wave length λ and the wave period T are linked by the following relation:

$\lambda = g\,T^2 / 2\,\pi$

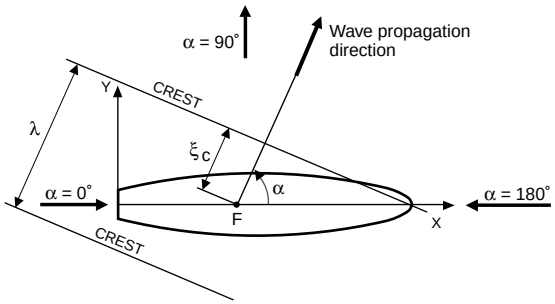
The range of variation of design wave period is between T1 and 22 seconds, where T1 is equal to:

$$T1 = 2\sqrt{\frac{\pi B_{WS}}{g}}$$

The possible wave height H, in m, is limited by the maximum wave steepness according to the relation (see Fig 2):

$H = 0,02\ g\ T^2$

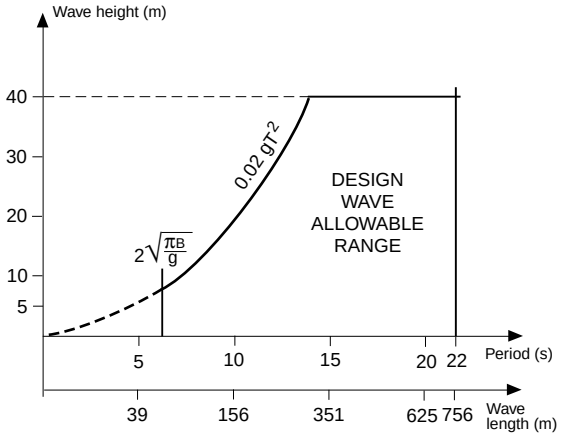
Figure 1 : Wave heading



Phase angle = 360 ξ_C / λ (in degrees)

F : Centre of rotation.

Figure 2 : Allowable range of design waves



3.2.5 Design wave amplitude

The amplitude of the design wave is obtained by dividing the design value of the dominant load effect by the value of the response amplitude operator of this effect computed for the relevant heading and wave length.

The design values of load effect, heading and wave length are given for each load case in [3.3.2].

When positioning the finite element model of the ship on the design wave, the amplitude of the wave is to be corrected to obtain the design value of the dominant load effect in order to take into account the non linear effects due to the hull shape and to the pressure distribution above the mean waterline given in [3.2.7].

The design wave phase is the phase of the dominant load effect.

3.2.6 Combined load cases

For the wave characteristics and crest position selected according to [3.2.5], the value of the wave-induced motions, accelerations and other load effects is obtained by the following formula:

$E_i = RAO_i\ a\ \cos(\varphi_d - \varphi_i)$

where:

E_i : Value of amplitude of the load component i

RAO_i : Response amplitude operator of the load component i computed for the design heading and wave length

a : Design wave amplitude

φ_d : Phase of the dominant load effect

φ_i : Phase of the load component i.

As a rule, the amplitude of the load components computed above are not to exceed their rule reference value by a factor C_{max} given in Tab 3.

3.2.7 Finite element model loading

The loads are applied to the finite element model according to the following indications:

a) For fatigue analysis of structural members located in the vicinity of the mean waterline, the sum of the wave and hydrostatic parts of the pressure is zero above the deformed wave profile and varies linearly between the mean waterline and the wave crest levels.

b) The fluid pressure in tanks is affected by the change of direction of the total acceleration vector defined in Ch 5, Sec 6, [1.2.2].

c) For dry unit cargoes, the inertial forces are computed at the centre of mass, taking into account the mass moment of inertia.

d) Inertial loads for structure weight and dry uniform cargo are computed using local accelerations calculated at their location.

Table 3 : Values of factor C_{max}

Load component	C_{max}
Wave bending moments (see Ch 5, Sec 2, [3])	1,10
Wave shear forces (see Ch 5, Sec 2, [3])	1,40
Absolute motions and accelerations (see Ch 5, Sec 3, [2])	1,10
Relative vertical motions (see Ch 5, Sec 3, [3])	1,20

3.2.8 Equilibrium check

The finite element model is to be in equilibrium condition with all the still water and wave loads applied.

The unbalanced forces in the three axes are not to exceed 2% of the displacement.

The unbalanced moments are not to exceed 2% of $\Delta.B_{WS}$ around Y and Z axes and 0,2% of $\Delta.B_{WS}$ around X axis.

3.3 Load cases

3.3.1 Hydrostatic calculation

For each cargo loading condition given in the relevant chapter of Part D, the longitudinal distribution of still water shear force and bending moment is to be computed and checked by reference to the approved loading manual (see Ch 11, Sec 2).

The convergence of the displacement, trim and vertical bending moment is deemed satisfactory if within the following tolerances:

- 2% of the displacement
- 0,1 degrees of the trim angle
- 10% of the still water wave bending moment.

3.3.2 Value of load effects

The wave length and heading which maximize each dominant load effect are specified in Tab 5. Where two values of heading angle are indicated in the table, the angle which corresponds to the highest peak value of the load effect's RAO is to be considered.

The design value of dominant load effects is specified in Tab 4.

Table 4 : Dominant load effect values

Dominant load effect	Design value	Combined load components	References
Vertical wave bending moment in hogging condition	0,625 γ_{W1} $M_{WV,H}$	vertical relative motion at sides at F.P.	$M_{WV,H}$ defined in Ch 5, Sec 2, [3.1.1]
Vertical wave bending moment in sagging condition	0,625 γ_{W1} F_D $M_{WV,S}$		$M_{WV,S}$ defined in Ch 5, Sec 2, [3.1.1] F_D defined in Ch 5, Sec 2, [4.2.2]
Vertical wave shear force	0,625 γ_{W1} Q_{WV}	–	Q_{WV} defined in Ch 5, Sec 2, [3.4]
Horizontal wave bending moment	0,625 γ_{W1} M_{WH}	–	M_{WH} defined in Ch 5, Sec 2, [3.2.1]
Vertical acceleration at centreline in upright ship condition	γ_{W2} AZ1	–	AZ1 defined in Ch 5, Sec 3, [3.4.1]
Vertical acceleration at centreline in inclined ship condition	γ_{W2} AZ2	–	AZ2 defined in Ch 5, Sec 3, [3.4.1]
Transverse acceleration at deck at sides	γ_{W2} AY2	roll angle	AY2 defined in Ch 5, Sec 3, [3.4.1]
Vertical relative motion at sides in upright ship condition	γ_{W2} h_1	wave pressure on bottom	h_1 defined in Ch 5, Sec 3, [3.3.1]
Vertical relative motion at sides in inclined ship condition	γ_{W2} h_2	–	h_2 defined in Ch 5, Sec 3, [3.3.2]

Table 5 : Load cases and load effect values

Load case	Dominant load effect	Wave parameters **(1)**		Location(s)
		Wave length λ, in m	Heading angle α	
1	Vertical wave bending moment in hogging condition	peak value of vertical wave bending moment RAO without being taken less than 0,9 L	180°	Midship section
2	Vertical wave bending moment in sagging condition	same as load case 1	180°	Midship section
3	Vertical wave shear force	peak value of vertical wave shear force RAO: • at 0,50 L for 0,35 L < x < 0,65 L • at 0,25 L elsewhere where: x : X coordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]	0° or 180°	Each transverse bulkhead
4	Horizontal wave bending moment	peak value of horizontal wave bending moment RAO or 0,5 L	120° or 135° **(2)**	Midship section
5	Vertical acceleration in inclined ship condition	$\lambda = \frac{12,3 C_\beta \Delta}{B_{WS} L C_W}$ where: C_β = 1,00 for 90° heading C_β = 1,15 for 105° heading C_W : Waterplane coefficient at load waterline	90° or 105°	Midship section
6	Vertical acceleration in upright ship condition	$\lambda = 1,6\ L\ (0,575 + 0,8\ F)^2$	180°	from forward end of cargo area to F.P.
7	Transverse acceleration	$\lambda = 1,35\ g\ T_R^2 / (2\ \pi)$ without being taken greater than 756	90°	Midship section
8	Vertical relative motion at sides in upright ship condition	0,7 L **(3)**	180° or 0°	Midship section
9	Vertical relative motion at sides in inclined ship condition	$\lambda = 0,35\ g\ T_R^2 / (2\ \pi)$ without being taken less than 2,0 B_{WS}	90°	Midship section

(1) The forward ship speed is to be taken equal to 0,6 V_{max}.

(2) Select the heading such that the value of C_{max} for vertical wave bending moment is not exceeded.

(3) λ may have to be increased to keep the wave steepness below wave breaking limit.

4 Stress calculation

4.1 Stress components

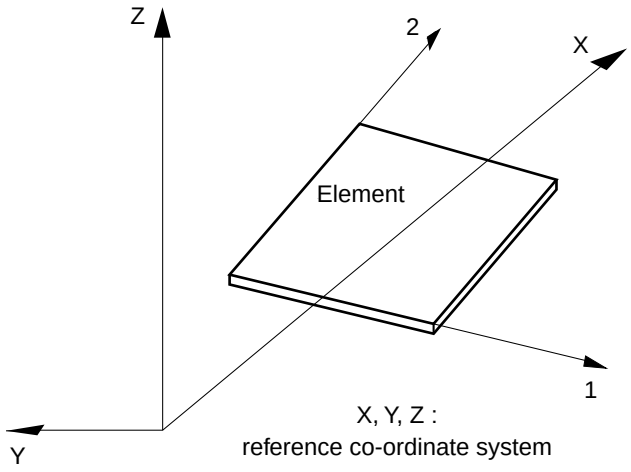
4.1.1 Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 3. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 2, [10].

The following stress components are to be calculated at the centroid of each element:

- the normal stresses σ_1 and σ_2 in the directions of element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

Figure 3 : Reference and element co-ordinate systems



CHAPTER 8
OTHER STRUCTURES

Section 1 Fore Part
Section 2 Aft Part
Section 3 Machinery Space
Section 4 Superstructures and Deckhouses
Section 5 Bow Doors and Inner Doors
Section 6 Side Doors and Stern Doors
Section 7 Watertight and Weathertight Doors
Section 8 Hatch Covers
Section 9 Movable Decks and Inner Ramps - External Ramps
Section 10 Arrangement of Hull and Superstructure Openings
Section 11 Helicopter Decks

Section 1 Fore Part

Symbols

β_b , β_s : Coefficients defined in Ch 7, Sec 2, [3.7.3]

λ_{bS} , λ_{bW} , λ_{sS} , λ_{sW} : Coefficients defined in Ch 7, Sec 2, [3.4.3]

ρ_L : Density, in t/m^3, of the liquid carried

a_{Z1} : Reference value of the vertical acceleration, defined in Ch 5, Sec 3, [3.4]

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1{,}21\sqrt{1 + 0{,}33\left(\frac{s}{\ell}\right)^2} - 0{,}69\frac{s}{\ell}$$

to be taken not greater than 1,0

c_E : Coefficient to be taken equal to:

- for $L \leq 65$ m:

  $c_E = 1$
- for $65 \text{ m} < L < 90$ m:

  $c_E = 3 - L / 32{,}5$
- for $L \geq 90$ m:

  $c_E = 0$

c_F : Coefficient to be taken equal to:

- for forecastle sides:

  $c_F = 0{,}9$
- in the other cases:

  $c_F = 1{,}0$

c_r : Coefficient of curvature of the panel, equal to:

$c_r = 1 - 0{,}5\ s / r$

to be taken not less than 0,5

where:

r : Radius of curvature, in m

g : Gravity acceleration, in m/s^2:

$g = 9{,}81$ m/s^2

h_1 : Reference value of the ship relative motion, defined in Ch 5, Sec 3, [3.3]

k : Material factor, defined in Ch 4, Sec 1, [2.3]

ℓ : Span, in m, of ordinary stiffeners or primary supporting members, as applicable

L_1 , L_2 : Lengths, in m, defined in Ch 1, Sec 2, [2.1.1]

m : Boundary coefficient, to be taken equal to:

- m = 12 in general, for stiffeners considered as clamped
- m = 8 for stiffeners considered as simply supported
- other values of m may be considered, on a case-by-case basis, for other boundary conditions.

p_{BI} : Bottom impact pressure, defined in [3.2]

p_{FI} : Bow impact pressure, defined in [4.2]

p_S , p_W : Still water pressure and wave pressure defined in [2.3]

R_y : Minimum yield stress, in N/mm^2, of the material, to be taken equal to 235/k, unless otherwise specified

s : Spacing, in m, of ordinary stiffeners or primary supporting members, as applicable

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10]

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantling of structures located forward of the collision bulkhead, i.e.:

- fore peak structures
- stem.

In addition, the requirements of this Section apply to structure subjected to impact loads, i.e.:

- flat bottom forward area, according to Article [3]
- bow flare area, according to Article [4].

1.1.2 Fore peak structures which form the boundary of spaces not intended to carry liquids, and which do not belong to the outer shell, are to be subjected to lateral pressure in flooding conditions. Their scantlings are to be determined according to the relevant criteria in Part B, Chapter 6 or Part B, Chapter 7, as applicable.

1.2 Connections of the fore part with structures located aft of the collision bulkhead

1.2.1 Tapering

Adequate tapering is to be ensured between the scantlings in the fore part and those aft of the collision bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

1.2.2 Supports of fore peak structures

Aft of the collision bulkhead, side girders are to be fitted as specified in Ch 4, Sec 5, [2.2] or Ch 4, Sec 5, [3.2], as applicable.

1.3 Net scantlings

1.3.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

Gross scantlings are obtained as specified in Ch 4, Sec 2.

2 Fore peak

2.1 Partial safety factors

2.1.1 The partial safety factors to be considered for the checking of fore peak structures are specified in Tab 1.

2.2 Load point

2.2.1 Unless otherwise specified, lateral pressure is to be calculated at:

- the lower edge of the elementary plate panel considered, for plating
- mid-span, for stiffeners.

2.3 Load model

2.3.1 General

The still water and wave lateral pressures in intact conditions are to be considered. They are to be calculated as specified in [2.3.2] for the elements of the outer shell and in [2.3.3] for the other elements.

Still water pressure p_S includes:

- the still water sea pressure, defined in Tab 2
- the still water internal pressure due to liquids or ballast, defined in Tab 4
- for decks, the still water internal pressure due to uniform loads, defined in Tab 5.

Wave pressure p_W includes:

- the wave pressure, defined in Tab 2
- the inertial internal pressure due to liquids or ballast, defined in Tab 4
- for decks, the inertial internal pressure due to uniform loads, defined in Tab 5.

2.3.2 Lateral pressures for the elements of the outer shell

The still water and wave lateral pressures are to be calculated considering separately:

- the still water and wave external sea pressures
- the still water and wave internal pressures, considering the compartment adjacent to the outer shell as being loaded.

If the compartment adjacent to the outer shell is not intended to carry liquids, only the external sea pressures are to be considered.

2.3.3 Lateral pressures for elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

Table 1 : Fore peak structures - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors			
	Symbol	Plating	Ordinary stiffeners	Primary supporting members
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave induced pressure	γ_{W2}	1,20	1,20	1,20
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	1,20	1,40	1,60

Table 2 : Still water and wave pressures

Location	Still water sea pressure p_S, in kN/m²	Wave pressure p_W, in kN/m²
Bottom and side below the waterline: $z \le T$	$\rho g (T - z)$	$\rho g h_1 e^{\frac{-2\pi(T-z)}{L}}$
Side above the waterline: $z > T$	0	$\rho g (T + h_1 - z)$ without being taken less than $0,15 \varphi_1 \varphi_2 L$
Exposed deck	Pressure due to the load carried **(1)**	$19,6 \varphi_1 \varphi_2 \sqrt{H}$

(1) The pressure due to the load carried is to be defined by the Designer and, in any case, it may not be taken less than $10 \varphi_1 \varphi_2$ kN/m², where φ_1 and φ_2 are defined hereafter.

The Society may accept pressure values lower than $10 \varphi_1 \varphi_2$ kN/m² when considered appropriate on the basis of the intended use of the deck.

Note 1:

φ_1 : Coefficient defined in Tab 3

φ_2 = Min (L / 90 ; 1,0) without being taken less than 0,42

$$H = \left[2,66\left(\frac{x}{L} - 0,7\right)^2 + 0,14\right]\sqrt{\frac{VL}{C_B}} - (z - T)$$

without being taken less than 0,8

V : Maximum ahead service speed, in knots, to be taken not less than 13 knots.

Table 3 : Coefficient φ_1 for pressure on exposed deck

Exposed deck location	φ_1
Watertight deck	1,00
Superstructure deck	0,75
1st tier of deckhouse	0,56
2nd tier of deckhouse	0,42
3rd tier of deckhouse	0,32
4th tier of deckhouse and above	0,25

Table 4 : Still water and inertial internal pressures due to liquids

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
$\rho_L g(z_L - z)$	$\rho_L a_{Z1}(z_{TOP} - z)$

Note 1:

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank

z_L : Z co-ordinate, in m, of the highest point of the liquid:

$z_L = z_{TOP} + 0,5 (z_{AP} - z_{TOP})$

z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend, to be taken not less than z_{TOP}.

Table 5 : Still water and inertial internal pressures due to uniform loads

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
The value of p_S is, in general, defined by the Designer; in any case it may not be taken less than 10 kN/m² When the value of p_S is not defined by the Designer, it may be taken, in kN/m², equal to 6,9 h_{TD}, where h_{TD} is the compartment 'tweendeck height at side, in m	$p_S \frac{a_{Z1}}{g}$

2.4 Longitudinally framed bottom

2.4.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Tab 6 and the minimum values in the same Table.

2.4.2 Floors

Floors are to be fitted at every four frame spacings and generally spaced no more than 2,5 m apart.

The floor dimensions and scantlings are to be not less than those specified in Tab 7.

In no case may the above scantlings be lower than those of the corresponding side transverses, as defined in [2.6.2].

2.4.3 Centre girder

Where no centreline bulkhead is to be fitted (see [2.10]), a centre bottom girder having the same dimensions and scantlings required in [2.4.2] for floors is to be provided.

The centre bottom girder is to be connected to the collision bulkhead by means of a large end bracket.

2.4.4 Side girders

Side girders, having the same dimensions and scantlings required in [2.4.2] for floors, are generally to be fitted every two longitudinals, in line with bottom longitudinals located aft of the collision bulkhead. Their extension is to be compatible in each case with the shape of the bottom.

2.5 Transversely framed bottom

2.5.1 Plating

The net scantling of plating is to be not less than the value obtained from the formulae in Tab 6 and the minimum values in the same Table.

2.5.2 Floors

Solid floors are to be fitted at every frame spacing.

The solid floor dimensions and scantlings are to be not less than those specified in Tab 8.

2.5.3 Centre girder

Where no centreline bulkhead is to be fitted (see [2.10]), a centre bottom girder is to be fitted according to [2.4.3].

Table 6 : Scantling of bottom plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$	Minimum net thickness, in mm **(1)**: • in general: $t = c_F(0{,}03L + 5{,}5)k^{1/2} - c_E$ • for inner bottom: $t = 2 + 0{,}017Lk^{1/2} + 4{,}5s$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$ Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$	Web minimum net thickness, in mm, to be not less than the lesser of: • $t = 1{,}5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating.
(1) L need not be taken greater than 300 m. **Note 1:** σ_{X1} : Hull girder normal stress, taken equal to: • the value defined in Ch 7, Sec 2, [3.3.7], for stiffeners contributing to the hull girder longitudinal stress • $\sigma_{X1} = 0$, for stiffeners not contributing to the hull girder longitudinal stress.		

Table 7 : Longitudinally framed bottom - Floor dimensions and scantlings

Dimension or scantling	Specified value
Web height, in m	$h_M = 0{,}085\ D + 0{,}15$
Web net thickness, in mm	To be not less than that required for double bottom floors aft of the collision bulkhead; in any case, it may be taken not greater than 10 mm.
Floor face plate net sectional area, in cm²	$A_P = 3{,}15\ D$
Floor face plate net thickness, in mm	$t_p = 0{,}4\ D + 5$ May be assumed not greater than 14 mm.

Table 8 : Transversely framed bottom - Floor dimensions and scantlings

Dimension or scantling	Specified value
Web height, in m	$h_M = 0,085\ D + 0,15$
Web net thickness, in mm	To be not less than that required for double bottom floors aft of the collision bulkhead; in any case, it may be taken not greater than 10 mm.
Floor face plate net sectional area, in cm^2	$A_P = 1,67\ D$

2.6 Longitudinally framed side

2.6.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Tab 9 and the minimum values in the same Table.

2.6.2 Side transverses

Side transverses are to be located in way of bottom transverse and are to extend to the upper deck. Their ends are to be amply faired in way of bottom and deck transverses.

Their net section modulus w, in cm^3, and net shear sectional area A_{Sh}, in cm^2, are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} \lambda_{bS} p_S + \gamma_{W2} \lambda_{bW} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} \lambda_{sS} p_S + \gamma_{W2} \lambda_{sW} p_W}{R_y} s \ell$$

2.7 Transversely framed side

2.7.1 Plating and ordinary stiffeners (side frames)

Side frames fitted at every frame space are to have the same vertical extension as the collision bulkhead.

The net scantlings of plating and side frames are to be not less than the values obtained from the formulae in Tab 9 and the minimum values in the same Table.

The value of the side frame section modulus is generally to be maintained for the full extension of the side frame.

2.7.2 Side girders

Depending on the hull body shape and structure aft of the collision bulkhead, one or more adequately spaced side girders per side are to be fitted.

Their net section modulus w, in cm^3, and net shear sectional area A_{Sh}, in cm^2, are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

Moreover, the depth b_A, in mm, and the net thickness t_A, in mm, of the side girder web are generally to be not less than the values obtained from the following formulae:

$$b_A = 2,5\ (180 + L)$$

$$t_A = (6 + 0,018\ L)\ k^{1/2}$$

2.7.3 Panting structures

In order to withstand the panting loads, horizontal structures are to be provided. These structures are to be fitted at a spacing generally not exceeding 2 m and consist of side girders supported by panting beams or side transverses whose ends are connected to deck transverses, located under the tank top, so as to form a strengthened ring structure.

Panting beams, which generally consist of sections having the greater side vertically arranged, are to be fitted every two frames.

Table 9 : Scantling of side plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14{,}9 c_a c_r s \sqrt{\frac{\gamma_R \gamma_m (\gamma_{S2} p_S + \gamma_{W2} p_W)}{R_y}}$	Minimum net thickness, in mm **(1)**: $t = c_F (0{,}03 L + 5{,}5) k^{1/2} - c_E$
Ordinary stiffeners	Net section modulus, in cm^3: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web minimum net thickness, in mm, to be not less than the lesser of: • $t = 1{,}5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating
	Net shear sectional area, in cm^2: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$	

(1) L need not be taken greater than 300 m.

Note 1:

σ_{X1} : Hull girder normal stress, taken equal to:

- the value defined in Ch 7, Sec 2, [3.3.7], for stiffeners contributing to the hull girder longitudinal stress
- $\sigma_{X1} = 0$, for stiffeners not contributing to the hull girder longitudinal stress.

2.7.4 Connection between panting beams, side frames and side girders

Each panting beam is to be connected to the side transverses by means of brackets whose arms are generally to be not less than twice the panting beam depth.

2.7.5 Connection between side frames and side girders

Side transverses not supporting panting beams are to be connected to side girders by means of brackets having the same thickness as that of the side girder and arms which are to be not less than one half of the depth of the side girder.

2.7.6 Panting beam scantlings

The net area A_B, in cm^2, and the net inertia J_B, in cm^4, of the panting beam section are to be not less than the values obtained from the following formulae:

$A_B = 0{,}5 L - 18$

$J_B = 0{,}34 (0{,}5 L - 18) b_B^2$

where:

b_B : Beam length, in m, measured between the internal edges of side girders or the internal edge of the side girder and any effective central or lateral support.

Where side girder spacing is other than 2 m, the values A_B and J_B are to be modified according to the relation between the actual spacing and 2 m.

2.7.7 Panting beams of considerable length

Panting beams of considerable length are generally to be supported at the centreline by a wash bulkhead or pillars arranged both horizontally and vertically.

2.7.8 Non-tight platforms

Non-tight platforms may be fitted in lieu of side girders and panting beams. Their openings and scantlings are to be in accordance with [2.9.1].

Their spacing is to be not greater than 2,5 m.

If the peak exceeds 10 m in depth, a non-tight platform is to be arranged at approximately mid-depth.

2.7.9 Additional transverse bulkheads

Where the peak exceeds 10 m in length and the frames are supported by panting beams or non-tight platforms, additional transverse wash bulkheads or side transverses are to be fitted.

2.8 Decks

2.8.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Tab 10 and the minimum values in the same Table.

2.8.2 Primary supporting members

Scantlings of primary supporting members are to be in accordance with Ch 7, Sec 3, considering the loads in [2.3].

Table 10 : Scantling of deck plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$	Minimum net thickness, in mm **(1)**: $t = 2,1 + 0,013 L k^{1/2} + 4,5 s$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web minimum net thickness, in mm, to be not less than the lesser of: • $t = 1,5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$	

(1) L need not be taken greater than 300 m.

Note 1:

σ_{X1} : Hull girder normal stress, taken equal to:

- the value defined in Ch 7, Sec 2, [3.3.7], for stiffeners contributing to the hull girder longitudinal stress
- $\sigma_{X1} = 0$, for stiffeners not contributing to the hull girder longitudinal stress.

2.9 Platforms

2.9.1 Non-tight platforms

Non-tight platforms located inside the peak are to be provided with openings having a total area not less than 10% of that of the platforms. Moreover, the thickness of the plating and the section modulus of ordinary stiffeners are to be not less than those required in [2.10] for the non-tight central longitudinal bulkhead.

The number and depth of non-tight platforms within the peak is considered by the Society on a case-by-case basis.

The platforms may be replaced by equivalent horizontal structures whose scantlings are to be supported by direct calculations.

2.9.2 Platform transverses

The net sectional area of platform transverses, calculated considering a width of attached plating whose net sectional area is equal to that of the transverse flange, is to be not less than the value obtained, in cm², from the following formula:

$$A = 10 \gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{C_P R_y} d_S h_S$$

where:

p_S, p_W : Still water pressure and wave pressure, defined in [2.9.1], acting at the ends of the platform transverse in the direction of its axis

d_S : Half of the longitudinal distance, in m, between the two transverses longitudinally adjacent to that under consideration

h_S : Half of the vertical distance, in m, between the two transverses vertically adjacent to that under consideration

C_P : Coefficient, to be taken equal to:

$$C_P = 1 \quad \text{for } \frac{d_P}{r_P} \leq 70$$

$$C_P = 1,7 - 0,01 \frac{d_P}{r_P} \quad \text{for } 70 < \frac{d_P}{r_P} \leq 140$$

When $d_P / r_P > 140$, the scantlings of the struts are considered by the Society on a case-by-case basis

d_P : Distance, in cm, from the face plate of the side transverse and that of the bulkhead vertical web, connected by the strut, measured at the level of the platform transverse

r_P : Radius of gyration of the strut, to be obtained, in cm, from the following formula:

$$r_P = \sqrt{\frac{J}{A_E}}$$

J : Minimum net moment of inertia, in cm⁴, of the strut considered

A_E : Actual net sectional area, in cm², of the transverse section of the strut considered.

2.9.3 Breasthooks

Breasthooks are to have the same thickness of that required for platforms. They are to be arranged on the stem, in way of every side longitudinal, or at equivalent spacing in the case of transverse framing, extending aft for a length equal to approximately twice the breasthook spacing.

Other dispositions may be accepted by the Society if deemed equivalent.

2.10 Central longitudinal bulkhead

2.10.1 General

Unless otherwise agreed by the Society on a case-by-case basis, a centreline non-tight longitudinal bulkhead is not to be fitted. In case such a bulkhead is fitted, the following requirements apply.

2.10.2 Extension

In the case of a bulbous bow, such bulkhead is generally to extend for the whole length and depth of the fore peak.

Where hull structures are flared, such as those situated above the bulb and in the fore part of the peak, the bulkhead may be locally omitted.

Similarly, the extension of the bulkhead may be limited for bows without a bulb, depending on the shape of the hull. However, the bulkhead is to be fitted in the higher part of the peak.

2.10.3 Plating thickness

The net plating thickness of the lower part of the longitudinal bulkhead over a height at least equal to h_M defined in [2.4.2] is to be not less than that required for the centre girder in [2.4.3].

Elsewhere, the net thickness of the longitudinal bulkhead plating is to be not less than the value obtained, in mm, from the following formula:

$t = 6,5 + 0,013\ L_1$

2.10.4 Ordinary stiffeners

The net section modulus of ordinary stiffeners is to be not less than the value obtained, in cm^3, from the following formula:

$w = 3,5\ s\ \ell^2\ k\ (z_{TOP} - z_M)$

where:

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank

z_M : Z co-ordinate, in m, of the stiffener mid-span.

2.10.5 Primary supporting members

Vertical and longitudinal primary supporting members, to be made preferably with symmetrical type sections, are to have a section modulus not less than 50% of that required for the corresponding side or longitudinal webs.

The vertical and longitudinal webs are to be provided with adequate fairing end brackets and to be securely connected to the struts, if any.

2.10.6 Openings

Bulkhead openings are to be limited in the zone corresponding to the centre girder to approximately 2% of the area, and, in the zone above, to not less than 10% of the area. Openings are to be located such as to affect as little as possible the plating sections adjacent to primary supporting members.

2.11 Bulbous bow

2.11.1 General

Where a bulbous bow is fitted, fore peak structures are to effectively support the bulb and are to be adequately connected to its structures.

When the bulbous bow is intended to contain a sonar device, the requirements in [2.11.7] apply.

2.11.2 Shell plating

The thickness of the shell plating of the fore end of the bulb and the first strake above the keel is generally to be not less than that required in [5.2.1] for plate stems. This thickness is to be extended to the bulbous zone, which, depending on its shape, may be damaged by anchors and chains during handling.

2.11.3 Connection with the fore peak

Fore peak structures are to be extended inside the bulb as far as permitted by the size and shape of the latter.

2.11.4 Floors

Solid floors are to be part of reinforced transverse rings generally arranged not more than 3 frame spaces apart.

2.11.5 Longitudinal centreline wash bulkhead

For a bulb of considerable width, a longitudinal centreline wash bulkhead may be required by the Society in certain cases.

2.11.6 Transverse wash bulkhead

In way of a long bulb, transverse wash bulkheads or side transverses of adequate strength arranged not more than 5 frame spaces apart may be required by the Society in certain cases.

2.11.7 Bulbous bow intended to contain a sonar device

The fore part of the bulbous bow is generally constituted by a GRP dome bolted to the fore structures. The aft part of the bulbous bow, of metallic construction, is to be connected with the fore structures according to [2.11.3] to [2.11.6] as far as practicable.

The sonar space is generally filled with water and is provided with a system for filling and emptying it. The hull watertightness is to be ensured by means of an horizontal flat and a transverse watertight floor, which contour the sonar dome. The scantlings of these watertight elements are to be checked considering them as being part of the outer shell.

If the access, in floating condition, to the sonar dome is to be ensured, for inspection and maintenance, two watertight hatches are, in general, to be fitted. For small domes, one hatch only may be accepted provided that its clear opening is such to allow contemporary easy access and ventilation. For the scantlings of these hatches, the sea pressures acting on the outer shell are to be considered.

3 Reinforcements of the flat bottom forward area

3.1 Area to be reinforced

3.1.1 In addition to the requirements in Article [2], the structures of the flat bottom forward area are to be able to sustain the dynamic pressures due to the bottom impact. The flat bottom forward area is:

- longitudinally, over the bottom located between ξL and 0,05L aft of the fore end, where the coefficient ξ is obtained from the following formula:

  $\xi = 0,25\ (1,6 - C_B)$

  without being taken less than 0,20 or greater than 0,25
- transversely, over the whole flat bottom and the adjacent zones up to a height, from the base line, not less than 2 L, in mm. In any case, it is not necessary that such height is greater than 300 mm.

3.1.2 The bottom dynamic impact pressure is to be considered if:

$T_F < \text{Min}\ (0,04\ L\ ;\ 8,6)$

where T_F is the minimum forward draught, in m, among those foreseen in operation in ballast conditions or conditions of partial loading.

3.1.3 The value of the minimum forward draught T_F adopted for the calculations is to be specified in the loading manual.

3.1.4 An alternative arrangement and extension of strengthening with respect to the above may also be required where the minimum forward draught exceeds 0,04 L, depending on the shape of the forward hull body and the ship length and service speed.

3.2 Bottom impact pressure

3.2.1 The bottom impact pressure p_{BI} is to be obtained, in kN/m^2, from the following formula:

$$p_{BI} = 25\left[0,004 - \left(\frac{T_F}{L}\right)^2\right]\frac{L_1 L}{T_F}$$

where T_F is the draught defined in [3.1.2].

3.3 Partial safety factors

3.3.1 The partial safety factors to be considered for checking the reinforcements of the flat bottom forward area are specified in Tab 11.

Table 11 : Reinforcements of the flat bottom forward area - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbol	Plating	Ordinary stiffeners
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10
Material	γ_m	1,02	1,02
Resistance	γ_R	1,30	1,15

3.4 Scantlings

3.4.1 Plating and ordinary stiffeners

In addition to the requirements in [2.4.1] and [2.5.1], the net scantlings of plating and ordinary stiffeners of the flat bottom forward area, defined in [3.1], are to be not less than the values obtained from the formulae in Tab 12 and the minimum values in the same Table.

3.4.2 Tapering

Outside the flat bottom forward area, scantlings are to be gradually tapered so as to reach the values required for the areas considered.

Table 12 : Reinforcements of plating and ordinary stiffeners of the flat bottom forward area

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 13,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{W2} p_{BI}}{R_y}}$	Minimum net thickness, in mm **(1)**: $t = c_F(0,03L + 5,5)k^{1/2} - c_E$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{W2} p_{BI}}{16 c_P R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web minimum net thickness, in mm, to be not less than the lesser of: • $t = 1,5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{W2} p_{BI}}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$	

(1) L need not be taken greater than 300 m.

Note 1:

c_P : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with attached shell plating, to be taken equal to 1,16 in the absence of more precise evaluation.

3.5 Arrangement of primary supporting members and ordinary stiffeners: longitudinally framed bottom

3.5.1 The requirements in [3.5.2] to [3.5.4] apply to the structures of the flat bottom forward area, defined in [3.1], in addition to the requirements of [2.4].

3.5.2 Bottom longitudinals and side girders, if any, are to extend as far forward as practicable, and their spacing may not exceed that adopted aft of the collision bulkhead.

3.5.3 The spacing of solid floors in a single or double bottom is to be not greater than:

- either the spacing required in Ch 4, Sec 4 for the midship section, or
- (1,35 + 0,007 L) m,

whichever is the lesser.

However, where the minimum forward draught T_F is less than 0,02 L, the spacing of floors forward of 0,2 L from the stem is to be not greater than (0,9 + 0,0045 L) m.

3.5.4 The Society may require adequately spaced side girders having a depth equal to that of the floors. As an alternative to the above, girders with increased scantlings may be fitted.

3.6 Arrangement of primary supporting members and ordinary stiffeners: transversely framed double bottom

3.6.1 The requirements from [3.6.2] to [3.6.4] apply to the structures of the flat bottom forward area, defined in [3.1], in addition to the requirements of [2.5].

3.6.2 Solid floors are to be fitted:

- at every second frame between 0,75 L and 0,80 L from the aft end
- at every frame space forward of 0,80 L from the aft end.

3.6.3 Side girders with a depth equal to that of the floors are to be fitted at a spacing generally not exceeding 2,4 m. In addition, the Society may require intermediate half height girders, half the depth of the side girders, or other equivalent stiffeners.

3.6.4 Intercostal longitudinal ordinary stiffeners are to be fitted at a spacing generally not exceeding 1,2 m. Their section modulus is to be not less than 250 cm³.

4 Reinforcements of the bow flare area

4.1 Area to be reinforced

4.1.1 In addition to the requirements in [2], the structures of the bow flare area are to be able to sustain the dynamic pressures due to the bow impact pressure.

4.1.2 The bow area to be reinforced is that extending forward of 0,9 L from the aft end of L and above the full load waterline up to the level at which a knuckle with an angle greater than 15° is located on the side shell.

4.2 Bow impact pressure

4.2.1 The bow impact pressure p_{FI} is to be obtained, in kN/m^2, from the following formula:

$$p_{FI} = C_S C_L C_Z (0,22 + 0,15 \tan\alpha)(0,4 V \sin\beta + 0,6\sqrt{L})^2$$

where:

C_S : Coefficient depending on the type of structures on which the bow impact pressure is considered to be acting:

- $C_S = 1,8$ for plating and ordinary stiffeners
- $C_S = 0,5$ for primary supporting members

C_L : Coefficient depending on the ship length:

- $C_L = 0,0125\ L$ for $L < 80$ m
- $C_L = 1,0$ for $L \geq 80$ m

C_Z : Coefficient depending on the distance between the full load waterline and the calculation point:

- $C_Z = C - 0,5\ (z - T)$ for $z \geq 2\ C + T - 11$
- $C_Z = 5,5$ for $z < 2\ C + T - 11$

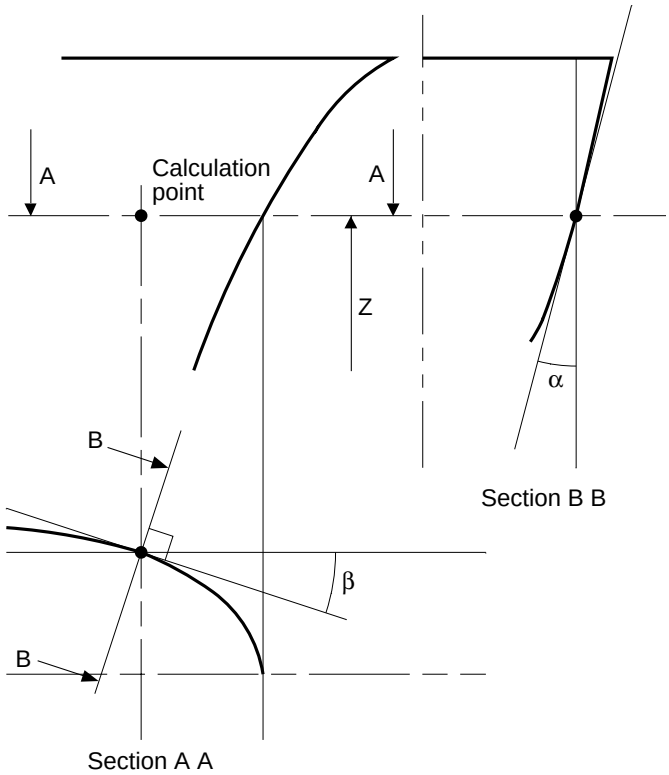
C : Wave parameter, defined in Ch 5, Sec 2

α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the side plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 1)

β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 1)

V : Maximum service speed, in knots.

Figure 1 : Definition of angles α and β



4.3 Partial safety factors

4.3.1 The partial safety factors to be considered to check the reinforcements of the bow flare area are specified in Tab 13.

4.4 Scantlings

4.4.1 Plating and ordinary stiffeners

In addition to the requirements in [2.6.1] and [2.7.1], the net scantlings of plating and ordinary stiffeners of the bow flare area, defined in [4.1], are to be not less than the values obtained from the formulae in Tab 14 and the minimum values in the same Table.

4.4.2 Tapering

Outside the bow flare area, scantlings are to be gradually tapered so as to reach the values required for the areas considered.

4.4.3 Intercostal stiffeners

Intercostal stiffeners are to be fitted at mid-span where the angle between the stiffener web and the attached plating is less than 70°.

4.4.4 Primary supporting members

In addition to the requirements in [2.6] and [2.7], primary supporting members are generally to be verified through direct calculations carried out according to Ch 7, Sec 3, considering the bow impact pressures defined in [4.2].

Table 13 : Reinforcements of the bow flare area - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbol	Plating	Ordinary stiffeners
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10
Material	γ_m	1,02	1,02
Resistance	γ_R	1,30	1,02

Table 14 : Reinforcements of plating and ordinary stiffeners of the bow flare area

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 11 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{W2} p_{FI}}{R_y}}$	Minimum net thickness, in mm **(1)**: $t = c_F(0,03L + 5,5)k^{1/2} - c_E$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{W2} p_{FI}}{18 c_P R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web minimum net thickness, in mm, to be not less than the lesser of: • $t = 1,5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{W2} p_{FI}}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$	

(1) L need not be taken greater than 300 m.

Note 1:

c_P : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with attached shell plating, to be taken equal to 1,16 in the absence of more precise evaluation.

5 Stems

5.1 General

5.1.1 Arrangement

Adequate continuity of strength is to be ensured at the connection of stems to the surrounding structure.

Abrupt changes in sections are to be avoided.

5.1.2 Gross scantlings

With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in [5.2] and [5.3] are gross, i.e. they include the margins for corrosion.

5.2 Plate stems

5.2.1 Where the stem is constructed of shaped plates, the gross thickness of the plates below the load waterline is to be not less than the value obtained, in mm, from the following formula:

$$t_S = 1{,}37(0{,}95 + \sqrt{L_3})\sqrt{k}$$

where:

L_3 : Ship length L, in m, but to be taken not greater than 300.

Above the load waterline this thickness may be gradually tapered towards the stem head, where it is to be not less than that required for side plating at ends.

5.2.2 The plating forming the stems is to be supported by horizontal diaphragms spaced not more than 1200 mm apart and connected, as far as practicable, to the adjacent frames and side stringers.

5.2.3 If considered necessary, and particularly where the stem radius is large, a centreline stiffener or web of suitable scantlings is to be fitted.

5.3 Bar stems

5.3.1 The gross area of bar stems constructed of forged or rolled steel is to be not less than the value obtained, in cm^2, from the following formulae:

$$A_P = \left(0{,}40 + \frac{10T}{L}\right)(0{,}009L^2 + 20)\sqrt{k} \quad \text{for } L \leq 90$$

$$A_P = \left(0{,}40 + \frac{10T}{L}\right)(1{,}8L - 69)\sqrt{k} \quad \text{for } 90 < L \leq 200$$

where the ratio T/L in the above formulae is to be taken neither less than 0,050 nor greater than 0,075.

5.3.2 The gross thickness t_B of the bar stem is to be not less than the value obtained, in mm, from the following formula:

$$t_B = (0{,}4L + 13)\sqrt{k}$$

5.3.3 The cross-sectional area of the stem may be gradually tapered from the load waterline to the upper end, where it may be equal to the two thirds of the value as calculated above.

5.3.4 The lower part of the stem may be constructed of cast steel subject to the examination by the Society; where necessary, a vertical web is to be fitted for welding of the centre keelson.

5.3.5 Welding of the bar stem with the bar keel and the shell plating is to be in accordance with Ch 11, Sec 1, [3.4].

6 Transverse thrusters

6.1 Scantlings of the thruster tunnel and connection with the hull

6.1.1 The thickness of the tunnel is to be not less than the thickness of the adjacent hull plating.

6.1.2 When the tunnel is not welded to the hull, the connection devices are examined by the Society on a case-by-case basis.

Section 2 Aft Part

Symbols

β_b , β_s : Coefficients defined in Ch 7, Sec 2, [3.7.3]

λ_{bS} , λ_{bW} , λ_{sS} , λ_{sW} : Coefficients defined in Ch 7, Sec 2, [3.4.3]

ρ : Sea water density, in t/m^3

a_{Z1} : Reference value of the vertical acceleration, defined in Ch 5, Sec 3, [3.4]

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1{,}21\sqrt{1 + 0{,}33\left(\frac{s}{\ell}\right)^2} - 0{,}69\frac{s}{\ell}$$

to be taken not greater than 1,0

c_r : Coefficient of curvature of the panel, equal to:

$c_r = 1 - 0{,}5\ s / r$

to be taken not less than 0,5

r : Radius of curvature, in m

c_E : Coefficient to be taken equal to:

- for $L \leq 65$ m:

  $c_E = 1$

- for 65 m < L < 90 m:

  $c_E = 3 - L/30$

- for $L \geq 90$ m:

  $c_E = 0$

c_F : Coefficient:

- for poop sides:

  $c_F = 0{,}8$

- in the other cases:

  $c_F = 1{,}0$

g : Gravity acceleration, in m/s^2:

g = 9,81 m/s^2

h_1 : Reference value of the ship relative motion, defined in Ch 5, Sec 3, [3.3]

k : Material factor, defined in Ch 4, Sec 1, [2.3]

ℓ : Span, in m, of ordinary stiffeners or primary supporting members, as applicable

L_1 , L_2 : Lengths, in m, defined in Ch 1, Sec 2, [2.1.1]

m : Boundary coefficient, to be taken equal to:

- m = 12 in general, for stiffeners considered as clamped
- m = 8 for stiffeners considered as simply supported
- other values of m may be considered, on a case-by-case basis, for other boundary conditions.

p_S , p_W : Still water pressure and wave pressure defined in [2.3]

R_y : Minimum yield stress, in N/mm^2, of the material, to be taken equal to 235/k, unless otherwise specified

s : Spacing, in m, of ordinary stiffeners or primary supporting members, as applicable

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10]

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantlings of structures located aft of the after peak bulkhead and for the reinforcements of the flat bottom aft area.

1.1.2 Aft peak structures which form the boundary of spaces not intended to carry liquids, and which do not belong to the outer shell, are to be subjected to lateral pressure in flooding conditions. Their scantlings are to be determined according to the relevant criteria in Part B, Chapter 7, as applicable.

1.2 Connections of the aft part with structures located fore of the after peak bulkhead

1.2.1 Tapering

Adequate tapering is to be ensured between the scantlings in the aft part and those fore of the after peak bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

1.3 Net scantlings

1.3.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

Gross scantlings are obtained as specified in Ch 4, Sec 2.

2 Aft peak

2.1 Partial safety factors

2.1.1 The partial safety factors to be considered for the checking of aft peak structures are specified in Tab 1.

Table 1 : Aft peak structures - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors			
	Symbol	Plating	Ordinary stiffeners	Primary supporting members
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,20	1,20
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	1,20	1,40	1,60

2.2 Load point

2.2.1 Unless otherwise specified, lateral pressure is to be calculated at:

- the lower edge of the elementary load panel considered, for plating
- mid-span, for stiffeners.

2.3 Load model

2.3.1 General

The still water and wave lateral pressures in intact conditions are to be considered. They are to be calculated as specified in [2.3.2] for the elements of the outer shell and in [2.3.3] for the other elements.

Still water pressure p_S includes:

- the still water sea pressure, defined in Tab 2
- the still water internal pressure due to liquid or ballast, defined in Tab 4
- for decks, the still water internal pressure due to dry uniform weights, defined in Tab 5.

Wave pressure p_W includes:

- the wave pressure, defined in Tab 2
- the inertial pressure due to liquids or ballast, defined in Tab 4
- for decks, the inertial pressure due to uniform loads, defined in Tab 5.

2.3.2 Lateral pressures for the elements of the outer shell

The still water and wave lateral pressures are to be calculated considering separately:

- the still water and wave external sea pressures
- the still water and wave internal pressure, considering the compartment adjacent to the outer shell as being loaded.

If the compartment adjacent to the outer shell is not intended to carry liquids, only the external sea pressures are to be considered.

2.3.3 Lateral pressures for elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

Table 2 : Still water and wave pressures

Location	Still water sea pressure p, in kN/m²	Wave pressure p_W, in kN/m²
Bottom and side below the waterline: $z \leq T$	$\rho g (T - z)$	$\rho g h_1 e^{\frac{-2\pi(T-z)}{L}}$
Side above the waterline: $z > T$	0	$\rho g (T + h_1 - z)$ without being taken less than $0,15 \varphi_1 \varphi_2 L$
Exposed deck	Pressure due to the load carried**(1)**	$17,5 \varphi_1 \varphi_2$

(1) The pressure due to the load carried is to be defined by the Designer and, in any case, it may not be taken less than $10 \varphi_1 \varphi_2$ kN/m², where φ_1 and φ_2 are defined hereafter.

The Society may accept pressure values lower than $10 \varphi_1 \varphi_2$ kN/m² when considered appropriate on the basis of the intended use of the deck.

Note 1:

φ_1 : Coefficient defined in Tab 3

φ_2 = Min (L / 90 ; 1,0) without being taken less than 0,42.

Table 3 : Coefficient φ_1 for pressure on exposed deck

Exposed deck location	φ_1
Watertight deck	1,00
Superstructure deck	0,75
1st tier of deckhouse	0,56
2nd tier of deckhouse	0,42
3rd tier of deckhouse	0,32
4th tier of deckhouse	0,25
5th tier of deckhouse	0,20
6th tier of deckhouse	0,15
7th tier of deckhouse and above	0,10

Table 4 : Still water and wave internal pressures due to liquids

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
$\rho g (z_L - z)$	$\rho a_{Z1} (z_{TOP} - z)$

Note 1:

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank

z_L : Z co-ordinate, in m, of the highest point of the liquid:
$z_L = z_{TOP} + 0,5 (z_{AP} - z_{TOP})$

z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend, to be taken not less than z_{TOP}.

Table 5 : Still water and inertial internal pressures due to uniform loads

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
The value of p_S is, in general, defined by the Designer: in any case it may not be taken less than 10 kN/m². When the value of p_S is not defined by the Designer, it may be taken, in kN/m², equal to 6,9 h_{TD}, where h_{TD} is the compartment 'tweendeck height at side, in m.	$p_S \frac{a_{Z1}}{g}$

3 After peak

3.1 Arrangement

3.1.1 General

The provisions of this sub-article apply to transversely framed after peak structure.

3.1.2 Floors

Solid floors are to be fitted at every frame spacing.

The floor height is to be adequate in relation to the shape of the hull. Where a sterntube is fitted, the floor height is to extend at least above the sterntube. Where the hull lines do not allow such extension, plates of suitable height with upper and lower edges stiffened and securely fastened to the frames are to be fitted above the sterntube.

In way of and near the rudder post, propeller post and rudder horn, floors are to be extended up to the peak tank top and are to be increased in thickness; the increase will be considered by the Society on a case-by-case basis, depending on the arrangement proposed.

Floors are to be fitted with stiffeners having spacing not greater than 800 mm.

3.1.3 Side frames

Side frames are to be extended up to a deck located above the full load waterline.

Side frames are to be supported by one of the following types of structure:

- non-tight platforms, to be fitted with openings having a total area not less than 10% of the area of the platforms
- side girders supported by side primary supporting members connected to deck transverses.

The distance between the above side frame supports is to be not greater than 2,5 m.

3.1.4 Platforms and side girders

Platforms and side girders within the peak are to be arranged in line with those located in the area immediately forward.

Where this arrangement is not possible due to the shape of the hull and access needs, structural continuity between the peak and the structures of the area immediately forward is to be ensured by adopting wide tapering brackets.

Where the after peak is adjacent to a machinery space whose side is longitudinally framed, the side girders in the after peak are to be fitted with tapering brackets.

3.1.5 Longitudinal bulkheads

A longitudinal non-tight bulkhead is to be fitted on the centreline of the ship, in general in the upper part of the peak, and stiffened at each frame spacing.

Where either the stern overhang is very large or the maximum breadth of the peak is greater than 20 m, additional longitudinal wash bulkheads may be required.

3.2 Scantlings

3.2.1 Plating and ordinary stiffeners (side frames)

The net scantlings of plating and ordinary stiffeners are to be not less than those obtained from the formulae in:

- Tab 6 for plating
- Tab 7 for ordinary stiffeners,

and not less than the minimum values in the same Tables.

3.2.2 Floors

The net thickness of floors is to be not less than that obtained, in mm, from the following formula:

$t_M = 6,5 + 0,02\ L_2\ k^{1/2}$

3.2.3 Side transverses

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of side transverses are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

3.2.4 Side girders

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of side girders are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

3.2.5 Deck primary supporting members

Scantlings of deck primary supporting members are to be in accordance with Ch 7, Sec 3, as applicable, considering the loads in [2.3].

Table 6 : Net thickness of plating

Plating location	Net thickness, in mm	Minimum net thickness, in mm**(1)**
Bottom and side	$14,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$	$c_F (0,03 L + 5,5) k^{1/2} - c_E$
Inner bottom		$2 + 0,017 L k^{1/2} + 4,5 s$
Deck		For strength deck: $2,1 + 0,013 L k^{1/2} + 4,5 s$
Platform and wash bulkhead		$1,3 + 0,004 L k^{1/2} + 4,5 s$ for $L < 120$ m $2,1 + 2,2 k^{1/2} + s$ for $L \geq 120$ m
(1) L need not be taken greater than 300 m.		

Table 7 : Net scantlings of ordinary stiffeners

Ordinary stiffener location	Formulae	Minimum value
Bottom, side and deck	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web minimum net thickness, in mm, to be not less than the lesser of: • $t = 1,5 L_2^{1/3} k^{1/6}$ • the net thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$	
Platform and wash bulkhead	Net section modulus, in cm³: $w = 3,5 s \ell^2 k (z_{TOP} - z_M)$	

Note 1:

σ_{X1} : Hull girder normal stress, taken equal to:
- the value defined in Ch 7, Sec 2, [3.3.7], for stiffeners contributing to the hull girder longitudinal stress
- $\sigma_{X1} = 0$, for stiffeners not contributing to the hull girder longitudinal stress

Z_{TOP} : Z co-ordinate, in m, of the highest point of the peak tank

Z_M : Z co-ordinate, in m, of the stiffener mid-span.

4 Reinforcements of the flat area of the bottom aft

4.1 General

4.1.1 In the flat area of the bottom aft, if any, increased bottom plating thickness as well as additional bottom stiffeners may be considered by the Society on a case-by-case basis.

5 Connection of hull structures with the rudder horn

5.1 Connection of after peak structures with the rudder horn

5.1.1 General

The requirement of this sub-article apply to the connection between peak structure and rudder horn where the sternframe is of an open type and is fitted with the rudder horn.

5.1.2 Rudder horn

Horn design is to be such as to enable sufficient access for welding and inspection.

The scantlings of the rudder horn, which are to comply with Ch 9, Sec 1, [9.2], may be gradually tapered inside the hull.

Connections by slot welds are not acceptable.

5.1.3 Hull structures

Direct calculations are to be performed to check the connection of the rudder horn to the structure of the vessel, taking into account of the reactions induced by the rudder on the rudder horn.

In general, between the horn intersection with the shell and the peak tank top, the vertical extension of the hull structures is to be not less than the horn height, defined as the distance from the horn intersection with the shell to the mid-point of the lower horn gudgeon.

The thickness of the structures adjacent to the rudder horn, such as shell plating, floors, platforms and side girders, the centreline bulkhead and any other structures, is to be adequately increased in relation to the horn scantlings.

5.2 Structural arrangement above the after peak

5.2.1 Side transverses

Where a rudder horn is fitted, side transverses, connected to deck beams, are to be arranged between the platform forming the peak tank top and the weather deck.

The side transverse spacing is to be not greater than:

- 2 frame spacings in way of the horn
- 4 frame spacings for and aft of the rudder horn
- 6 frame spacings in the area close to the after peak bulkhead.

The side transverses are to be fitted with end brackets and located within the poop. Where there is no poop, the scantlings of side transverses below the weather deck are to be adequately increased.

5.2.2 Side girders

Where the depth from the peak tank top to the weather deck is greater than 2,6 m and the side is transversely framed, one or more side girders are to be fitted, preferably in line with similar structures existing forward.

6 Sternframes

6.1 General

6.1.1 Sternframes may be made of cast or forged steel, with a hollow section, or fabricated from plate.

6.1.2 Cast steel and fabricated sternframes are to be strengthened by adequately spaced horizontal plates.

Abrupt changes of section are to be avoided in castings; all sections are to have adequate tapering radius.

6.2 Connections

6.2.1 Connection with hull structure

The requirements below are applicable to single screw ships.

Sternframes are to be effectively attached to the aft structure and the lower part of the sternframe is to be extended forward of the propeller post to a length not less than (1500 + 6 L) mm, in order to provide an effective connection with the keel. However, the sternframe need not extend beyond the after peak bulkhead.

The net thickness of shell plating connected with the sternframe is to be not less than that obtained, in mm, from the following formula:

$t = 0,045\ L\ k^{1/2} + 8,5$

6.2.2 Connection with the keel

The requirements below are applicable to single screw ships.

The thickness of the lower part of the sternframes is to be gradually tapered to that of the solid bar keel or keel plate.

Where a keel plate is fitted, the lower part of the sternframe is to be so designed as to ensure an effective connection with the keel.

6.2.3 Connection with transom floors

The requirements below are applicable to single screw ships.

Rudder posts and, in the case of ships greater than 90 m in length, propeller posts are to be connected with transom floors having height not less than that of the double bottom and net thickness not less than that obtained, in mm, from the following formula:

$t = 9 + 0,023\ L_1\ k^{1/2}$

6.2.4 Connection with centre keelson

The requirements below are applicable to single screw ships.

Where the sternframe is made of cast steel, the lower part of the sternframe is to be fitted, as far as practicable, with a longitudinal web for connection with the centre keelson.

6.3 Propeller posts

6.3.1 Gross scantlings

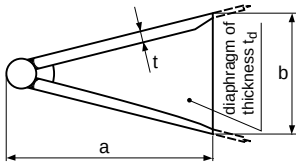
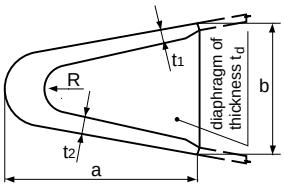
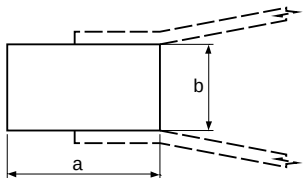
With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in [6.3.2] to [6.3.4] are gross, i.e. they include the margins for corrosion.

6.3.2 Gross scantlings of propeller posts

The gross scantlings of propeller posts are to be not less than those obtained from the formulae in Tab 8 for single screw ships and Tab 9 for twin screw ships.

Scantlings and proportions of the propeller post which differ from those above may be considered acceptable provided that the section modulus of the propeller post section about its longitudinal axis is not less than that calculated with the propeller post scantlings in Tab 8 or Tab 9, as applicable.

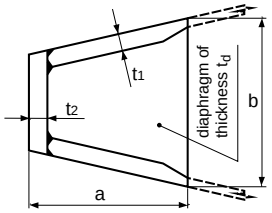
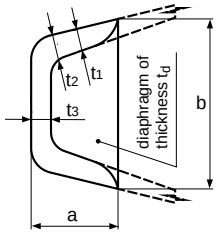
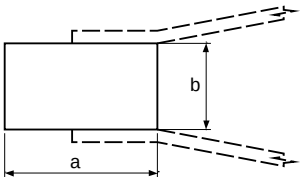
Table 8 : Single screw ships - Gross scantlings of propeller posts

Gross scantlings of propeller posts, in mm	**Fabricated propeller post**	**Cast propeller post**	**Bar propeller post, cast or forged, having rectangular section**
			
a	$50\ L^{1/2}$	$33\ L^{1/2}$	$10\sqrt{2,5(L+10)}$ for $L \le 60$ $10\sqrt{7,2L-256}$ for $L > 60$
b	$35\ L^{1/2}$	$23\ L^{1/2}$	$10\sqrt{1,6(L+10)}$ for $L \le 60$ $10\sqrt{4,6L-164}$ for $L > 60$
t_1 **(1)**	$2,5\ L^{1/2}$	$3,2\ L^{1/2}$ to be taken not less than 19 mm	N.A.
t_2 **(1)**	N.A.	$4,4\ L^{1/2}$ to be taken not less than 19 mm	N.A.
t_D	$1,3\ L^{1/2}$	$2,0\ L^{1/2}$	N.A.
R	N.A.	$50\ L^{1/2}$	N.A.

(1) Propeller post thicknesses t_1 and t_2 are, in any case, to be not less than $(0,05\ L + 9,5)$ mm.

Note 1: N.A. = not applicable.

Table 9 : Twin screw ships - Gross scantlings of propeller posts

Gross scantlings of propeller posts, in mm	**Fabricated propeller post**	**Cast propeller post**	**Bar propeller post, cast or forged, having rectangular section**
			
a	$25\ L^{1/2}$	$12,5\ L^{1/2}$	$0,72\ L + 90$ for $L \le 50$ $2,40\ L + 6$ for $L > 50$
b	$25\ L^{1/2}$	$25\ L^{1/2}$	$0,24\ L + 30$ for $L \le 50$ $0,80\ L + 2$ for $L > 50$
t_1 **(1)**	$2,5\ L^{1/2}$	$2,5\ L^{1/2}$	N.A.
t_2 **(1)**	$3,2\ L^{1/2}$	$3,2\ L^{1/2}$	N.A.
t_3 **(1)**	N.A.	$4,4\ L^{1/2}$	N.A.
t_D	$1,3\ L^{1/2}$	$2,0\ L^{1/2}$	N.A.

(1) Propeller post thicknesses t_1, t_2 and t_3 are, in any case, to be not less than $(0,05\ L + 9,5)$ mm.

Note 1: N.A. = not applicable.

6.3.3 Section modulus below the propeller shaft bossing

In the case of a propeller post without a sole piece, the section modulus of the propeller post may be gradually reduced below the propeller shaft bossing down to 85% of the value calculated with the scantlings in Tab 8 or Tab 9, as applicable.

In any case, the thicknesses of the propeller posts are to be not less than those obtained from the formulae in the Tables.

6.3.4 Welding of fabricated propeller post with the propeller shaft bossing

Welding of a fabricated propeller post with the propeller shaft bossing is to be in accordance with Ch 11, Sec 1, [3.3].

6.4 Integral rudder posts

6.4.1 Net section modulus of integral rudder post

The net section modulus around the horizontal axis X (see Fig 1) of an integral rudder post is to be not less than that obtained, in cm^3, from the following formula:

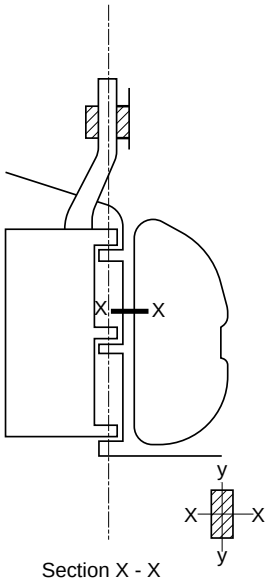
$w_{RP} = 14,4\ C_R\ L_D\ 10^{-6}$

where:

C_R : Rudder force, in N, acting on the rudder blade, defined in Ch 9, Sec 1, [2.1.2] and Ch 9, Sec 1, [2.2.2], as the case may be

L_D : Length of rudder post, in m.

Figure 1 : Integral rudder post



6.5 Propeller shaft bossing

6.5.1 In single screw ships, the thickness of the propeller shaft bossing, included in the propeller post, is to be not less than 60% of the dimension "b" required in [6.3.2] for bar propeller posts with a rectangular section.

6.6 Rudder gudgeon

6.6.1 Rudder gudgeons

In general, gudgeons are to be solidly forged or cast with the sternframe.

The height of the gudgeon is to be not greater than 1,2 times the pintle diameter. In any case, the height and diameter of the gudgeons are to be suitable to house the rudder pintle.

The thickness of the metal around the finished bore of the gudgeons is to be not less than half the diameter of the pintle.

6.7 Sterntubes

6.7.1 The sterntube thickness is considered by the Society on a case-by-case basis. In no case, however, may it be less than the thickness of the side plating adjacent to the sternframe.

Where the materials adopted for the sterntube and the plating adjacent to the sternframe are different, the sterntube thickness is to be at least equivalent to that of the plating.

Section 3 Machinery Space

Symbols

L_2 : Length, in m, defined in Ch 1, Sec 2, [2.1.1]

k : Material factor, defined in Ch 4, Sec 1, [2.3]

s : Spacing, in m, of ordinary stiffeners

P : Maximum power, in kW, of the engine

n_r : Number of revolutions per minute of the engine shaft at power equal to P

L_E : Effective length, in m, of the engine foundation plate required for bolting the engine to the seating, as specified by the engine manufacturer.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the arrangement and scantling of machinery space structures as regards general strength. It is no substitute to machinery manufacturer's requirements which have to be dealt with at Shipyard diligence.

1.2 Scantlings

1.2.1 Net scantlings

As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.2.2 General

Unless otherwise specified in this Section, the scantlings of plating, ordinary stiffeners and primary supporting members in the machinery space are to be determined according to the relevant criteria in Part B, Chapter 7 as applicable. In addition, the minimum thickness requirements specified in this Section apply.

1.2.3 Primary supporting members

The Designer may propose arrangements and scantlings alternative to the requirements of this Section, on the basis of direct calculations which are to be submitted to the Society for examination on a case-by-case basis.

The Society may also require such direct calculations to be carried out whenever deemed necessary.

1.3 Connections of the machinery space with structures located aft and forward

1.3.1 Tapering

Adequate tapering is to be ensured between the scantlings in the machinery space and those aft and forward. The tapering is to be such that the scantling requirements for all areas are fulfilled.

1.3.2 Deck discontinuities

Decks which are interrupted in the machinery space are to be tapered on the side by means of horizontal brackets.

2 Double bottom

2.1 Arrangement

2.1.1 General

Where the machinery space is immediately forward of the after peak, the double bottom is generally to be transversely framed. In all other cases it may be transversely or longitudinally framed.

2.1.2 Double bottom height

The double bottom height at the centreline, irrespective of the location of the machinery space, is to be not less than the value defined in Ch 4, Sec 4, [4.2.1]. This depth may need to be considerably increased in relation to the type and depth of main machinery seatings.

The above height is to be increased by the Shipyard where the machinery space is very large and where there is a considerable variation in draught between light ballast and full load conditions.

Where the double bottom height in the machinery space differs from that in adjacent spaces, structural continuity of longitudinal members is to be ensured by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the sloped inner bottom are to be located close to the floors.

2.1.3 Centre bottom girder

In general, the centre bottom girder may not be provided with holes. In any case, in way of any openings for manholes on the centre girder, permitted only where absolutely necessary for double bottom access and maintenance, local strengthening is to be arranged.

2.1.4 Side bottom girders

In the machinery space the number of side bottom girders is to be adequately increased, with respect to the adjacent areas, to ensure adequate rigidity of the structure.

The side bottom girders are to be a continuation of any bottom longitudinals in the areas adjacent to the machinery space and are generally to have a spacing not greater than 3 times that of longitudinals and in no case greater than 3 m.

2.1.5 Side bottom girders in way of machinery seatings

Additional side bottom girders are to be fitted in way of machinery seatings.

Side bottom girders arranged in way of main machinery seatings are to extend for the full length of the machinery space.

Where the machinery space is situated amidships, the bottom girders are to extend aft of the after bulkhead of such space for at least three frame spaces, and beyond to be connected to the hull structure by tapering.

Where the machinery space is situated aft, the bottom girders are to extend as far aft as practicable in relation to the shape of the bottom and to be supported by floors and side primary supporting members at the ends.

Forward of the machinery space forward bulkhead, the bottom girders are to be tapered for at least three frame spaces and are to be effectively connected to the hull structure.

2.1.6 Floors in longitudinally framed double bottom

Where the double bottom is longitudinally framed, the floor spacing is to be not greater than:

- 1 frame spacing in way of the main engine and thrust bearing
- 2 frame spacings in other areas of the machinery space.

Additional floors are to be fitted in way of other important machinery.

2.1.7 Floors in transversely framed double bottom

Where the double bottom in the machinery space is transversely framed, floors are to be arranged at every frame.

Furthermore, additional floors are to be fitted in way of boiler foundations or other important machinery.

2.1.8 Floors stiffeners

In addition to the requirements in Ch 4, Sec 3, [4.7], floors are to have web stiffeners sniped at the ends and spaced not more than approximately 1 m apart.

The section modulus of web stiffeners is to be not less than 1,2 times that required in Ch 4, Sec 3, [4.7].

2.1.9 Manholes and wells

The number and size of manholes in floors located in way of seatings and adjacent areas are to be kept to the minimum necessary for double bottom access and maintenance.

The depth of manholes is generally to be not greater than 40% of the floor local depth, and in no case greater than 750 mm, and their width is to be equal to approximately 400 mm.

In general, manhole edges are to be stiffened with flanges; failing this, the floor plate is to be adequately stiffened with flat bars at manhole sides.

Manholes with perforated portable plates are to be fitted in the inner bottom in the vicinity of wells arranged close to the aft bulkhead of the engine room.

Drainage of the tunnel is to be arranged through a well located at the aft end of the tunnel.

2.2 Minimum thicknesses

2.2.1 The net thicknesses of inner bottom, floor and girder webs are to be not less than the values given in Tab 1.

The Society may consider lower thicknesses than those in Tab 1, on a case-by-case basis, when this is deemed appropriate on the basis of scantling calculations for all type s of loading cases.

Table 1 : Double bottom - Minimum net thicknesses of inner bottom, floors and girder webs

Element	Minimum net thickness, in mm	
	Machinery space within 0,4L amidships	Machinery space outside 0,4L amidships
Inner bottom	$[0,75\ L^{1/2} + 1,35 + 4,5\ (s - 0,23\ L^{1/4})]\ k^{1/2}$ The Society may require the thickness of the inner bottom in way of the main machinery seatings and on the main thrust blocks to be increased, on a case-by-case basis	
Margin plate	$L^{1/2}\ k^{1/4} + 1$	$0,9\ L^{1/2}\ k^{1/4} + 1$
Centre girder	$1,8\ L^{1/3}\ k^{1/6} + 4$	$1,55\ L^{1/3}\ k^{1/6} + 3,5$
Floors and side girders	$1,7\ L^{1/3}\ k^{1/6} + 1$	
Girder bounding a duct keel	$0,8\ L^{1/2}\ k^{1/4} + 2,5$ to be taken not less than that required for the centre girder	

3 Single bottom

3.1 Arrangement

3.1.1 Bottom girder

For single bottom girder arrangement, the requirements of Ch 4, Sec 4, [2.1] and Ch 4, Sec 4, [3.1] apply for longitudinally framed and transversely framed single bottoms respectively.

3.1.2 Floors in longitudinally framed single bottom

Where the single bottom is longitudinally framed, the floor spacing is to be not greater than:

- 1 frame spacing in way of the main engine and thrust bearing
- 2 frame spacings in other areas of the machinery spaces.

Additional floors are to be fitted in way of other important machinery.

3.1.3 Floors in transversely framed single bottom

Where the single bottom is transversely framed, the floors are to be arranged at every frame.

Furthermore, additional floors are to be fitted in way of boiler foundations or other important machinery.

3.1.4 Floor height

The height of floors in way of machinery spaces located amidships is to be not less than B/14,5. Where the top of the floors is recessed in way of main machinery, the height of the floors in way of this recess is generally to be not less than B/16. Lower values will be considered by the Society on a case-by-case basis.

Where the machinery space is situated aft or where there is considerable rise of floor, the depth of the floors will be considered by the Society on a case-by-case basis.

3.1.5 Floor flanging

Floors are to be fitted with welded face plates in way of:

- engine bed plates
- thrust blocks
- auxiliary seatings.

3.2 Minimum thicknesses

3.2.1 The net thicknesses of floor and girder webs are to be not less than the values given in Tab 2.

The Society may consider lower thicknesses than those in Tab 2, on a case-by-case basis, when this is deemed appropriate on the basis of scantling calculations for all types of loading cases.

Table 2 : Single bottom Minimum net thicknesses of floors and girder webs

Element	Minimum net thickness, in mm	
	Machinery space within 0,4L amidships	Machinery space outside 0,4L amidships
Centre girder	$7 + 0,05\ L_2\ k^{1/2}$	$6 + 0,05\ L_2\ k^{1/2}$
Floors and side girders	$6,5 + 0,05\ L_2\ k^{1/2}$	$5 + 0,05\ L_2\ k^{1/2}$

4 Side

4.1 Arrangement

4.1.1 General

The type of side framing in machinery spaces is generally to be the same as that adopted in the adjacent areas.

4.1.2 Extension of the hull longitudinal structure within the machinery space

In ships where the machinery space is located aft and where the side is longitudinally framed, the longitudinal structure is preferably to extend for the full length of the machinery space.

In any event, the longitudinal structure is to be maintained for at least 0,3 times the length of the machinery space, calculated from the forward bulkhead of the latter, and abrupt structural discontinuities between longitudinally and transversely framed structures are to be avoided.

4.1.3 Side transverses

Side transverses are to be aligned with floors. One is preferably to be located in way of the forward end and another in way of the after end of the machinery casing.

For a longitudinally framed side, the side transverse spacing is to be not greater than 4 frame spacings.

For a transversely framed side, the side transverse spacing is to be not greater than 5 frame spaces. The web height is to be not less than twice that of adjacent frames and the section modulus is to be not less than four times that of adjacent frames.

Side transverse spacing greater than that above may be accepted provided that the scantlings of ordinary frames are increased, according to the Society's requirements to be defined on a case-by-case basis.

5 Platforms

5.1 Arrangement

5.1.1 General

The location and extension of platforms in machinery spaces are to be arranged so as to be a continuation of the structure of side longitudinals, as well as of platforms and side girders located in the adjacent hull areas.

5.1.2 Platform transverses

In general, platform transverses are to be arranged in way of side or longitudinal bulkhead transverses.

For longitudinally framed platforms, the spacing of platform transverses is to be not greater than 4 frame spacings.

5.2 Minimum thicknesses

5.2.1 The net thickness of platforms is to be not less than that obtained, in mm, from the following formula:

$t = 0,018\ L_2\ k^{1/2} + 4,5$

The Society may consider lower thicknesses, on a case-by-case basis, based on scantling calculations with appropriate loadings.

6 Pillaring

6.1 Arrangement

6.1.1 General

The pillaring arrangement in machinery spaces is to account both for the concentrated loads transmitted by machinery and superstructures and for the position of main machinery and auxiliary engines.

6.1.2 Pillars

Pillars are generally to be arranged in the following positions:

- in way of machinery casing corners and corners of large openings on platforms; alternatively, two pillars may be fitted on the centreline (one at each end of the opening)
- in way of the intersection of platform transverses and girders
- in way of transverse and longitudinal bulkheads of the superstructure.

In general, pillars are to be fitted with brackets at their ends.

6.1.3 Pillar bulkheads

In general, pillar bulkheads, fitted 'tweendecks below the upper deck, are to be located in way of load-bearing bulkheads in the superstructures.

Longitudinal pillar bulkheads are to be a continuation of main longitudinal hull structures in the adjacent spaces forward and aft of the machinery space.

Pillar bulkhead scantlings are to be not less than those required in [7.3] for machinery casing bulkheads.

7 Machinery casing

7.1 Arrangement

7.1.1 Ordinary stiffener spacing

Ordinary stiffeners are to be located:

- at each frame, in longitudinal bulkheads
- at a distance of about 750 mm, in transverse bulkheads.

The ordinary stiffener spacing in portions of casings which are particularly exposed to wave action is considered by the Society on a case-by-case basis.

7.2 Openings

7.2.1 General

All machinery space openings, which are to comply with the requirements in Ch 8, Sec 10, [6], are to be enclosed in a steel casing leading to the highest open deck. Lower parts of casings are to be reinforced at the ends by deck beams and girders associated to pillars.

In the case of large openings, the arrangement of cross-ties as a continuation of deck beams may be required.

7.2.2 Access doors

Access doors to casings are to comply with Ch 8, Sec 10, [6.2].

7.3 Scantlings

7.3.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than those obtained according to the applicable requirements in Ch 8, Sec 4.

7.3.2 Minimum thicknesses

The net thickness of bulkheads is to be not less than:

- 5,5 mm for bulkheads in way of cargo holds
- 4,0 mm for bulkheads in way of accommodation spaces.

The Society may consider lower thicknesses, on a case-by-case basis, based on scantling calculations with appropriate loadings.

8 Main machinery seatings

8.1 Arrangement

8.1.1 General

The scantlings of main machinery seatings and thrust bearings are to be adequate in relation to the weight and power of engines and the static and dynamic forces transmitted by the propulsive installation.

8.1.2 Seating supporting structure

Transverse and longitudinal members supporting the seatings are to be located in line with floors and double or single bottom girders, respectively.

They are to be so arranged as to avoid discontinuity and ensure sufficient accessibility for welding of joints and for surveys and maintenance.

8.1.3 Seatings included in the double bottom structure

Where high-power internal combustion engines or turbines are fitted, seatings are to be integral with the double bottom structure. Girders supporting the bedplates in way of seatings are to be aligned with double bottom girders and are to be extended aft in order to form girders for thrust blocks.

The girders in way of seatings are to be continuous from the bedplates to the bottom shell.

8.1.4 Seatings above the double bottom plating

Where the seatings are situated above the double bottom plating, the girders in way of seatings are to be fitted with flanged brackets, generally located at each frame and extending towards both the centre of the ship and the sides.

The extension of the seatings above the double bottom plating is to be limited as far as practicable while ensuring adequate spaces for the fitting of bedplate bolts. Bolt holes are to be located such that they do not interfere with seating structures.

8.1.5 Seatings in a single bottom structure

For ships having a single bottom structure within the machinery space, seatings are to be located above the floors and to be adequately connected to the latter and to the girders located below.

8.1.6 Number of girders in way of machinery seatings

In general, at least two girders are to be fitted in way of main machinery seatings.

One girder may be fitted only where the following three formulae are complied with:

$L < 150$ m

$P < 7100$ kW

$P < 2{,}3\ n_r\ L_E$

8.2 Minimum scantlings

8.2.1 The net scantlings of the structural elements in way of the internal combustion engine seatings are to be not less than those obtained from the formulae in Tab 3.

Table 3 : Minimum scantlings of structural elements in way of engine seatings

Scantling	Minimum value
Net cross-sectional area, in cm^2, of each bedplate of the seatings	$40 + 70\frac{P}{n_r L_E}$
Net thickness, in mm, of each bedplate of the seatings	• Bedplate supported by two or more longitudinal members: $\sqrt{240 + 175\frac{P}{n_r L_E}}$ • Bedplate supported by one longitudinal member: $5 + \sqrt{240 + 175\frac{P}{n_r L_E}}$
Web net thickness, in mm, of longitudinal members fitted in way of each bedplate of the seatings	• Bedplate supported by two or more longitudinal members: $\frac{1}{n_G}\sqrt{320 + 215\frac{P}{n_r L_E}}$ where n_G is the number of longitudinal members in way of the bedplate considered • Bedplate supported by one longitudinal member: $\sqrt{95 + 65\frac{P}{n_r L_E}}$
Web net thickness, in mm, of transverse members fitted in way of bedplates of the seating**(1)**	$\sqrt{55 + 40\frac{P}{n_r L_E}}$
(1) When intermediate transverse members welded to the bedplate are fitted, the web minimum net thickness may be reduced on a case-by-case basis.	

Section 4 Superstructures and Deckhouses

Symbols

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10]

s : Spacing, in m, of ordinary stiffeners

k : Material factor, defined in:

- Ch 4, Sec 1, [2.3], for steel
- Ch 4, Sec 1, [4.4], for aluminium alloys

t_c : Corrosion addition, in mm, defined in Ch 4, Sec 2, Tab 2.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantling of plating and associated structures of front, side and aft bulkheads and decks of superstructures and deckhouses, which may or may not contribute to the longitudinal strength.

1.1.2 The requirements of this Section comply with the applicable regulations of the 1966 International Convention on Load Lines, with regard to the strength of enclosed superstructures.

1.2 Net scantlings

1.2.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.3 Definitions

1.3.1 Superstructures and deckhouses contributing to the longitudinal strength

Superstructures and deckhouses contributing to the longitudinal strength are defined in Ch 6, Sec 1, [2.2].

1.3.2 Tiers of superstructures and deckhouses

The lowest tier is normally that which is directly situated above the main watertight deck.

Where the difference of height between the deepest subdivision loadline and the watertight deck exceeds the value given, in m, by the following formula:

1,80 + 0,01 (L – 75) to be taken neither less than 1,80 m, nor greater than 2,30 m, the lowest tier may be considered as an upper tier when calculating the scantlings of superstructures and deckhouses.

The second tier is that located immediately above the lowest tier, and so on.

1.4 Connections of superstructures and deckhouses with the hull structure

1.4.1 Superstructure and deckhouse frames are to be fitted as far as practicable as extensions of those underlying and are to be effectively connected to both the latter and the deck beams above.

Ends of superstructures and deckhouses are to be efficiently supported by bulkheads, diaphragms, webs or pillars.

Where hatchways are fitted close to the ends of superstructures, additional strengthening may be required.

1.4.2 Connection to the deck of corners of superstructures and deckhouses is considered by the Society on a case-by-case basis. Where necessary, doublers or reinforced welding may be required.

1.4.3 As a rule, the frames of sides of superstructures and deckhouses are to have the same spacing as the beams of the supporting deck.

Web frames are to be arranged to support the sides and ends of superstructures and deckhouses.

1.4.4 The side plating at ends of superstructures is to be tapered into the bulwark or sheerstrake of the strength deck.

Where a raised deck is fitted, this arrangement is to extend over at least 3 frame spacings.

1.5 Structural arrangement of superstructures and deckhouses

1.5.1 Strengthening in way of superstructures and deckhouses

Web frames, transverse partial bulkheads or other equivalent strengthening are to be fitted inside deckhouses of at least 0,5 B in breadth extending more than 0,15 L in length within 0,4 L amidships. These transverse strengthening reinforcements are to be spaced approximately 9 m apart and are to be arranged, where practicable, in line with the transverse bulkheads below.

Web frames are also to be arranged in way of large openings, boats davits and other areas subjected to point loads.

Web frames, pillars, partial bulkheads and similar strengthening are to be arranged, in conjunction with deck transverses, at ends of superstructures and deckhouses.

1.5.2 Strengthening of the raised quarter deck stringer plate

When a superstructure is located above a raised quarter deck, the thickness of the raised quarter deck stringer plate is to be increased by 30% and is to be extended within the superstructure.

The increase above may be reduced when the raised quarter deck terminates outside 0,5 L amidships.

1.5.3 Openings

Openings are to be in accordance with Ch 6, Sec 1.

Continuous coamings are to be fitted above and below doors or similar openings.

1.5.4 Access and doors

Access openings cut in sides of enclosed superstructures are to be fitted with doors made of steel or other equivalent material, and permanently attached.

Special consideration is to be given to the connection of doors to the surrounding structure.

Securing devices which ensure watertightness are to include tight gaskets, clamping dogs or other similar appliances, and are to be permanently attached to the bulkheads and doors. These doors are to be operable from both sides.

1.5.5 Strengthening of deckhouses in way of lifeboats and rescue boats

Stiffening of sides of deckhouses in way of lifeboats and rescue boats is to be compatible with the launching operation. Deckhouses in way of launching appliances are to be adequately strengthened.

1.5.6 Constructional details

Lower tier stiffeners are to be welded to the decks at their ends.

Brackets are to be fitted at the upper and preferably also the lower ends of vertical stiffeners of exposed front bulkheads of engine casings and superstructures or deckhouses protecting pump room openings.

1.5.7 Use of aluminium alloys

Unprotected front bulkheads of first tier superstructures or deckhouses are generally to be built of steel and not of aluminium alloy.

Aluminium alloys may be adopted for front bulkheads of superstructures or deckhouses above the first tier.

2 Design loads

2.1 Sides contributing to the longitudinal strength

2.1.1 Load point

Lateral pressure is to be calculated at:

- the lower edge of the elementary plate panel, for plating
- mid-span, for stiffeners.

2.1.2 Lateral pressure

The lateral pressure is constituted by the still water sea pressure p_S and the wave pressure p_W, defined in Ch 5, Sec 5.

Moreover, when the side is a tank boundary, the lateral pressure constituted by the still water internal pressure p_S and the inertial pressure p_W, defined in Ch 5, Sec 6, [1] is also to be considered.

2.2 Front, side and aft bulkheads not contributing to the longitudinal strength

2.2.1 Load point

Lateral pressure is to be calculated at:

- mid-height of the bulkhead, for plating
- mid-span, for stiffeners.

2.2.2 Lateral pressure

The lateral pressure to be used for the determination of scantlings of the structure of front, side and aft bulkheads of superstructures and deckhouses is to be obtained, in kN/m^2, from the following formula:

$p = 10\ a\ c\ [b\ f - (z - T)]$

without being less than p_{min}

where:

a : Coefficient defined in Tab 1

c : Coefficient taken equal to:

$$c = 0,3 + 0,7\frac{b_1}{B_1}$$

For exposed parts of machinery casings, c is to be taken equal to 1

b_1 : Breadth of deckhouse, in m, at the position considered, to be taken not less than $0,25\ B_1$

B_1 : Actual maximum breadth of ship on the exposed weather deck, in m, at the position considered

b : Coefficient defined in Tab 2

f : Coefficient defined in Tab 3

p_{min} : Minimum lateral pressure defined in Tab 4.

2.3 Decks

2.3.1 The lateral pressure for decks which may or may not contribute to the longitudinal strength is constituted by the still water internal pressure p_S and the inertial pressure p_W, defined in Ch 5, Sec 6, [5] or Ch 5, Sec 6, [6] as applicable.

Moreover, when the deck is a tank boundary, the lateral pressure constituted by the still water internal pressure p_S and the inertial pressure p_W, defined in Ch 5, Sec 6, [1] is also to be considered.

Table 1 : Lateral pressure for superstructures and deckhouses - Coefficient a

Type of bulkhead	Location	a	a maximum
Unprotected front	Lowest tier	$2 + \frac{L}{120}$	4,5
	Second tier	$1 + \frac{L}{120}$	3,5
	Third tier	$0,5 + \frac{L}{150}$	2,5
	Fourth tier	$0,9\left(0,5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0,8\left(0,5 + \frac{L}{150}\right)$	2,0
Protected front	Lowest, second and third tiers	$0,5 + \frac{L}{150}$	2,5
	Fourth tier	$0,9\left(0,5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0,8\left(0,5 + \frac{L}{150}\right)$	2,0
Side	Lowest, second and third tiers	$0,5 + \frac{L}{150}$	2,5
	Fourth tier	$0,9\left(0,5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0,8\left(0,5 + \frac{L}{150}\right)$	2,0
Aft end	All tiers, when: $x/L \leq 0,5$	$0,7 + \frac{L}{1000} - 0,8\frac{x}{L}$	$1 - 0,8\frac{x}{L}$
	All tiers, when: $x/L > 0,5$	$0,5 + \frac{L}{1000} - 0,4\frac{x}{L}$	$0,8 - 0,4\frac{x}{L}$

Table 2 : Lateral pressure for superstructures and deckhouses - Coefficient b

Location of bulkhead **(1)**	b
$\frac{x}{L} \leq 0,45$	$1 + \left(\frac{\frac{x}{L} - 0,45}{C_B + 0,2}\right)^2$
$\frac{x}{L} > 0,45$	$1 + 1,5\left(\frac{\frac{x}{L} - 0,45}{C_B + 0,2}\right)^2$
(1) For deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding 0,15 L each, and x is to be taken as the co-ordinate of the centre of each part considered. **Note 1:** C_B : Block coefficient, with $0,6 \leq C_B \leq 0,8$	

Table 3 : Lateral pressure for superstructures and deckhouses - Coefficient f

Length L of ship, in m	f
L < 150	$\frac{L}{10}e^{-L/300} - \left[1 - \left(\frac{L}{150}\right)^2\right]$
150 ≤ L < 300	$\frac{L}{10}e^{-L/300}$
L ≥ 300	11,03

Table 4 : Minimum lateral pressurefor superstructures and deckhouses

Location and type of bulkhead	p_{min}, in kN/m²
Lowest tier of unprotected fronts	$30 \leq 25,0 + 0,10L \leq 50$
Elsewhere: • if $z \leq T + 0,5\ B\ A_R + 0,5\ h_w$ • if $T + 0,5\ B\ A_R + 0,5\ h_w < z$ and $z \leq T + 0,5\ B\ A_R + h_w$ • if $z > T + 0,5\ B\ A_R + h_w$	$15 \leq 12,5 + 0,05\ L \leq 25$ linear interpolation 2,5
Note 1: A_R : Roll amplitude, in rad, defined in Ch 5, Sec 3, [2.4] or taken equal to 0,35 for ships less than 65 m in length h_w : Wave parameter, in m, defined in Ch 5, Sec 3.	

3 Plating

3.1 Front, side and aft bulkheads

3.1.1 Plating contributing to the longitudinal strength

The net thickness of side plate panels contributing to the longitudinal strength is to be determined in accordance with the applicable requirements of Ch 7, Sec 1, as applicable, considering the lateral pressure defined in [2.1.2].

3.1.2 Plating not contributing to the longitudinal strength

The net thickness of plating of front, side and aft bulkheads not contributing to the longitudinal strength is to be not less than the value obtained, in mm, from the following formula:

$$t = 0,95 s \sqrt{kp} - t_c$$

without being less than the values indicated in Tab 5, where p is the lateral pressure, in kN/m², defined in [2.2].

The Society may consider lower thicknesses than those in Tab 5, on a case-by-case basis, when this is deemed appropriate on the basis of scantling calculations for all types of loading cases.

For plating which forms tank boundaries, the net thickness is to be determined in accordance with [3.1.1], considering the hull girder stress equal to 0.

Table 5 : Superstructures and deckhouses - Minimum thicknesses

Location	Minimum thickness, in mm
Lowest tier	$k_1 (5 + 0,01 L) k^{1/2} - t_C$
Second tier and above	$k_1 (4 + 0,01 L) k^{1/2} - t_C$
Note 1: L is to be taken not less than 100 m and not greater than 300 m. k_1 : • for steel: $k_1 = 1,00$ • for aluminium: $k_1 = 0,65$	

3.2 Decks

3.2.1 The net thickness of plate panels of decks which may or may not contribute to the longitudinal strength is to be determined in accordance with the applicable requirements of Ch 7, Sec 1 or Ch 8, Sec 3, as applicable.

3.2.2 For decks sheathed with wood, the net thickness obtained from [3.2.1] may be reduced by 10 percent.

4 Ordinary stiffeners

4.1 Front, side and aft bulkheads

4.1.1 Ordinary stiffeners of plating contributing to the longitudinal strength

The net scantlings of ordinary stiffeners of plating contributing to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 2.

4.1.2 Ordinary stiffeners of plating not contributing to the longitudinal strength

The net section modulus w of ordinary stiffeners of plating not contributing to the longitudinal strength is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 0,35 \varphi k s \ell^2 p (1 - \alpha t_c) - \beta t_c$$

where:

ℓ : Span of the ordinary stiffener, in m, equal to the 'tweendeck height and to be taken not less than 2 m

p : Lateral pressure, in kN/m^2, defined in [2.2.2]

φ : Coefficient depending on the stiffener end connections, and taken equal to:

- 1 for lower tier stiffeners
- value defined in Tab 6 for stiffeners of upper tiers

α, β : Parameters defined in Ch 4, Sec 2, Tab 1.

The section modulus of side ordinary stiffeners need not be greater than that of the side ordinary stiffeners of the tier situated directly below taking account of spacing and span.

For ordinary stiffeners of plating forming tank boundaries, the net scantlings are to be determined in accordance with [4.1.1], considering the hull girder stress equal to 0.

In addition, the net section modulus, in cm^3, of ordinary stiffeners is not to be less than the values given in Tab 7.

4.2 Decks

4.2.1 The net scantlings of ordinary stiffeners of decks which may or may not contribute to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 2.

Table 6 : Stiffeners of superstructures and deckhouses - Coefficient φ for end connections

Coefficient φ	Upper end welded to deck	Bracketed upper end	Sniped upper end
Lower end welded to deck	1,00	0,85	1,15
Bracketed lower end	0,85	0,85	1,00
Sniped lower end	1,15	1,00	1,15

Table 7 : Minimum ordinary stiffener section modulus (cm^3)

	Lowest tier	Second tier	Third tier	Fourth tier and above
Unprotected front	30 $k^{0.25}$	21 $k^{0.25}$	15 $k^{0.25}$	10 $k^{0.25}$
Side	20 $k^{0.25}$	14 $k^{0.25}$	10 $k^{0.25}$	
Aft end and protected front	27 $k^{0.25}$	19 $k^{0.25}$	13 $k^{0.25}$	

5 Primary supporting members

5.1 Front, side and aft bulkheads

5.1.1 Primary supporting members of plating contributing to the longitudinal strength

The net scantlings of side primary supporting members of plating contributing to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 3, as applicable.

5.1.2 Primary supporting members of plating not contributing to the longitudinal strength

The net scantlings of side primary supporting members of plating not contributing to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 3, as applicable, using the lateral pressure defined in [2.2.2].

5.2 Decks

5.2.1 The net scantlings of primary supporting members of decks which may or may not contribute to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 3.

Section 5 Bow Doors and Inner Doors

Symbols

L_1 : Length, in m, defined in Ch 1, Sec 2, [2.1.1].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement, strength and securing of bow doors and inner doors leading to a complete or long forward enclosed superstructure.

1.1.2 Two types of bow doors are provided for:

- visor doors opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary supporting members of the door by longitudinally arranged lifting arms
- side-opening doors opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the ship. It is anticipated that side-opening bow doors are arranged in pairs.

Other types of bow door are considered by the Society on a case-by-case basis in association with the applicable requirements of this Section.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangement

1.3.1 Bow doors are to be situated above the watertight deck. A watertight recess in the watertight deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the watertight deck for the purpose of this requirement.

1.3.2 An inner door is to be fitted as part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, as per Ch 2, Sec 1, [3.1].

A vehicle ramp may be arranged for this purpose, provided its position complies with Ch 2, Sec 1, [3.1].

If this is not possible, a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

1.3.3 Bow doors are to be so fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors.

Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

1.3.4 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in [1.3.2].

1.3.5 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in stowed position.

1.4 Definitions

1.4.1 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges.

1.4.2 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship structure.

1.4.3 Locking device

A locking device is a device that locks a securing device in the closed position.

2 Design loads

2.1 Bow doors

2.1.1 Design external pressure

The design external pressure to be considered for the scantlings of primary supporting members and securing and supporting devices of bow doors is to be not less than that obtained, in kN/m^2, from the following formula:

$$p_E = 0,5 C_L C_Z (0,22 + 0,15 \tan\alpha)(0,4 V \sin\beta + 0,6\sqrt{L_1})^2$$

where:

V : Maximum ahead service speed, in knots

C_L : Coefficient depending on the ship length:

$C_L = 0,0125\ L$ for $L < 80$ m

$C_L = 1,0$ for $L \geq 80$ m

C_Z : Coefficient defined in Ch 8, Sec 1, [4.2.1], to be taken equal to 5,5

α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the side plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 1)

β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 1).

2.1.2 Design external forces

The design external forces F_X, F_Y, F_Z to be considered for the scantlings of securing and supporting devices of bow doors are to be not less than those obtained, in kN, from the following formulae:

$F_X = p_E A_X$

$F_Y = p_E A_Y$

$F_Z = p_E A_Z$

where:

p_E : External pressure, in kN/m^2, to be calculated according to [2.1.1], assuming the angles α and β measured at the point on the bow door located $\ell/2$ aft of the stem line on the plane h/2 above the bottom of the door, as shown in Fig 1

h : Height, in m, to be taken as the lesser of h_1 and h_2

h_1 : Height, in m, of the door between the levels of its bottom and the upper deck

h_2 : Height, in m, of the door between its bottom and top

ℓ : Length, in m, of the door at a height h/2 above the bottom of the door

A_X : Area, in m^2, to be taken as the lesser of A_{X1} and A_{X2}

A_Y : Area, in m^2, to be taken as the lesser of A_{Y1} and A_{Y2}

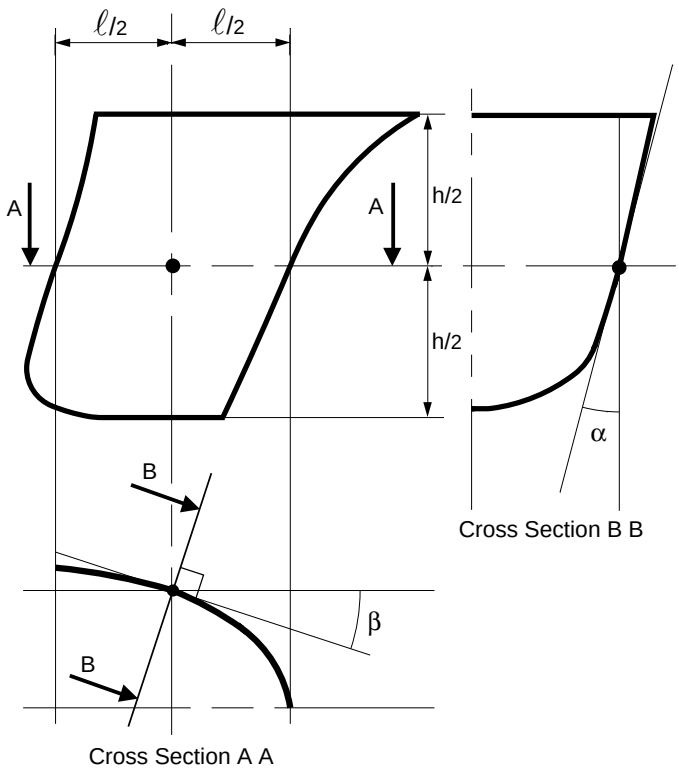
A_Z : Area, in m^2, to be taken as the lesser of A_{Z1} and A_{Z2}

A_{X1}, A_{Y1}, A_{Z1} : Areas, in m^2, of the vertical transverse, vertical longitudinal and horizontal projections, respectively, of the door between the levels of its bottom and the upper deck

A_{X2}, A_{Y2}, A_{Z2} : Areas, in m^2, of the vertical transverse, vertical longitudinal and horizontal projections, respectively, of the door between the levels of its bottom and top.

For bow doors, including bulwark, of unusual form or proportions, e.g. ships with a rounded nose and large stem angles, the areas and angles used for determination of the design values of external forces will be considered on a case-by-case basis.

Figure 1 : Definition of angles α and β



2.1.3 Closing moment

For visor doors, the closing moment under external loads is to be obtained, in kN·m, from the following formula:

$M_Y = F_X\, a + 10\, W\, c - F_Z\, b$

where:

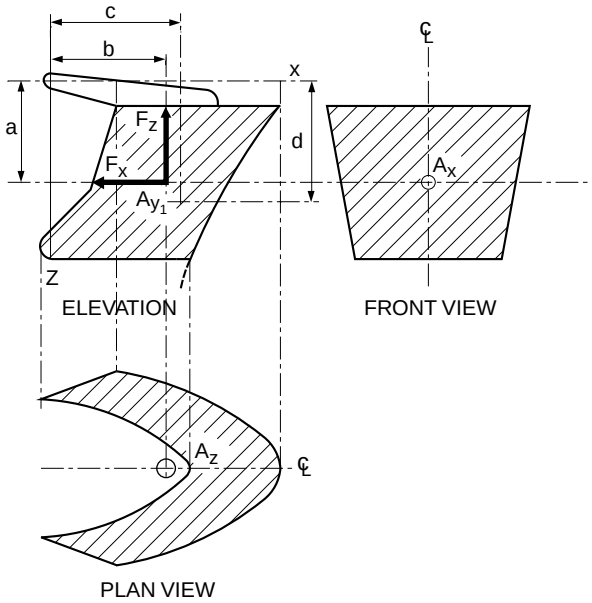
W : Mass of the visor door, in t

a : Vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig 2

b : Horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Fig 2

c : Horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Fig 2.

Figure 2 : Bow doors of visor type



2.1.4 Forces acting on the lifting arms

The lifting arms of a visor door and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m^2 is to be taken into account.

2.2 Inner doors

2.2.1 Design external pressure

The design external pressure to be considered for the scantlings of primary supporting members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of the values obtained, in kN/m^2, from the following formulae:

$p_E = 0,45\ L_1$

$p_E = 10\ h$

where:

h : Distance, in m, from the calculation point to the top of the cargo space.

2.2.2 Design internal pressure

The design internal pressure p_I to be considered for the scantlings of securing devices of inner doors is to be not less than 25 kN/m^2.

3 Scantlings of bow doors

3.1 General

3.1.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

3.1.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed.

For visor doors, adequate strength for opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the ship structure.

3.2 Plating and ordinary stiffeners

3.2.1 Plating

The thickness of the bow door plating is to be not less than that obtained according to the requirements in Ch 8, Sec 1 for the fore part, using the bow door stiffener spacing. In no case may it be less than the minimum required thickness of fore part shell plating.

3.2.2 Ordinary stiffeners

The section modulus of bow door ordinary stiffeners is to be not less than that obtained according to the requirements in Ch 8, Sec 1 for the fore part, using the bow door stiffener spacing.

Consideration is to be given, where necessary, to differences in conditions of fixity between the ends of ordinary stiffeners of bow doors and those of the fore part shell.

3.3 Primary supporting members

3.3.1 Bow door ordinary stiffeners are to be supported by primary supporting members constituting the main stiffening of the door.

3.3.2 The primary supporting members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

3.3.3 Scantlings of primary supporting members are generally to be verified through direct calculations on the basis of the external pressure p_E in [2.1.1] and the strength criteria in [6.1.1] and [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

4 Scantlings of inner doors

4.1 General

4.1.1 The gross scantlings of the primary supporting members are generally to be verified through direct calculations on the basis of the external pressure p_E in [2.1.1] and the strength criteria in [6.1.1] and [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

4.1.2 Where inner doors also serve as vehicle ramps, their scantlings are to be not less than those obtained according to Ch 8, Sec 9.

4.1.3 The distribution of the forces acting on the securing and supporting devices is generally to be supported by direct calculations taking into account the flexibility of the structure and the actual position and stiffness of the supports.

5 Securing and supporting of bow doors

5.1 General

5.1.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case-by-case basis.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

5.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [5.2.5].

The number of securing and supporting devices is generally to be the minimum practical while taking into account the requirements for redundant provision given in [5.2.6] and [5.2.7]and the available space for adequate support in the hull structure.

5.1.3 For visor doors which open outwards, the pivot arrangement is generally to be such that the visor is self-closing under external loads, i.e. it is to be checked that the closing moment M_Y, defined in [2.1.3], is in compliance with the following formula:

$M_Y > 0$

Moreover, the closing moment M_Y is to be not less than the value M_{Y0}, in kN.m, obtained from the following formula:

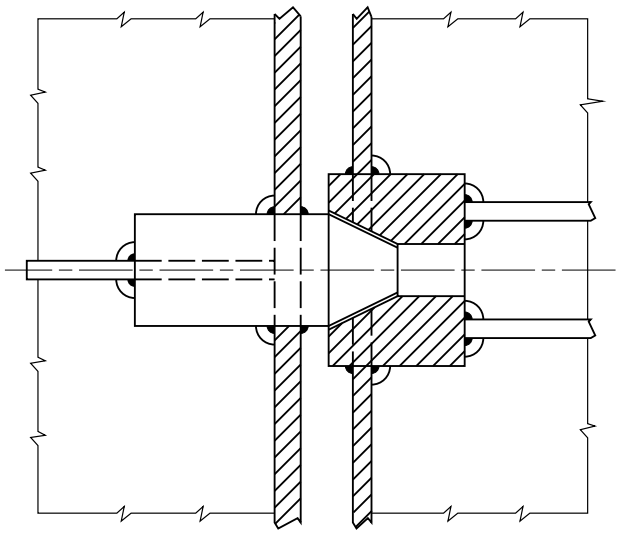
$$M_{Y0} = 10Wc + 0,1\sqrt{a^2 + b^2}\sqrt{F_X^2 + F_Z^2}$$

5.1.4 For side-opening doors, a thrust bearing is to be provided in way of girder ends at the closing of the two leaves to prevent one leaf from shifting towards the other under the effect of unsymmetrical pressure (see example in Fig 3).

The parts of the thrust bearing are to be kept secured to each other by means of securing devices.

The Society may consider any other arrangement serving the same purpose.

Figure 3 : Thrust bearing



5.2 Scantlings

5.2.1 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the allowable stresses defined in [6.1.1].

5.2.2 For visor doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

- Case 1: F_X and F_Z
- Case 2: 0,7 F_Y acting on each side separately together with 0,7 F_X and 0,7 F_Z,

where F_X, F_Y and F_Z are to be calculated as indicated in [2.1.2] and applied at the centroid of projected areas.

5.2.3 For side-opening doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

- Case 1: F_X, F_Y and F_Z acting on both doors
- Case 2: 0,7 F_X and 0,7 F_Z acting on both doors and 0,7 F_Y acting on each door separately,

where F_X, F_Y and F_Z are to be calculated as indicated in [2.1.2] and applied at the centroid of projected areas.

5.2.4 The support forces as calculated according to Case 1 in [5.2.2] and Case 1 in [5.2.3] are to generally give rise to a zero moment about the transverse axis through the centroid of the area A_X.

For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be in the forward direction.

5.2.5 The distribution of the reaction forces acting on the securing and supporting devices may need to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

5.2.6 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that, in the event of failure of any single securing or supporting device, the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the allowable stresses defined in [6.1.1].

5.2.7 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the allowable stresses defined in [6.1.1].

The opening moment M_0 to be balanced by this reaction force is to be taken not less than that obtained, in kN.m, from the following formula:

$$M_0 = 10\ W\ d + 5\ A_X\ a$$

where:

d : Vertical distance, in m, from the hinge axis to the centre of gravity of the door, as shown in Fig 2

a : Vertical distance, in m, defined in [2.1.3].

5.2.8 For visor doors, the securing and supporting devices excluding the hinges are to be capable of resisting the vertical design force (F_Z – 10 W), in kN, within the allowable stresses defined in [6.1.1].

5.2.9 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices.

6 Strength criteria

6.1 Primary supporting members and securing and supporting devices

6.1.1 Yielding check

It is to be checked that the normal stresses σ, the shear stress τ and the equivalent stress σ_{VM}, induced in the primary supporting members and in the securing and supporting devices of bow doors by the design load defined in [2], are in compliance with the following formulae:

$$\sigma \leq \sigma_{ALL}$$

$$\tau \leq \tau_{ALL}$$

$$\sigma_{VM} = (\sigma^2 + 3\ \tau^2)^{0,5} \leq \sigma_{VM,ALL}$$

where:

σ_{ALL} : Allowable normal stress, in N/mm^2, equal to: $\sigma_{ALL} = 120 / k$

τ_{ALL} : Allowable shear stress, in N/mm^2, equal to: $\tau_{ALL} = 80 / k$

$\sigma_{VM,ALL}$: Allowable equivalent stress, in N/mm^2, equal to: $\sigma_{VM,ALL} = 150 / k$

k : Material factor, defined in Ch 4, Sec 1, [2.3], but to be taken not less than 0,72 unless a fatigue analysis is carried out.

6.1.2 Buckling check

The buckling check of primary supporting members is to be carried out according to Ch 7, Sec 3, [5].

6.1.3 Bearings

For steel to steel bearings in securing and supporting devices, it is to be checked that the nominal bearing pressure σ_B, in N/mm^2, is in compliance with the following formula:

$\sigma_B \leq 0,8\ R_{e,HB}$

where:

$$\sigma_B = 10\frac{F}{A_B}$$

F : Design force, in kN, defined in [2.1.2]

A_B : Projected bearing area, in cm^2

$R_{e,HB}$: Yield stress, in N/mm^2, of the bearing material.

For other bearing materials, the allowable bearing pressure is to be determined according to the manufacturer's specification.

6.1.4 Bolts

The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces.

It is to be checked that the tension σ_T in way of threads of bolts not carrying support forces is in compliance with the following formula:

$\sigma_T \leq \sigma_{T,ALL}$

where:

$\sigma_{T,ALL}$: Allowable tension in way of threads of bolts, in N/mm^2, equal to: $\sigma_{T,ALL} = 125 / k$

k : Material coefficient defined in [6.1.1].

7 Securing and locking arrangement

7.1 Systems for operation

7.1.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type.

The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

7.1.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the main watertight deck, of:

- the closing and opening of the doors, and
- associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations.

The operating panels for operation of doors are to be inaccessible to unauthorized persons.

A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

7.1.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

7.2 Systems for indication/monitoring

7.2.1 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

7.2.2 The indicator system is to be designed on the fail safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured.

The power supply for the indicator system is to be independent of the power supply for operating and closing the doors.

The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.

7.2.3 The indication panel on the navigation bridge is to be equipped with a mode selection function “harbour/sea voyage”, so arranged that an audible alarm is given if the ship leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

7.2.4 A water leakage detection system with an audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

7.2.5 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room.

The system is to monitor the position of doors and a sufficient number of their securing devices.

Special consideration is to be given to the lighting and contrasting colour of the objects under surveillance.

7.2.6 The indicator system for the closure of the doors and the television surveillance systems for the doors and water leakage detection, and for special category and ro-ro spaces are to be suitable to operate correctly in the ambient conditions on board and to be type approved on the basis of the applicable tests.

7.2.7 A drainage system is to be arranged in the area between bow door and ramp, as well as in the area between the ramp and inner door, where fitted.

The system is to be equipped with an audible alarm providing an indication on the navigation bridge when the water level in these areas exceeds 0,5 m above the car deck level.

8 Operating and maintenance manual

8.1 General

8.1.1 An Operating and Maintenance Manual (OMM) for the bow door and inner door is to be provided on board and is to contain the necessary information on:

a) main particulars and design drawings:
   - special safety precautions
   - details of ship
   - equipment and design loading (for ramps)
   - key plan of equipment (doors and ramps)
   - manufacturer’s recommended testing for equipment
   - description of equipment:
     - bow doors
     - inner bow doors
     - bow ramp/doors
     - central power pack
     - control panels.

b) service conditions:
   - limiting heel and trim of ship for loading/unloading
   - limiting heel and trim for door operations
   - doors/ramps operating instructions
   - doors/ramps emergency operating instructions.

c) maintenance:
   - schedule and extent of maintenance
   - trouble shooting and acceptable clearances
   - manufacturer’s maintenance procedures.

d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This manual is to be submitted to the Society for approval. It is to be checked that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance/rejection criteria.

Note 1: It is recommended that inspections of the doors and supporting and securing devices be carried out by ship’s personnel at monthly intervals or following any incidents which could result in damage, including heavy weather or contact in the region of the shell doors. A record is to be kept and any damage found during such inspections is to be reported to the Society.

8.1.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

Section 6 Side Doors and Stern Doors

Symbols

L_1 : Length, in m, defined in Ch 1, Sec 2, [2.1.1].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement, strength and securing of side doors, located below the bulkhead deck and abaft the collision bulkhead, and to stern doors located below the bulkhead deck.

Shell doors not covered by this Section are dealt with in Ch 8, Sec 7.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangement

1.3.1 Side doors and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure.

1.3.2 Where the sill of any side door is below the uppermost load line, the arrangement is considered by the Society on a case-by-case basis.

1.3.3 Doors are preferably to open outwards.

1.4 Definitions

1.4.1 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges or about pivoted attachments to the ship.

1.4.2 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship structure.

1.4.3 Locking device

A locking device is a device that locks a securing device in the closed position.

2 Design loads

2.1 Side and stern doors

2.1.1 Design forces

The design external forces F_E and the design internal forces F_I to be considered for the scantlings of primary supporting members and securing and supporting devices of side doors and stern doors are to be obtained, in kN, from the formulae in Tab 1.

Table 1 : Design forces

Structural elements	External force F_E, in kN	Internal force F_I, in kN
Securing and supporting devices of doors opening inwards	$A\ p_E + F_P$	$F_0 + 10\ W$
Securing and supporting devices of doors opening outwards	$A\ p_E$	$F_0 + 10\ W + F_P$
Primary supporting members **(1)**	$A\ p_E$	$F_0 + 10\ W$

(1) The design force to be considered for the scantlings of the primary supporting members is the greater of F_E and F_I.

Note 1:

A : Area, in m^2, of the door opening

W : Mass of the door, in t

F_P : Total packing force, in kN; the packing line pressure is normally to be taken not less than 5 N/mm

F_0 : The greater of F_C and 5 A, in kN

F_C : Accidental force, in kN, due to loose cargoes etc., to be uniformly distributed over the area A and to be taken not less than 300 kN. For small doors such as bunker doors and pilot doors, the value of F_C may be appropriately reduced. However, the value of F_C may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes

p_E : External design pressure determined at the centre of gravity of the door opening and to be taken not less than that obtained, in kN/m^2, from the following formulae:

$p_E = 10\ (T - Z_G) + 25$ for $Z_G < T$

$p_E = 25$ for $Z_G \geq T$

Moreover, for stern doors of ships fitted with bow doors, p_E is to be taken not less than that obtained, in kN/m^2, from the following formula:

$$p_E = 0{,}6 C_L (0{,}8 + 0{,}6 \sqrt{L_1})^2$$

T : Draught, in m, at the highest subdivision load line

Z_G : Height of the centre of the area of the door, in m, above the baseline

C_L : Coefficient depending on the ship length:

$C_L = 0{,}0125\ L$ for $L < 80$ m

$C_L = 1{,}0$ for $L \geq 80$ m.

3 Scantlings of side doors and stern doors

3.1 General

3.1.1 The strength of side doors and stern doors is to be commensurate with that of the surrounding structure.

3.1.2 Side doors and stern doors are to be adequately stiffened and means are to be provided to prevent any lateral or vertical movement of the doors when closed.

Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship structure.

3.1.3 Where doors also serve as vehicle ramps, the design of the hinges is to take into account the ship angle of trim and heel which may result in uneven loading on the hinges.

3.1.4 Shell door openings are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below.

3.2 Plating and ordinary stiffeners

3.2.1 Plating

The thickness of the door plating is to be not less than that obtained according to the requirements in Ch 7, Sec 1 for side plating, using the door stiffener spacing. In no case may it be less than the minimum required thickness of side plating.

Where doors also serve as vehicle ramps, the thickness of the door plating is to be not less than that obtained according to Ch 8, Sec 9.

3.2.2 Ordinary stiffeners

The scantling of door ordinary stiffeners is to be not less than that obtained according to the requirements in Ch 7, Sec 2 for the side, using the door stiffener spacing.

Consideration is to be given, where necessary, to differences in conditions of fixity between the ends of ordinary stiffeners of doors and those of the side.

Where doors also serve as vehicle ramps, the scantling of ordinary stiffeners is to be not less than that obtained according to Ch 8, Sec 9.

3.3 Primary supporting members

3.3.1 The door ordinary stiffeners are to be supported by primary supporting members constituting the main stiffening of the door.

3.3.2 The primary supporting members and the hull structure in way are to have sufficient stiffness to ensure structural integrity of the boundary of the door.

3.3.3 Scantlings of primary supporting members are generally to be verified through direct calculations on the basis of the design forces in [2.1.1] and the strength criteria in [5.1.1] and [5.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

4 Securing and supporting of doors

4.1 General

4.1.1 Side doors and stern doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case-by-case basis.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

4.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [4.2.2].

The number of securing and supporting devices is generally to be the minimum practical while taking into account the requirements for redundant provision given in [4.2.3] and the available space for adequate support in the hull structure.

4.2 Scantlings

4.2.1 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the allowable stresses defined in [5.1.1].

4.2.2 The distribution of the reaction forces acting on the securing and supporting devices may need to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position of the supports.

4.2.3 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that, in the event of failure of any single securing or supporting device, the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the allowable stresses defined in [5.1.1].

4.2.4 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices.

5 Strength criteria

5.1 Primary supporting members and securing and supporting devices

5.1.1 Yielding check

It is to be checked that the normal stress σ, the shear stress τ and the equivalent stress σ_{VM}, induced in the primary supporting members and in the securing and supporting devices of doors by the design load defined in [2], are in compliance with the following formulae:

$\sigma \leq \sigma_{ALL}$

$\tau \leq \tau_{ALL}$

$\sigma_{VM} = (\sigma^2 + 3\,\tau^2)^{0,5} \leq \sigma_{VM,ALL}$

where:

σ_{ALL} : Allowable normal stress, in N/mm^2: $\sigma_{ALL} = 120 / k$

τ_{ALL} : Allowable shear stress, in N/mm^2: $\tau_{ALL} = 80 / k$

$\sigma_{VM,ALL}$: Allowable equivalent stress, in N/mm^2: $\sigma_{VM,ALL} = 150 / k$

k : Material factor, defined in Ch 4, Sec 1, [2.3], but to be taken not less than 0,72 unless a fatigue analysis is carried out.

5.1.2 Buckling check

The buckling check of primary supporting members is to be carried out according to Ch 7, Sec 3, [5].

5.1.3 Bearings

For steel to steel bearings in securing and supporting devices, it is to be checked that the nominal bearing pressure σ_B, in N/mm^2, is in compliance with the following formula:

$\sigma_B \leq 0,8\ R_{eH,B}$

where:

$$\sigma_B = 10\frac{F}{A_B}$$

with:

F : Design force, in KN, defined in [2.1.1]

A_B : Projected bearing area, in cm^2

$R_{eH,B}$: Yield stress, in N/mm^2, of the bearing material.

For other bearing materials, the allowable bearing pressure is to be determined according to the manufacturer's specification.

5.1.4 Bolts

The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces.

It is to be checked that the tension σ_T in way of threads of bolts not carrying support forces is in compliance with the following formula:

$\sigma_T \leq \sigma_{T,ALL}$

where:

$\sigma_{T,ALL}$: Allowable tension in way of threads of bolts, in N/mm^2: $\sigma_{T,ALL} = 125 / k$

k : Material factor, defined in [5.1.1].

6 Securing and locking arrangement

6.1 Systems for operation

6.1.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type.

The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

6.1.2 Doors which are located partly or totally below the watertight deck with a clear opening area greater than 6 m^2 are to be provided with an arrangement for remote control, from a position above the main watertight deck, of:

- the closing and opening of the doors
- associated securing and locking devices.

For doors which are required to be equipped with a remote control arrangement, indication of the open/closed position of the door and the securing and locking device is to be provided at the remote control stations.

The operating panels for operation of doors are to be inaccessible to unauthorized persons.

A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

6.1.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

7 Operating and maintenance manual

7.1 General

7.1.1 An Operating and Maintenance Manual (OMM) for the side doors and stern doors is to be provided on board and is to contain the necessary information on:

a) main particulars and design drawings:
   - special safety precautions
   - details of ship
   - equipment and design loading (for ramps)
   - key plan of equipment (doors and ramps)
   - manufacturer's recommended testing for equipment
   - description of equipment:
     - side doors
     - stern doors
     - central power pack
     - control panels.

b) service conditions:
   - limiting heel and trim of ship for loading / unloading
   - limiting heel and trim for door operations
   - doors / ramps operating instructions
   - doors / ramps emergency operating instructions.

c) maintenance:
   - schedule and extend of maintenance
   - trouble shooting and acceptable clearances
   - manufacturer's maintenance procedures.

d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This manual is to be submitted to the Society for approval. It is to be checked that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance / rejection criteria.

Note 1: It is recommended that inspections of the door and supporting and securing devices be carried out by ship's personnel at monthly intervals or following any incidents which could result in damage, including heavy weather or contact in the region of the shell doors. A record is to be kept and any damage recorded during such inspections is to be reported to the Society.

7.1.2 Documented operating procedures for closing and securing the side and stern doors are to be kept on board and posted at an appropriate place.

Section 7 Watertight and Weathertight Doors

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the scantling of shell doors not covered by Ch 8, Sec 5 and doors in bulkheads that are required to be watertight or weathertight.

1.2 Definitions

1.2.1 Watertightness

The various degrees of watertightness are defined in Ch 3, Sec 3, [2.2.2].

1.2.2 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges, or from sliding open.

1.2.3 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship's structure.

1.2.4 Locking device

A locking device is a device locking the securing device in the closed position.

1.3 Partial Safety Factors

1.3.1 The partial safety factors for checking door structures are to be taken according to:

- Ch 7, Sec 1, [1.2] for door leaf plating
- Ch 7, Sec 2, [1.2] for door leaf stiffeners
- Ch 7, Sec 3, [1.3] for securing and supporting devices.

2 Design loads

2.1 General

2.1.1 Doors are to be designed to offer equivalent strength compared to the adjacent bulkhead in which they are fitted. Therefore, they are to be assessed considering the same design loads, as per the examples given in the following requirements.

2.1.2 Assessment of test pressure, p_T, according to Article [3] and Article [4] is required for all watertight doors, including those not subject to hydrostatic pressure testing in accordance with [5.1].

2.2 Load point

2.2.1 In general, load points are to be selected to ensure consideration of worst case loads. Unless otherwise specified by the Society, pressures are to be calculated as follows:

- at the lower edge of the door opening, for door leaf plating
- at mid-span, for door leaf stiffeners.

2.3 Load model

2.3.1 Sea pressure

The still water and wave pressures p_S and p_W , in kN/m², are defined in Ch 5, Sec 5.

2.3.2 Flooding pressure

The still water and inertial pressures p_{SF} and p_{WF} , in kN/m², are defined in Ch 5, Sec 6, [7].

If detailed information on the head of water after damage is not available and justified, the following values are to be considered:

- for watertight doors located between the watertight deck and the bulkhead deck, p_{WF} equal to 0 and p_{SF} , in kN/m², corresponding to the head measured vertically between the bulkhead deck and the calculation point defined in [2.2.1]
- for watertight doors located below the watertight deck, p_{WF} equal to 0 and p_{SF} , in kN/m², corresponding to the head measured vertically between the margin line and the calculation point defined in [2.2.1].

2.3.3 Lateral pressure for superstructure doors

The lateral pressure, p, in kN/m², is defined in Ch 8, Sec 4, [2.2.2].

2.3.4 Test pressure

The test pressure, p_T , in kN/m², is to be taken not less than the maximum of the following values, considering the loads which are applicable to the door:

- the sum of p_S and p_W for sea pressure, as defined in [2.3.1]
- the sum of p_{SF} and p_{WF} for flooding pressure, as defined in [2.3.2]
- lateral pressure p for superstructure doors, as defined in [2.3.3].

3 Door leaf scantling

3.1 Plating

3.1.1 Side shell doors

The net thickness of door leaf plating for side shell doors is to be not less than the values determined according to:

- Ch 7, Sec 1, [3.5.1] for sea pressure
- Ch 7, Sec 1, [3.5.3] for test conditions.

3.1.2 Internal bulkhead doors

The net thickness of door leaf plating for doors fitted in watertight bulkheads is to be not less than the values determined according to:

- Ch 7, Sec 1, [3.5.2] for flooding conditions
- Ch 7, Sec 1, [3.5.3] for test conditions.

3.1.3 Superstructure doors

The net thickness of door leaf plating for doors in front, side and aft bulkheads of superstructures and deckhouses is to be not less than the values determined according to:

- Ch 8, Sec 4, [3.1.2] for lateral pressure
- Ch 7, Sec 1, [3.5.3] for test conditions.

3.2 Stiffeners

3.2.1 General

Stiffeners of doors are generally to be considered as simply supported at ends instead of clamped.

3.2.2 Side shell doors

The net scantlings of stiffeners for side shell doors are to be determined according to:

- Ch 7, Sec 2, [3.7.3] for sea pressure, taking σ_{X1} equal to 0
- Ch 7, Sec 2, [3.9.3] for test conditions.

3.2.3 Internal bulkhead doors

The net scantlings of stiffeners for doors fitted in watertight bulkheads are to be determined according to:

- Ch 7, Sec 2, [3.8.3] for flooding conditions, taking σ_{X1} equal to 0
- Ch 7, Sec 2, [3.9.3] for test conditions.

3.2.4 Superstructure doors

The net scantlings of stiffeners for doors in front, side and aft bulkheads of superstructures and deckhouses are to be determined according to:

- Ch 8, Sec 4, [4.1.2] for lateral pressure, taking ℓ equal to stiffener span, in m, or 2 m, whichever is greater, and φ equal to 1,15
- Ch 7, Sec 2, [3.9.3] for test conditions.

3.2.5 Glass

If permitted, when glazing is fitted in the door leaf, its thickness is to be in line with the requirements of Ch 8, Sec 10, [3.3].

4 Securing and supporting

4.1 General

4.1.1 Doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case by case basis.

In order to prevent damage to the packing material, the edges of the part of the door frame in contact with the seal should be rounded or chamfered.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

4.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [4.2].

The number and distribution of securing and supporting devices is to be set to achieve the scantling criteria in [4.2] and the required degree of watertightness.

4.2 Scantlings

4.2.1 Securing and supporting devices are to be adequately designed so that they can comply with the checking criteria defined in Ch 7, Sec 3, [3.3.1] for primary members.

4.2.2 In addition to the requirements in [4.2.1], every element transmitting loads by means of direct contact must be checked against bearing. In that respect, the maximum normal compressive stress σ_c distributed over the contact area between the two elements is not to be higher than R_{eH}.

4.2.3 The distribution of the reaction forces acting on the securing and supporting devices is generally to be supported by direct calculations taking into account the flexibility of the hull structure, the actual position of the supports and the design load pattern.

4.2.4 In case of homogeneously distributed supports and uniform design pressure, the total force acting on the door may be considered as evenly divided amongst the supports.

4.2.5 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices. These elements include pins, support brackets and back-up brackets.

5 Inspection and testing

5.1 General

5.1.1 Watertight doors which become immersed by an equilibrium or intermediate waterplane or which are otherwise located between the watertight deck and the bulkhead deck, including doors defined in the Internal Watertight Plan as constituting boundaries intended to stop vertical and horizontal flooding or which are otherwise required to be watertight, are to be subjected to a hydrostatic pressure test.

5.1.2 For large doors of more than 6 m^2 intended for use in watertight boundaries, structural analysis may be accepted in lieu of pressure testing. Where such doors utilize gasket seals, a prototype pressure test to confirm that the compression of the gasket material is capable of accommodating any deflection, revealed by the structural analysis, is to be carried out.

5.1.3 Doors above the buklhead deck which are not immersed by an equilibrium or intermediate waterplane but which become intermittently immersed at angles of heel in the required range of positive stability beyond the equilibrium position may be only hose tested (required only to be weathertight according to Ch 3, Sec 3, [2.2.2]).

5.2 Hydrostatic pressure testing

5.2.1 The head of water used for the pressure test of each door is to correspond to a value specified by the Designer and to be taken not less than the test pressure, p_T, defined in [2.3.4].

5.2.2 Testing may be carried out at the factory or other shore based testing facility prior to installation in the ship. The duration of the test is to be at least 30 min.

5.2.3 Leakage criteria for watertight doors

The following acceptable leakage criteria should apply:

- doors with gaskets: no leakage
- doors with metallic sealing: max leakage 1 litre/min.

Limited leakage may be accepted for pressure tests on large doors located in cargo spaces employing gasket seals, in accordance with the following value, in litre/min:

$$\frac{(P + 4,572) \times h^3}{6568}$$

where:

P : Perimeter of door opening (m)

h : Test head of water (m).

However, in the case of doors where the water head taken for the determination of the scantling does not exceed 6,10 m, the leakage rate may be taken equal to 0,375 litre/min if this value is greater than that calculated by the above-mentioned formula.

5.3 Hose testing

5.3.1 All watertight and weathertight doors are to be subject to a hose test after installation in a ship. Hose testing is to be carried out:

- from both sides of a watertight door unless, for a specific application, exposure to floodwater is anticipated only from one side
- from both sides of internal bulkheads weathertight doors
- from the exposed side of external weathertight doors.

Where a hose test is not practicable because of possible damage to machinery, electrical equipment insulation or outfitting items, it may be replaced by means such as an ultrasonic leak test or an equivalent test. Alternatively, a compartment air test may be conducted as per Ch 11, Sec 3, [3.3.7].

6 Type approval procedure

6.1 General

6.1.1 Type approval certificates of doors may be issued to applicant manufacturers to certify that the design of the door has been assessed against a given strength level.

6.1.2 The documents and information listed in [6.2.1] must allow for the door strength to be checked against the applied design load.

6.1.3 In case a type approved door is fitted onboard a vessel, the hull supporting structure in way of the door is to be checked to have adequate strength according to Article [4].

6.1.4 A type approved door fitted onboard a vessel is to be selected to have a design load at least equivalent to the adjacent bulkhead in which it is fitted.

6.2 Documents and information to be submitted

6.2.1 Prior to issuance of type approval certificate, the following documents and information must be submitted to the Society for review, for each door model and variant:

- maximum considered design load
- tightness level (weathertight or watertight)
- door dimensions
- structural drawings of the door, including securing devices
- material and mechanical properties of each part of the door
- test and inspection procedure.

6.3 Prototype test

6.3.1 Prototype pressure test is to be conducted for each type and size of door with a test pressure to be defined by the Designer and which corresponds to at least the worst case value of p_T across the positions where each type and size of door will be installed. The prototype test is to be carried out before the door is fitted. The installation method and procedure for fitting the door on board is to correspond to that of the prototype test. When fitted on board, each door is to be checked for proper seating between the bulkhead, the frame and the door.

The corresponding test reports are to be annexed to the type approval certificate.

6.3.2 The test procedure is to be submitted to the Society for review and is to be in line with the relevant requirements in [5].

Section 8 Hatch Covers

Symbols

p_0 : Conventional pressure for hatch covers on exposed decks, in kN/m^2 (see [5.3])

p_S : Still water pressure, in kN/m^2 (see [5.1])

p_{SF} : Still water pressure for flooding, in kN/m^2 (see [5.2])

p_W : Wave pressure, in kN/m^2 (see [5.1])

p_{WF} : Wave pressure for flooding, in kN/m^2 (see [5.2])

p_T : Test pressure, in kN/m^2 (see [5.4]

s : Length, in m, of the shorter side of the plate panel

ℓ : Length, in m, of the longer side of the plate panel

b_P : Width, in m, of the plating attached to the ordinary stiffener or primary supporting member, defined in Article [4]

w : Net section modulus, in cm^3, of the ordinary stiffener or primary supporting member, with an attached plating of width b_p

A_{Sh} : Net shear sectional area, in cm^2, of the ordinary stiffener or primary supporting member, to be calculated as specified in Ch 4, Sec 3, [3.4], for ordinary stiffeners, and Ch 4, Sec 3, [4.3], for primary supporting members

m : Boundary coefficient for ordinary stiffeners and primary supporting members, taken equal to:

- m = 8 in the case of ordinary stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other
- m = 12 in the case of ordinary stiffeners and primary supporting members clamped at both ends

t_C : Corrosion additions, in mm, defined in [1.6]

R_{eH} : Minimum yield stress, in N/mm^2, of the material, defined in Ch 4, Sec 1, [2]

R_m : Minimum ultimate tensile strength, in N/mm^2, of the material, defined in Ch 4, Sec 1, [2]

R_y : Yield stress, in N/mm^2, of the material, to be taken equal to 235/k N/mm^2, unless otherwise specified

k : Material factor, defined in Ch 4, Sec 1, [2.3]

c_S : Coefficient, taken equal to:

- $c_S = 1 - (s / 2\ell)$ for ordinary stiffeners
- $c_S = 1,0$ for primary supporting members

g : Gravity acceleration, in m/s^2: g = 9,81 m/s^2.

1 General

1.1 Application

1.1.1 The requirements of this Section apply to steel hatch covers in positions 1 and 2 on weather decks, defined in Ch 1, Sec 2, [9.1] as well as hatches installed in watertight boundaries and in emergency escape routes.

1.2 Definitions

1.2.1 Large hatches

Large hatches are hatches with openings greater than 2,5 m^2.

1.2.2 Small hatches

Small hatches are hatches designed for access to spaces below the deck and are capable to be closed weathertight or watertight, as applicable. Their opening is generally equal to or less than 2,5 m^2.

1.3 Materials

1.3.1 Steel

The formulae for scantlings given in the requirements in Article [6] are applicable to steel hatch covers.

Materials used for the construction of steel hatch covers are to comply with the applicable requirements of NR216 Materials and Welding, Chapter 2.

1.3.2 Other materials

The use of materials other than steel is considered by the Society on a case-by-case basis, by checking that criteria adopted for scantlings are such as to ensure strength and stiffness equivalent to those of steel hatch covers.

1.4 Net scantlings

1.4.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.5 Partial safety factors

1.5.1 The partial safety factors to be considered for checking hatch cover structures are to be taken according to:

- Ch 7, Sec 1, [1.2] for plating
- Ch 7, Sec 2, [1.2] for stiffeners
- Ch 7, Sec 3, [1.3] for primary supporting members.

1.6 Corrosion additions

1.6.1 General

The requirements of Ch 4, Sec 2, [1] and Ch 4, Sec 2, [2] apply.

1.6.2 Corrosion additions for hatch covers on exposed decks

In general, for steel other than stainless steel the corrosion addition to be considered for the plating and internal members of hatch covers on exposed decks is the value specified in Tab 1 for the total thickness of the member under consideration.

Table 1 : Corrosion additions t_C for steel hatch covers on exposed decks

Steel hatch covers	t_C, in mm
Plating and stiffeners of single skin hatch cover	2,0
Top and bottom plating of pontoon hatch cover	2,0
Internal structures of pontoon hatch cover	1,5

1.6.3 Corrosion addition for hatch covers on non-exposed decks

For hatch covers on non-exposed decks, the corrosion addition t_C is to be taken equal to that of the adjacent deck.

1.6.4 Corrosion additions for stainless steel

For structural members made of stainless steel, the corrosion addition t_C is to be taken equal to 0.

1.6.5 Corrosion additions for aluminium alloys

For structural members made of aluminium alloys, the corrosion addition t_C is to be taken equal to 0.

2 Arrangement of large hatches

2.1 Height of hatch coamings

2.1.1 The height above the deck of hatch coamings for large hatches is to be not less than:

- 600 mm in position 1
- 450 mm in position 2.

2.1.2 The height of hatch coamings in positions 1 and 2 closed by steel covers provided with gaskets and securing devices may be reduced with respect to the above values or the coamings may be omitted entirely, on condition that the Society is satisfied that the safety of the ship is not thereby impaired in any sea conditions.

In such cases the scantlings of the covers, their gasketing, their securing arrangements and the drainage of recesses in the deck are considered by the Society on a case-by-case basis.

2.1.3 Regardless of the type of closing arrangement adopted, the coamings may have reduced height or be omitted in way of openings in closed superstructures or decks below the main watertight deck.

2.2 Hatch covers

2.2.1 Hatch covers on exposed decks are to be weathertight.

Hatch covers in closed superstructures need not be weathertight.

However, hatch covers fitted in way of ballast tanks, fuel oil tanks or other tanks are to be watertight.

2.2.2 The covers used in 'tweendecks are to be fitted with an appropriate system ensuring an efficient stowing when the ship is sailing with open 'tweendecks.

2.2.3 The ends of hatch covers are normally to be protected by efficiently secured galvanized steel strips.

2.2.4 The width of each bearing surface for hatch covers is to be at least 65 mm.

2.3 Hatch coamings

2.3.1 Coamings, stiffeners and brackets are to be capable of withstanding the local forces in way of the clamping devices and handling facilities necessary for securing and moving the hatch covers as well as those due to cargo stowed on the latter.

2.3.2 Special attention is to be paid to the strength of the fore transverse coaming of the forward hatch and to the scantlings of the closing devices of the hatch cover on this coaming.

2.3.3 Longitudinal coamings are to be extended at least to the lower edge of deck beams.

Where they are not part of continuous deck girders, longitudinal coamings are to extend for at least two frame spaces beyond the end of the openings.

Where longitudinal coamings are part of deck girders, their scantlings are to be as required in Ch 7, Sec 3.

2.3.4 Transverse coamings are to extend below the deck at least to the lower edge of longitudinals.

Transverse coamings not in line with ordinary deck beams below are to extend below the deck at least three longitudinal frame spaces beyond the side coamings.

3 Arrangement of small hatches

3.1 General

3.1.1 Hatchways of special design are considered by the Society on a case-by-case basis.

3.2 Height of hatch coamings

3.2.1 The height above the deck of hatch coamings for small hatches is to be not less than:

- 600 mm in position 1
- 450 mm in position 2.

3.2.2 Where the closing appliances are in the form of hinged steel covers secured weathertight by gaskets and swing bolts, the height of the coamings may be reduced or the coamings may be omitted altogether.

3.2.3 The height of coamings for hatches in escape routes are to be determined considering the rules in Pt C, Ch 4, Sec 8, [4.1].

3.3 Hatch covers fitted on exposed decks

3.3.1 Small hatch covers on exposed decks are to be weathertight.

3.3.2 Hold accesses located on the weather deck are to be provided with watertight metallic hatch covers, unless they are protected by a closed superstructure. The same applies to accesses located on the forecastle deck and leading directly to a dry cargo hold through a trunk.

3.4 Hatch covers fitted on non-exposed decks

3.4.1 Small hatch covers on non-exposed decks need not be weathertight.

3.4.2 Small hatch covers fitted on non-exposed decks are to have a level of tightness equivalent to that required for adjacent compartment(s).

3.5 Watertight hatch covers

3.5.1 Hatches defined in the Internal Watertight Plan as constituting boundaries intended to stop vertical and horizontal flooding are to have the same level of tightness as the structure in which they are installed.

3.5.2 Accesses to cofferdams and ballast tanks are to be manholes fitted with watertight covers fixed with bolts which are sufficiently closely spaced (refer to Ch 3, Sec 3, [2.2.2], c)).

4 Width of attached plating

4.1 Ordinary stiffeners

4.1.1 The width of the attached plating to be considered for the check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where the attached plating extends on both sides of the stiffener:
  $b_P = s$
- where the attached plating extends on one side of the stiffener:
  $b_P = 0,5\ s$

4.2 Primary supporting members

4.2.1 Primary supporting members parallel to ordinary stiffeners

The width of the attached plating to be considered for the check of primary supporting members parallel to ordinary stiffeners is to be obtained, in m, from the following formulae:

- if $\beta \leq 1,0$:
  $b_P = S_P$
- if $\beta > 1,0$:

$$b_P = \left(\frac{1,8}{\beta} - \frac{0,8}{\beta^2}\right) S_P$$

where:

$$\beta = 10^3 \frac{s}{t}\sqrt{\frac{R_{eH}}{E}}$$

E : Young's modulus, in N/mm^2, to be taken equal to $2,06 \cdot 10^5$ N/mm^2 for steels in general

S_P : Spacing, in m, of primary supporting members.

Where the attached plating extends on one side of the primary supporting member, the width b_P calculated as required above is to be multiplied by 0,5.

4.2.2 Primary supporting members perpendicular to ordinary stiffeners

The width of the attached plating to be considered for the check of primary supporting members perpendicular to ordinary stiffeners is to be obtained, in m, from the following formula:

$$b_P = \left[b_{P,L}\frac{s}{\ell} + 0,115\left(1 - \frac{s}{\ell}\right)\left(1 + \frac{1}{\beta^2}\right)^2\right]\ell$$

to be taken not greater than ℓ

where:

$$b_{P,L} = \frac{1,8}{\beta} - \frac{0,8}{\beta^2} \quad \text{for } \beta > 1,0$$

$$b_{P,L} = 1,0 \quad \text{for } \beta \leq 1,0$$

β : Defined in [4.2.1].

Where the attached plating extends on one side of the primary supporting member, the width b_P calculated as required above is to be multiplied by 0,5.

5 Load model

5.1 Lateral pressures and concentrated loads

5.1.1 General

The still water and wave lateral pressures p_S and p_W and the concentrated loads, to be considered as acting on hatch covers are those in [5.1.2] to [5.1.9].

All hatch covers are to be subject to the still water and wave lateral pressures in either [5.1.2] or [5.1.3], according to their position in exposed or non-exposed decks. In addition to this, the requirements in [5.1.4] to [5.1.9] are to be applied where applicable, depending upon the intended use and location of each cover. The applicable checks in [5.1.2] to [5.1.9] are to be conducted separately. Multiple checks as defined in [5.1.4] to [5.1.9] may apply to any individual hatch.

5.1.2 Hatch covers on exposed decks

The still water and wave lateral pressures p_S and p_W to be considered and are defined in Ch 5, Sec 5, [3].

5.1.3 Hatch covers on non-exposed decks

The still water and wave pressures p_S and p_W to be considered are those applicable to the adjacent deck structure, determined as per Ch 5, Sec 6, [5].

When a hatch cover is installed with a coaming in an emergency escape route on a non-exposed deck, a still water pressure of 3 kN/m² may be considered in lieu of the value applicable to the adjacent deck structure. In this case, a warning notice must be applied to ensure that the hatch cover remains unloaded and clear of obstacles as per Pt C, Ch 4, Sec 8, [2.1.1].

5.1.4 Additional lateral pressures for hatch covers in way of liquid cargo or ballast tanks

Additional checks are to be conducted for the still water and wave lateral pressures p_S and p_W defined in Ch 5, Sec 6, [1].

5.1.5 Additional lateral pressures for hatch covers carrying uniform cargoes

Additional checks are to be conducted for the still water and wave lateral pressures p_S and p_W defined in Ch 5, Sec 6, [2].

5.1.6 Additional loads for hatch covers carrying containers

Additional checks are to be conducted for the still water and wave loads defined in Ch 5, Sec 6, [3].

5.1.7 Additional loads for hatch covers carrying wheeled loads

Additional checks are to be conducted for the still water and wave loads defined in Ch 5, Sec 6, [4].

5.1.8 Additional lateral pressures for hatch covers carrying special cargoes

In the case of carriage on the hatch covers of special cargoes (e.g. pipes, etc.) which may temporarily retain water during navigation, the lateral pressure to be applied is considered by the Society on a case-by-case basis.

5.1.9 Additional lateral pressures for hatch covers in ammunition magazines

Attention is to be given to hatches in ammunition magazines which are subject to fire-extinguishing by flooding. In this case, additional checks are to be conducted for the still water and wave lateral pressures p_S and p_W determined as per Ch 5, Sec 6, [5.1.4].

5.2 Flooding pressure

5.2.1 For hatch covers defined in the Internal Watertight Plan as constituting boundaries intended to stop vertical and horizontal flooding, checks are to be conducted for the still water and inertial pressures due to flooding, p_{SF} and p_{WF}, defined in Ch 5, Sec 6, [7].

If detailed information on the head of water after damage is not available and justified, the following values are to be considered:

- for hatches fitted in the watertight deck, p_{WF} equal to 0 and p_{SF} , in kN/m², corresponding to the head measured vertically between the watertight deck and the bulkhead deck at the position of the hatch
- for watertight hatches located below the watertight deck, p_{WF} equal to 0 and p_{SF} , in kN/m², corresponding to the head measured vertically from the centre of the hatchway opening to the margin line, at the position of the hatch.

5.3 Conventional pressure for hatch covers on exposed decks

5.3.1 The conventional pressure p_0 is defined in Tab 2 according to the hatch cover position.

Table 2 : Conventional pressure on hatch covers

Conventional pressure p_0 , in kN/m²	
Position 1	Position 2
$g\left(\frac{58 + 0{,}75L}{76}\right)$	$g\left(\frac{43{,}8 + 0{,}55L}{76}\right)$
Note 1: L is to be taken not greater than 100 m.	

5.4 Test pressure

5.4.1 The test pressure, p_T , in kN/m², is to be taken not less than the maximum of the following values, considering the loads which are applicable to the hatch cover:

- the sum of the still water and wave lateral pressures p_S and p_W , for each applicable lateral pressure considered as per [5.1]
- the sum of p_{SF} and p_{WF} for the flooding pressure considered as per [5.2]
- the conventional pressure p_0, for hatch covers on exposed decks, considered as per [5.3].

5.5 Load point

5.5.1 Wave lateral pressure for hatch covers on exposed decks

The wave lateral pressure to be considered as acting on each hatch cover is to be calculated at a point located:

- longitudinally, at the hatch cover mid-length
- transversely, on the longitudinal plane of symmetry of the ship
- vertically, at the top of the hatch coaming.

5.5.2 Lateral pressures other than the wave pressure

The lateral pressure is to be calculated:

- in way of the geometrical centre of gravity of the plate panel, for plating
- at mid-span, for ordinary stiffeners and primary supporting members.

6 Strength check

6.1 General

6.1.1 Application

The requirements in [6.2] to [6.4] apply to rectangular hatch covers with primary supporting members arranged in one direction, and subjected to a uniform pressure.

When one or several of the following conditions are met, the scantlings of hatch covers are to be determined by direct calculations:

- primary supporting members are arranged as a grillage type
- plating is made of non-rectangular elementary plate panels
- specific boundary conditions are considered.

6.1.2 Hatch covers supporting wheeled loads

The scantlings of hatch covers supporting wheeled loads are to be obtained in accordance with:

- the applicable requirements of Ch 7, Sec 1 for plating
- the applicable requirements of Ch 7, Sec 2 for ordinary stiffeners
- the applicable requirements of Ch 7, Sec 3 for primary supporting members.

6.1.3 Hatch covers subjected to concentrated loads

For hatch covers supporting concentrated loads, ordinary stiffeners and primary supporting members are generally to be checked by direct calculations, taking into account the stiffener arrangements and their relative inertia. It is to be checked that stresses induced by concentrated loads are in accordance with the criteria in [6.3.4].

6.2 Plating

6.2.1 General

The net thickness of steel hatch cover plating subjected to lateral pressure is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$$

where p_S and p_W are the lateral pressures, in kN/m^2, defined in [5.1].

6.2.2 Flooding conditions

Watertight hatches defined in the Internal Watertight Plan as constituting boundaries intended to stop vertical and horizontal flooding are to be checked in flooding conditions. To this end, the net thickness of steel hatch cover plating is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y}}$$

where p_{SF} and p_{WF} are the still water and inertial pressures, in kN/m^2, defined in [5.2].

6.2.3 Testing conditions

Hatches installed on exposed positions and other hatches defined in the Internal Watertight Plan as constituting boundaries intended to stop vertical and horizontal flooding are to be checked in testing conditions. To this end, the net thickness of steel hatch cover plating is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_T}{R_y}}$$

where p_T is the test pressure, in kN/m^2, defined in [5.4].

6.2.4 Minimum net thickness of large hatch cover plating

In addition to the requirements in [6.2.1] to [6.2.3], the net thickness, in mm, of large hatch cover plating is to be not less than the values indicated in Tab 3.

Table 3 : Minimum net thicknesses for steel hatch covers

Type of hatch covers	Minimum net thickness, in mm		
	Single skin hatch cover	Double skin hatch cover	
	Plating and stiffeners	Top and bottom plating	Internal structure
Cargo tank hatch cover	6,0	6,0	6,5
Ballast tank hatch cover and fuel oil tank hatch cover	5,0	5,0	5,5
Dry cargo hold hatch cover	4,0	4,0	4,5

6.3 Ordinary stiffeners and primary supporting members

6.3.1 General

Ordinary stiffeners and primary supporting members of hatch covers located on exposed decks are also to fulfil the requirements in [6.4].

6.3.2 Application

The requirements in [6.3.3] to [6.3.10] apply to:

- ordinary stiffeners
- primary supporting members which may be analysed through isolated beam models.

Primary supporting members whose arrangement is of a grillage type and which cannot be analysed through isolated beam models are to be checked by direct calculations, using the checking criteria in [6.3.4].

6.3.3 Normal and shear stress

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm^2, from the following formulae:

$$\sigma = \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{mw} c_S s \ell^2 10^3$$

$$\tau = 5 \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{A_{Sh}} c_S s \ell$$

6.3.4 Checking criteria

It is to be checked that the normal stress σ and the shear stress τ, calculated according to [6.3.3], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0{,}5 \frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

6.3.5 Net section modulus and net shear sectional area

This requirement provides the minimum net section modulus and net shear sectional area of an ordinary stiffener or a primary supporting member subjected to lateral pressure, complying with the checking criteria indicated in [6.3.4].

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of an ordinary stiffener or a primary supporting member subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m R_y} c_S s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} c_S s \ell$$

where p_S and p_W are the lateral pressures, in kN/m^2, defined in [5.1].

6.3.6 Net section modulus and net shear sectional area for lateral pressure in flooding conditions

For watertight hatches defined in the Internal Watertight Plan as constituting boundaries intended to stop vertical and horizontal flooding, the net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of ordinary stiffeners and primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{m R_y} c_S s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y} c_S s \ell$$

where p_{SF} and p_{WF} are the lateral pressures, in kN/m^2, defined in [5.2].

6.3.7 Net section modulus and net shear sectional area for lateral pressure in testing conditions

Hatches installed on exposed positions and other hatches defined in the Internal Watertight Plan as constituting boundaries intended to stop vertical and horizontal flooding, the net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of ordinary stiffeners and primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \frac{\gamma_{S2} p_T}{m R_y} c_S s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \frac{\gamma_{S2} p_T}{R_y} c_S s \ell$$

where p_T is the test pressure, in kN/m^2, defined in [5.4].

6.3.8 Minimum net thickness of webs for small hatch covers

Minimum net web thickness of ordinary stiffeners and primary supporting members for small hatch covers is not to be less than the net thickness of the attached plating.

6.3.9 Minimum net thickness of webs for large hatch covers

The net thickness of the ordinary stiffeners and primary supporting members, in mm, is to be not less than the minimum values given in Tab 3.

6.3.10 Ordinary stiffeners and primary supporting members of variable cross-section

The section modulus of ordinary stiffeners and primary supporting members with a variable cross-section is to be not less than the greater of the values obtained, in cm^3, from the following formulae:

$$w = w_{CS}$$

$$w = \left(1 + \frac{3{,}2\alpha - \psi - 0{,}8}{7\psi + 0{,}4}\right) w_{CS}$$

where:

w_{CS} : Section modulus, in cm^3, for a constant cross-section, obtained according to [6.3.5] or, where applicable, according to [6.3.6] or [6.4.5].

$$\alpha = \frac{\ell_1}{\ell_0}$$

$$\psi = \frac{w_1}{w_0}$$

ℓ_1 : Length of the variable section part, in m (see Fig 1)

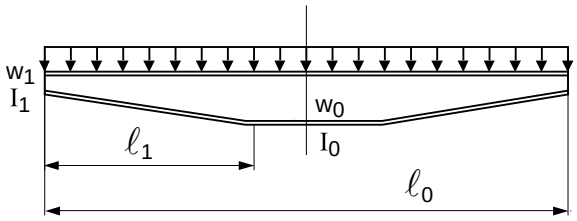
ℓ_0 : Span measured, in m, between end supports (see Fig 1)

w_1 : Section modulus at end, in cm^3 (see Fig 1)

w_0 : Section modulus at mid-span, in cm^3 (see Fig 1).

The use of this formula is limited to the determination of the strength of ordinary stiffeners and primary supporting members in which abrupt changes in the cross-section do not occur along their length.

Figure 1 : Variable cross-section stiffener



6.4 Additional requirements for ordinary stiffeners and primary supporting members of hatch covers on exposed decks

6.4.1 General

In addition to those in [6.3], ordinary stiffeners and primary supporting members of hatch covers on exposed decks are also to fulfil the requirements in [6.4.2] to [6.4.7].

6.4.2 Application

The requirements in [6.4.3] to [6.4.7] apply to:

- ordinary stiffeners
- primary supporting members which may be analysed through isolated beam models.

Primary supporting members whose arrangement is of a grillage type and which cannot be analysed through isolated beam models are to be checked by direct calculations, using the checking criteria in [6.4.4].

6.4.3 Normal and shear stress

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm^2, from the following formulae:

$$\sigma = \frac{p_0}{mw} c_S s \ell^2 10^3$$

$$\tau = 5 \frac{p_0}{A_{Sh}} c_S s \ell$$

where p_0 is the conventional pressure, in kN/m^2, defined in [5.3].

6.4.4 Checking criteria

It is to be checked that the normal stress σ and the shear stress τ, calculated according to [6.4.3], are in compliance with the following formulae:

$$\frac{R_m}{\gamma_{LL}} \geq \sigma$$

$$0,57 \frac{R_m}{\gamma_{LL}} \geq \tau$$

where γ_{LL} is a safety factor, taken equal to:

- 4,25 for hatch covers
- 5,00 for pontoon hatch covers and portable hatch covers.

6.4.5 Net section modulus and net shear sectional area

This requirement provides the minimum net section modulus and net shear sectional area of an ordinary stiffener or a primary supporting member subjected to conventional pressure, complying with the checking criteria indicated in [6.4.4].

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of an ordinary stiffener or a primary supporting member subjected to conventional pressure are to be not less than the values obtained from the following formulae:

$$w = \frac{\gamma_{LL} p_0}{m R_m} c_S s \ell^2 10^3$$

$$A_{Sh} = 8,8 \frac{\gamma_{LL} p_0}{R_m} c_S s \ell$$

where γ_{LL} is as defined in [6.4.4].

6.4.6 Moment of inertia of ordinary stiffeners and primary supporting members

The moment of inertia I_{CS} of an ordinary stiffener or a primary supporting member, calculated for the conventional pressure p_0, is to be such that the deflection does not exceed $\mu\ell$, where μ is defined in Tab 4.

Table 4 : Hatch covers - Deflection coefficient for ordinary stiffeners and primary supporting members

	μ
Weathertight hatch cover	0,0028
Pontoon hatch cover Portable beam	0,0022

6.4.7 Ordinary stiffeners and primary supporting members of variable cross-section

The section modulus of ordinary stiffeners and primary supporting members with a variable cross-section is to be not less than the value obtained according to [6.3.10], where w_{CS} is the section modulus for a constant cross-section obtained according to [6.4.5].

Moreover, the moment of inertia of ordinary stiffeners and primary supporting members with a variable cross-section is to be not less than the greater of the values obtained, in cm^4, from the following formulae:

$I = I_{CS}$

$$I = \left[1 + 8\alpha^3\left(\frac{1-\varphi}{0{,}2 + 3\sqrt{\varphi}}\right)\right] I_{CS}$$

where:

I_{CS} : Moment of inertia with a constant cross-section, in cm^4, obtained according to [6.4.6]

α : Coefficient defined in [6.3.10]

$$\varphi = \frac{I_1}{I_0}$$

I_1 : Moment of inertia at end, in cm^4 (see Fig 1)

I_0 : Moment of inertia at mid-span, in cm^4 (see Fig 1).

The use of this formula is limited to the determination of the strength of ordinary stiffeners and primary supporting members in which abrupt changes in the cross-section do not occur along their length.

7 Hatch coamings

7.1 Stiffening

7.1.1 Coamings are to be stiffened on their upper edges with a stiffener suitably shaped to fit the hatch cover closing appliances.

Moreover, when covers are fitted with tarpaulins, an angle or a bulb section is to be fitted all around coamings of more than 3 m in length or 600 mm in height; this stiffener is to be fitted at approximately 250 mm below the upper edge. The width of the horizontal flange of the angle is not to be less than 180 mm.

7.1.2 Where hatch covers are fitted with tarpaulins, coamings are to be strengthened by brackets or stays with a spacing not greater than 3 m.

Where the height of the coaming exceeds 900 mm, additional strengthening may be required.

However, reductions may be granted for transverse coamings in protected areas.

7.1.3 When two hatches are close to each other, underdeck stiffeners are to be fitted to connect the longitudinal coamings with a view to maintaining the continuity of their strength.

Similar stiffening is to be provided over 2 frame spacings at ends of hatches exceeding 9 frame spacings in length.

In some cases, the Society may require the continuity of coamings to be maintained above the deck.

7.1.4 Where watertight metallic hatch covers are fitted, other arrangements of equivalent strength may be adopted.

7.2 Scantlings

7.2.1 General

The scantlings of continuous side coamings are considered by the Society on a case-by-case basis.

7.2.2 Plating

The plate thickness of hatch coamings on the weather deck is generally to be not less than 11 mm.

In ships intended for the carriage of liquid cargoes, the plate thickness of coamings is also to be checked under liquid internal pressures.

7.2.3 Coamings of small hatchways

As a Rule, the coaming plate thickness is to be not less than the lesser of the following values:

- the thickness for the deck inside line of openings calculated for that position, assuming as spacing of stiffeners the lesser of the values of the height of the coaming and the distance between its stiffeners, if any, or
- 10 mm.

Coamings are to be suitably strengthened where their height exceeds 0,80 m or their greatest horizontal dimension exceeds 1,20 m, unless their shape ensures an adequate rigidity.

8 Weathertightness, closing arrangement and securing devices of large hatches

8.1 Weathertightness

8.1.1 Where the hatchway is exposed and closed with a single panel, the weathertightness is to be ensured by gaskets and clamping devices sufficient in number and quality.

Weathertightness may also be ensured means of tarpaulins.

8.1.2 The mean spacing of swing bolts or equivalent devices is, in general, to be not greater than:

- 2,0 m for dry cargo holds
- 1,5 m for ballast compartments
- 1,0 m for liquid cargo holds.

8.2 Gaskets

8.2.1 The weight of hatch covers and any cargo stowed thereon, together with inertia forces generated by ship motions, are to be transmitted to the ship structure through steel to steel contact.

This may be achieved by continuous steel to steel contact of the hatch cover skirt plate with the ship structure or by means of defined bearing pads.

8.2.2 The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements.

Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and to be made of a corrosion-resistant material.

8.2.3 The gasket and the securing arrangements are to maintain their efficiency when subjected to large relative movements between the hatch cover and the ship structure or between hatch cover elements.

If necessary, suitable devices are to be fitted to limit such movements.

8.2.4 The gasket material is to be of a quality suitable for all environmental conditions likely to be encountered by the ship, and is to be compatible with the cargoes transported.

The material and form of gasket selected are to be considered in conjunction with the type of hatch cover, the securing arrangement and the expected relative movement between the hatch cover and the ship structure.

The gasket is to be effectively secured to the hatch cover.

8.2.5 Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

8.2.6 Metallic contact is required for an earthing connection between the hatch cover and the hull structures. If necessary, this is to be achieved by means of a special connection for the purpose.

8.3 Closing arrangement and securing devices

8.3.1 General

Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings and between cover elements.

The securing and stop arrangements are to be fitted using appropriate means which cannot be easily removed.

In addition to the requirements above, all hatch covers, and in particular those carrying deck cargo, are to be effectively secured against horizontal shifting due to the horizontal forces resulting from ship motions.

Towards the ends of the ship, vertical acceleration forces may exceed the gravity force. The resulting lifting forces are to be considered when dimensioning the securing devices according to [8.3.5] to [8.3.7] Lifting forces from cargo secured on the hatch cover during rolling are also to be taken into account.

Hatch coamings and supporting structure are to be adequately stiffened to accommodate the loading from hatch covers.

Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height (see [2.1]) are considered by the Society on a case-by-case basis.

In the case of hatch covers carrying containers, the scantlings of the closing devices are to take into account the possible upward vertical forces transmitted by the containers.

8.3.2 Arrangements

The securing and stopping devices are to be arranged so as to ensure sufficient compression on gaskets between hatch covers and coamings and between adjacent hatch covers.

Arrangement and spacing are to be determined with due attention to the effectiveness for weathertightness, depending on the type and the size of the hatch cover, as well as on the stiffness of the hatch cover edges between the securing devices.

At cross-joints of multipanel covers, (male/female) vertical guides are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.

The location of stoppers is to be compatible with the relative movements between hatch covers and the ship structure in order to prevent damage to them. The number of stoppers is to be as small as possible.

8.3.3 Spacing

The spacing of the securing arrangements is to be generally not greater than 6 m.

The spacing of securing arrangements of tank hatch covers in ‘tweendecks is to be not greater than 600 mm.

8.3.4 Construction

Securing arrangements with reduced scantlings may be accepted provided it can be demonstrated that the possibility of water reaching the deck is negligible.

Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or hatch covers.

Individual securing devices on each hatch cover are to have approximately the same stiffness characteristics.

8.3.5 Area of securing devices

The net cross area of each securing device is to be not less than the value obtained, in cm^2, from the following formula:

$$A = 1,4 S_S \left(\frac{235}{R_{eH}}\right)^f$$

where:

S_S : Spacing, in m, of securing devices

f : Coefficient taken equal to:

- 0,75 for $R_{eH} > 235$ N/mm^2
- 1,00 for $R_{eH} \leq 235$ N/mm^2.

In the above calculations, R_{eH} may not be taken greater than 0,7 R_m.

Between hatch cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by securing devices. For packing line pressures exceeding 5 N/mm, the net cross area A is to be increased in direct proportion. The packing line pressure is to be specified.

In the case of securing arrangements which are particularly stressed due to the unusual width of the hatchway, the net cross area A of the above securing arrangements is to be determined through direct calculations.

8.3.6 Inertia of edges elements

The hatch cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices.

The moment of inertia of edge elements is to be not less than the value obtained, in cm^4, from the following formula:

$$I = 6\, p_L\, S_S^4$$

where:

p_L : Packing line pressure, in N/mm, to be taken not less than 5 N/mm

S_S : Spacing, in m, of securing devices.

8.3.7 Diameter of rods or bolts

Rods or bolts are to have a net diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

8.4 Tarpaulins

8.4.1 Where weathertightness of hatch covers is ensured by means of tarpaulins, at least two layers of tarpaulins are to be fitted.

Tarpaulins are to be free from jute and waterproof and are to have adequate characteristics of strength and resistance to atmospheric agents and high and low temperatures.

The mass per unit surface of tarpaulins made of vegetable fibres, before the waterproofing treatment, is to be not less than:

- 0,65 kg/m^2 for waterproofing by tarring
- 0,60 kg/m^2 for waterproofing by chemical dressing
- 0,55 kg/m^2 for waterproofing by dressing with black oil.

In addition to tarpaulins made of vegetable fibres, those of synthetic fabrics or plastic laminates may be accepted by the Society provided their qualities, as regards strength, waterproofing and resistance to high and low temperatures, are equivalent to those of tarpaulins made of vegetable fibres.

8.5 Cleats

8.5.1 The arrangements for securing the tarpaulins to hatch coamings are to incorporate cleats of a suitable pattern giving support to battens and wedges and with edges rounded so as to minimise damage to the wedges.

8.5.2 Cleats are to be spaced not more than 600 mm from centre to centre and are to be not more than 150 mm from the hatch corners.

8.5.3 The thickness of cleats is to be not less than 9,5 mm for angle cleats and 11 mm for forged cleats.

8.5.4 Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

8.5.5 Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

8.6 Wedges, battens and locking bars

8.6.1 Wedges

Wedges are to be of tough wood, generally not more than 200 mm in length and 50 mm in width.

They are generally to be tapered not more than 1 in 6 and their thickness is to be not less than 13 mm.

8.6.2 Battens and locking bars

For all hatchways in exposed positions, battens or transverse bars in steel or other equivalent means are to be provided in order to efficiently secure the portable covers after the tarpaulins are battened down.

Portable covers of more than 1,5 m in length are to be secured by at least two such securing appliances.

9 Tightness, closing arrangement and securing devices of small hatches

9.1 Tightness and gaskets

9.1.1 The seal for weathertight or watertight hatches is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary tightness.

9.1.2 Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

9.1.3 For non-bolted hatch covers, metal-to-metal contacts are to be provided in order to prevent over compression of the gasket. Gasket sealing arrangements are to be designed in order to withstand the bearing force induced by any relevant lateral load on the hatch cover.

9.2 Closing arrangement and securing devices

9.2.1 At least one securing device is to be fitted at each side. The hinges of scuttles and round hatch covers are considered equivalent to securing devices.

9.2.2 Securing arrangements and stiffening of hatch cover edges are to be such that the required degree of tightness can be maintained in any sea condition, for all loads acting on the hatch cover.

9.2.3 Towards the ends of the ship, vertical acceleration forces may exceed the gravity force. The resulting lifting forces are to be considered when dimensioning the securing devices.

9.2.4 The primary securing method is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.

9.2.5 Small hatches located on exposed fore deck are to be fitted with primary securing devices such that their hatch covers can be secured in place and made weathertight by means of a mechanism employing any one of the following methods:

a) butterfly nuts tightening onto forks (clamps)

b) quick acting cleats

c) central locking device.

Dogs (twist tightening handles) with wedges are not acceptable.

9.2.6 For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimize the risk of butterfly nuts being dislodged while in use by means of curving the forks upwards, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is to be not less than 16 mm. An example arrangement is shown in Fig 2.

9.2.7 Small hatches on the fore deck are to be fitted with an independent secondary securing device, e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

9.2.8 For small hatch covers located on the exposed deck forward of the foremost cargo hatch, the hinges are to be fitted such that the predominant direction of green seas is to cause the cover to close, which means that the hinges are normally to be located on the fore edge.

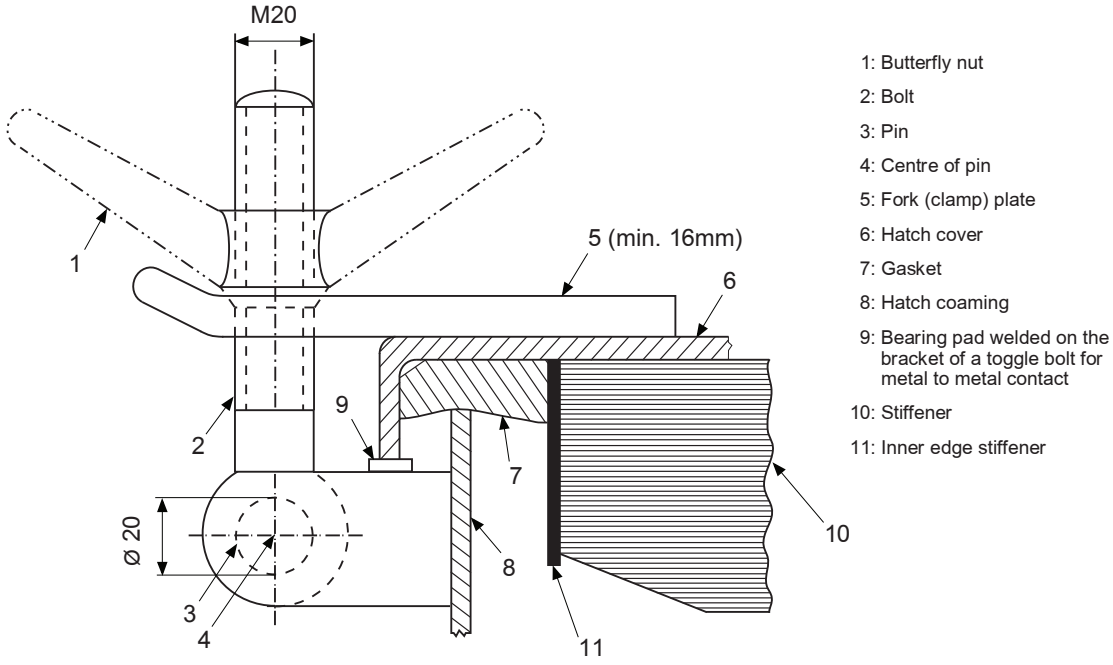
9.2.9 On small hatches located between the main hatches, for example between Nos. 1 and 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.

9.2.10 Securing devices of hatches designed for emergency escape shall, in general, be operable from both sides of the hatch cover.

9.2.11 Where wear of securing elements may eventually lead to degraded hatch tightness, the design of the securing arrangements shall permit the necessary periodic adjustment or renewal of elements in order to ensure the continued performance of the seal and hatch tightness.

9.2.12 The metal-to-metal contacts are to be arranged close to each securing device and shall be of a sufficient capacity to withstand the bearing force. Where stiffeners are fitted, they shall be aligned with the metal-to-metal contact points.

Figure 2 : Example of a primary securing method



10 Testing

10.1 Initial test of watertight hatches

10.1.1 Watertight hatches are to be subjected to structural test by application of a pressure to be specified by the Designer and taken not less than test pressure, p_T , defined in [5.4] for the position at which the hatch is to be fitted.

10.2 Prototype test

10.2.1 Testing of individual hatches may be replaced by a prototype pressure test of each type and size of hatch, conducted with a test pressure corresponding to at least the worst case value of p_T across the positions where each type and size of hatch will be installed. The prototype test is to be carried out before the hatch is fitted. The installation method and procedure for fitting the hatch on board is to correspond to that of the prototype test. When fitted on board, each hatch is to be checked for proper seating between the deck, the coaming and the hatch cover.

11 Drainage

11.1 Arrangement

11.1.1 If drain channels are provided inside the line of the gasket by means of a gutter bar or vertical extension of the hatch side and end coaming, drain openings are to be provided at appropriate positions in the drain channels.

11.1.2 Drain openings in hatch coamings are to be arranged with sufficient distance to areas of stress concentration (e.g. hatch corners).

11.1.3 Drain openings are to be arranged at the ends of drain channels and are to be provided with efficient means for preventing ingress of water from outside, such as non-return valves or equivalent.

11.1.4 Cross-joints of multipanel hatch covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

11.1.5 If a continuous outer steel contact is arranged between the cover and the ship structure, drainage from the space between the steel contact and the gasket is also to be provided.

11.1.6 Requirements [11.1.1] to [11.1.5] are not applicable to hatches of less than 0,6 m^2 and hatches on non-exposed decks.

Section 9 Movable Decks and Inner Ramps - External Ramps

1 Movable decks and inner ramps

1.1 Materials

1.1.1 The decks and inner ramps are to be made of steel or aluminium alloys complying with the requirements of NR216 Materials and Welding. Other materials of equivalent strength may be used, subject to a case-by-case examination by the Society.

1.2 Net scantlings

1.2.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.3 Plating

1.3.1 The net thickness of plate panels subjected to wheeled loads is to be not less than the value obtained from Ch 7, Sec 1, [4.3], where ($n P_0$) is not to be taken less than 50 kN.

1.4 Supporting structure

1.4.1 General

The supporting structure of movable decks and inner ramps is to be verified through direct calculation, considering the following cases:

- movable deck stowed in upper position, empty and locked, at sea
- movable deck in service, loaded, in lower position, resting on supports or supporting legs and locked, at sea
- movable inner ramp in sloped position, supported by hinges at one end and by a deck at the other, with possible intermediate supports, loaded, at harbour
- movable inner ramp in horizontal position, loaded and locked, at sea.

1.4.2 Loading cases

The scantlings of the structure are to be verified in both sea and harbour conditions for the following cases:

- loaded movable deck or inner ramp under loads according to the vehicle distribution indicated by the Designer
- loaded movable deck or inner ramp under uniformly distributed loads corresponding to a pressure, in kN/m^2, taken equal to:

$$p = \frac{n_V P_V + P_P}{A_P}$$

- empty movable deck under uniformly distributed masses corresponding to a pressure, in kN/m^2, taken equal to:

$$p = \frac{P_P}{A_P}$$

where:

n_V : Maximum number of vehicles loaded on the movable deck

P_V : Mass of a vehicle, in kN

P_P : Mass of the movable deck, in kN

A_P : Effective area of the movable deck, in m^2.

1.4.3 Still water and inertial pressures

The still water and inertial pressures transmitted to the movable deck or inner ramp structures are obtained, in kN/m^2, as specified in Tab 1.

Table 1 : Movable decks and inner ramps - Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water condition		$p_S = p$
Upright sea condition	"a"	No inertial pressure
	"b"	$p_{W,X} = p\frac{a_{X1}}{g}$ in x direction $p_{W,Z} = p\frac{a_{Z1}}{g}$ in z direction
Inclined sea condition (negative roll angle)	"c"	$p_{W,Y} = p\frac{C_{FA}a_{Y2}}{g}$ in y direction
	"d"	$p_{W,Z} = p\frac{C_{FA}a_{Z2}}{g}$ in z direction
Harbour condition **(1)**	during lifting	$p_{W,X} = 0,035\ p$ in x direction $p_{W,Y} = 0,087\ p$ in y direction $p_{W,Z} = 0,200\ p$ in z direction
	at rest	$p_{W,X} = 0,035\ p$ in x direction $p_{W,Y} = 0,087\ p$ in y direction $p_{W,Z} = 0,100\ p$ in z direction

(1) For harbour conditions, a heel angle of 5° and a trim angle of 2° are taken into account.

Note 1:

p : Pressure, in kN/m², to be calculated according to [1.4.2] for the condition considered

C_{FA} : Combination factor, to be taken equal to:

- $C_{FA} = 0,7$ for load case "c"
- $C_{FA} = 1,0$ for load case "d".

1.4.4 Checking criteria

It is to be checked that the combined stress σ_{VM} is in accordance with the criteria defined in Ch 7, Sec 3, [3.3.1].

1.4.5 Allowable deflection

The scantlings of main stiffeners and the distribution of supports are to be such that the deflection of the movable deck or inner ramp does not exceed 5 mm/m.

1.5 Supports, suspensions and locking devices

1.5.1 Scantlings of supports and wire suspensions are to be determined by direct calculation on the basis of the loads in [1.4.2] and [1.4.3], taking account of a safety factor at least equal to 5.

1.5.2 It is to be checked that the combined stress σ_{VM} in rigid supports and locking devices is in accordance with the criteria defined in Ch 7, Sec 3, [3.3.1].

2 External ramps

2.1 General

2.1.1 The external ramps are to be able to operate with a heel angle of 5° and a trim angle of 2°.

2.1.2 The external ramps are to be examined for their watertightness, if applicable, and as a support of vehicles at harbour.

2.1.3 The locking of external ramps in stowage position at sea is examined by the Society on a case-by-case basis.

2.1.4 The ship structure under the reactions due to the ramp is examined by the Society on a case-by-case basis.

Section 10 Arrangement of Hull and Superstructure Openings

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement of hull and superstructure openings excluding hatchways, for which the requirements in Ch 8, Sec 8 apply.

1.2 Definitions

1.2.1 Standard height of superstructure

The standard height of superstructure is defined in Tab 1.

Table 1 : Standard height of superstructure h_S

Length L in m	h_S, in m	
	Raised quarter deck	All the other superstructures
L ≤ 30	0,90	1,80
30 < L ≤ 75	0,9 + 0,00667 (L – 30)	1,80
75 < L ≤ 125	1,2 + 0,012 (L – 75)	1,8 + 0,01 (L – 75)
L > 125	1,80	2,30

1.2.2 Standard sheer

The standard sheer is that defined according to regulation 38 of the International Load Line Convention 1966, as amended.

1.2.3 Exposed zones

Exposed zones are the boundaries of superstructures or deckhouses set in from the ship side at a distance less than or equal to 0,04 B.

1.2.4 Unexposed zones

Unexposed zones are the boundaries of deckhouses set in from the ship side at a distance greater than 0,04 B.

2 External openings

2.1 General

2.1.1 All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, are required to be watertight.

2.1.2 External openings required to be watertight in accordance with [2.1.1] are to be of sufficient strength and, except for cargo hatch covers, are to be fitted with indicators on the bridge.

2.1.3 Openings in the shell plating below the deck limiting the vertical extent of damage are to be kept permanently closed while at sea. Should any of these openings be accessible during the voyage, they are to be fitted with a device which prevents unauthorized opening.

2.1.4 Notwithstanding the requirements of [2.1.3], the Society may authorize that particular doors may be opened at the discretion of the Master, if necessary for the operation of the ship and provided that the safety of the ship is not impaired.

2.1.5 Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of external openings are to be provided with a notice affixed to each appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

For watertight doors, a plate called “Harlequin” may be fitted, in equivalence to this notice. This plate precise the opening condition for each tightness situation.

2.2 Closing devices subjected to weapon firing loads

2.2.1 In addition to the applicable requirements of this Section, the net scantlings of closing devices subjected to weapon firing loads are to be not less that those obtained from the applicable formulae in Part B, Chapter 7, where the pressures are to be calculated according to Ch 5, Sec 6, [9].

3 Sidescuttles, windows and skylights

3.1 General

3.1.1 Application

The requirements in [3.1] to [3.4] apply to sidescuttles and rectangular windows providing light and air, located in positions which are exposed to the action of sea and/or bad weather.

3.1.2 Sidescuttle definition

Sidescuttles are round or oval openings with an area not exceeding 0,16 m^2. Round or oval openings having areas exceeding 0,16 m^2 are to be treated as windows.

3.1.3 Window definition

Windows are rectangular openings generally, having a radius at each corner relative to the window size in accordance with recognized national or international standards, and round or oval openings with an area exceeding 0,16 m^2.

3.1.4 Number of openings in the shell plating

The number of openings in the shell plating are to be reduced to the minimum compatible with the design and proper working of the ship.

3.1.5 Material and scantlings

Sidescuttles and windows together with their glasses, deadlights and storm covers, if fitted, are to be of approved design and substantial construction in accordance with, or equivalent to, recognized national or international standards.

Non-metallic frames are not acceptable. The use of ordinary cast iron is prohibited for sidescuttles below the main watertight deck.

3.1.6 Means of closing and opening

The arrangement and efficiency of the means for closing any opening in the shell plating are to be consistent with its intended purpose and the position in which it is fitted is to be generally to the satisfaction of the Society.

3.1.7 Opening of sidescuttles

All sidescuttles, the sills of which are below the bulkhead deck, are to be of such construction as to prevent effectively any person opening them without the consent of the Master of the ship. Please also refer to Ch 2, Sec 1, Tab 2.

Sidescuttles and their deadlights which are not accessible during navigation are to be closed and secured before the ship leaves port.

The Society, at its discretion, may prescribe that the time of opening such sidescuttles in port and of closing and locking them before the ship leaves port is to be recorded in a log book.

3.2 Opening arrangement

3.2.1 General

Sidescuttles may not be fitted in such a position that their sills are below a line drawn parallel to the watertight deck at side and having its lowest point 0,025 B or 0,5 m, whichever is the greater distance, above the deepest subdivision load line.

3.2.2 Sidescuttles below (1,4 + 0,025 B) m above the water

Where in 'tweendecks the sills of any of the sidescuttles are below a line drawn parallel to the bulkhead deck at side and having its lowest point (1,4 + 0,025 B) m above the water when the ship departs from any port, all the sidescuttles in that 'tweendecks are to be closed watertight and locked before the ship leaves port, and they may not be opened before the ship arrives at the next port. In the application of this requirement, the appropriate allowance for fresh water may be made when applicable.

For any ship that has one or more sidescuttles so placed that the above requirements apply when it is floating at its deepest subdivision load line, the Society may indicate the limiting mean draught at which these sidescuttles are to have their sills above the line drawn parallel to the bulkhead deck at side, and having its lowest point (1,4 + 0,025 B) above the waterline corresponding to the limiting mean draught, and at which it is therefore permissible to depart from port without previously closing and locking them and to open them at sea under the responsibility of the Master during the voyage to the next port. In tropical zones as defined in the International Convention on Load Lines in force, this limiting draught may be increased by 0,3 m.

3.2.3 Cargo spaces

No sidescuttles may be fitted in any spaces which are appropriated exclusively for the carriage of cargo.

Sidescuttles may, however, be fitted in spaces appropriated alternatively for the carriage of cargo or passengers, but they are to be of such construction as to prevent effectively any person opening them or their deadlights without the consent of the Master.

If cargo is carried in such spaces, the sidescuttles and their deadlights are to be closed watertight and locked before the cargo is shipped. The Society, at its discretion, may prescribe that the time of closing and locking is to be recorded in a log book.

3.2.4 Non-opening type sidescuttles

Sidescuttles are to be of the non-opening type in the following cases:

- where they become immersed by any intermediate stage of flooding or the final equilibrium waterplane in any required damage case for ships subject to damage stability regulations
- where they are fitted outside the space considered flooded and are below the final waterline for those ships where the freeboard is reduced on account of subdivision characteristics when a freeboard calculation is undertaken.

3.2.5 Manholes and flush scuttles

Manholes and flush scuttles in positions 1 or 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

3.2.6 Ships with several decks

In ships having several decks above the bulkhead deck, the arrangement of sidescuttles and rectangular windows is considered by the Society on a case-by-case basis.

Particular consideration is to be given to the ship side up to the upper deck and the front bulkhead of the superstructure.

3.2.7 Window arrangement

Windows may not be fitted below the watertight deck, in first tier end bulkheads or sides of enclosed superstructures and in first tier deckhouses considered as being buoyant in the stability calculations or protecting openings leading below.

In the front bulkhead of a superstructure situated on the upper deck, in the case of substantially increased watertight, rectangular windows with permanently fitted storm covers are acceptable.

3.2.8 Skylights

Fixed or opening skylights are to have glass thickness appropriate to their size and position as required for sidescuttles and windows. Skylight glasses in any position are to be protected from mechanical damage and, where fitted in positions 1 or 2, to be provided with permanently attached robust deadlights or storm covers.

3.2.9 Gangway and cargo ports

Gangway and cargo ports are to be of sufficient strength. They are to be effectively closed and secured watertight before the ship leaves port, and to be kept closed during navigation.

Such ports are in no case to be so fitted as to have their lowest point below the deepest subdivision load line.

3.3 Glasses

3.3.1 General

In general, toughened glasses with frames of special type are to be used in compliance with, or equivalent to, recognised national or international standards.

Direct metal to glass contact is to be avoided.

The use of clear plate glasses is considered by the Society on a case by case basis.

3.3.2 Design loads

The design load is to be determined in accordance with the applicable requirements of Ch 8, Sec 4, [2].

In damaged ship conditions, where windows or sidescuttles are located below the deepest equilibrium waterline, the design pressure p, in kN/m^2, is to be taken equal to:

$$p = p_S + p_W$$

where:

p_S : Still water pressure, taken equal to:

$$p_S = \rho\, g\, d_F$$

p_W : Wave pressure, taken equal to:

$$p_W = 0,6\rho g h_1 e^{\frac{-2\pi(d_F)}{L}}$$

d_F : Distance, in m, from the calculation point to the deepest equilibrium waterline.

The deepest equilibrium waterlines are to be provided by the Designer under his own responsibility.

h_1 : Reference values of the ship relative motions in the upright ship condition, defined in Ch 5, Sec 3, [3.3].

3.3.3 Scantling

The windows and sidescuttles assessment methodology defined in this Article is equivalent to Standard ISO 11336-1:2012.

The scantling of windows and sidescuttle defined in this sub-article are provided for the following types of window or sidescuttle:

- monolithic window or sidescuttle (see [3.3.4])
- laminated window or sidescuttle (see [3.3.5])
- double windows unit with gap (see [3.3.9]).

All the window and sidescuttle edges are considered as simply supported.

3.3.4 Thickness of monolithic window

The thicknesses, in mm, of monolithic windows and sidescuttles are to be obtained from the following formula:

- rectangular window or sidescuttle:

$$t = 31,6s\sqrt{\frac{\beta p S_f}{R_m}}$$

- circular window or sidescuttle:

$$t = 17,4d\sqrt{\frac{p S_f}{R_m}}$$

where:

s : Shorter side, in m, of rectangular window or sidescuttle

Where the window is supported only on 2 edges, s is to be taken as the unsupported side

ℓ : Longer side, in m, of rectangular window or sidescuttle

d : Diameter, in m, of circular window or sidescuttle

R_m : Guaranteed minimum flexural strength, in N/mm^2, of material used. For guidance only, the guaranteed minimum flexural strength R_m for glass window is:

- for thermally or chemically toughened glass: R_m = 120 N/mm^2
- for polymethylmethacrilate (PMMA) glass: R_m = 100 N/mm^2
- for polycarbonate (PC) glass: R_m = 90 N/mm^2

S_f : Safety factor taken equal to:

- 3,0 for thermally or chemically toughened glass:
- 3,5 for polymethylmethacrilate (PMMA) or polycarbonate (PC) glass:

β : Aspect ratio coefficient of the rectangular window or sidescuttle, obtained in Tab 2

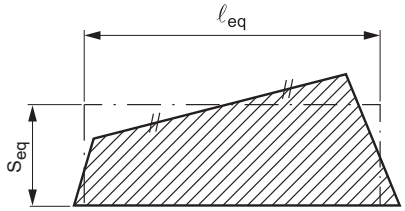
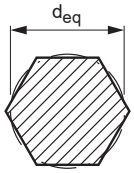
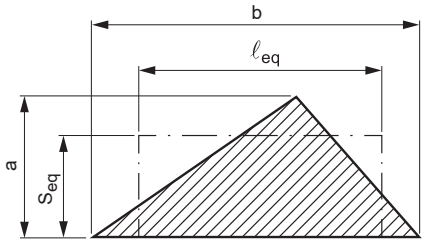
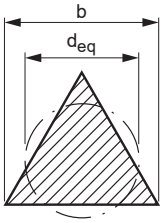
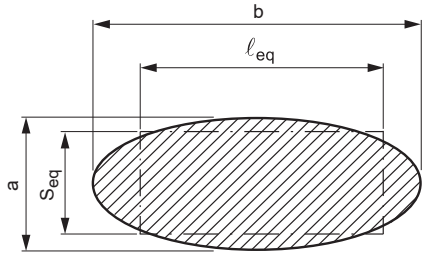
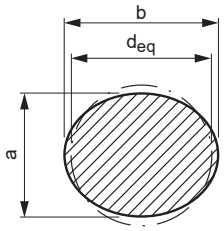
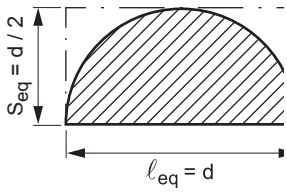
Where the window is supported only by 2 edges, β is to be taken equal to 1,0.

The thickness of windows or sidescuttles having other shapes may be obtained by considering rectangles or circles of equivalent dimensions s_{eq}, ℓ_{eq} or d_{eq} as defined in Tab 3.

Table 2 : Coefficient β

ℓ/s	β
1,0	0,284
1,5	0,475
2,0	0,608
2,5	0,684
3,0	0,716
3,5	0,734
≥ 4,0	0,750

Table 3 : Equivalent dimensions for windows having other shapes

<table>
<tr>
<td>a) Quadrangle
The equivalent rectangle has the same area

</td>
<td>b) Polygon
The equivalent circle has the same area

</td>
<td colspan="2">c) Triangle
$s_{eq} = 2a/3$
$l_{eq} = 3b/4$

</td>
</tr>
<tr>
<td>d) Equilateral triangle
$d_{eq} = 3b/4$

</td>
<td>e) Flat ellipse
$s_{eq} = 0,87a$
$l_{eq} = 0,87b$

</td>
<td>f) Round ellipse
$d_{eq} = \sqrt{ab}$

</td>
<td>g) Semi circle
$s_{eq} = d/2$
$l_{eq} = d$

</td>
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</table>

3.3.5 Laminated window

Laminated windows are windows realized by placing an interlayer of resin (polyvinyl butyral as a general rule) between plies of same or different materials.

For laminated windows made with plies of the same material:

- When the mechanical properties of the interlayer material (the laminating adhesive material) are not known, the plies of the laminated window are considered as mechanically independent, and the equivalent thickness is to be calculated as defined in [3.3.6].
- When the mechanical properties of the interlayer material are known in terms of shear modulus, G, in N/mm^2, the plies of the laminated window are considered as mechanically collaborating, and the equivalent thickness is to be calculated as defined in [3.3.7].

When the laminated window is made with plies of different materials, they are considered as mechanically independent, and the equivalent thickness is to be calculated as defined in [3.3.8].

3.3.6 Thickness of laminated window with independent plies

The equivalent thickness t_{eq}, in mm, of laminates made of n independent plies of thicknesses $t_{p,1}$, $t_{p,2}$, …, $t_{p,n}$, is to comply with the following formula:

$$t_{eq} \geq t$$

where:

$$t_{eq} = \min[t_{eq,j}]$$

$$t_{eq,j} = \sqrt{\frac{\sum_{j=1}^{n} t_{p,j}^3}{t_{p,j}}}$$

j : Ply index, ranging from 1 to n

t : Thickness, in mm, of a monolithic window, calculated according to [3.3.4].

3.3.7 Thickness of laminated window with collaborating plies

The equivalent thickness t_{eq}, in mm, of laminates made of two collaborating plies of the same material, and of thicknesses t_1 and t_2 separated by an interlayer of thickness t_i is to comply with the following formula:

$$t_{eq} \geq t$$

where:

$t_{eq} = min[t_{1eq,s}, t_{2eq,s}]$

$t_{1eq,s}$, $t_{2eq,s}$: Equivalent thickness for strength as obtained from the following formulae:

$$t_{1eq,s} = \sqrt{\frac{t_{eq,d}^3}{t_1 + 2\Gamma t_{s2}}}$$

$$t_{2eq,s} = \sqrt{\frac{t_{eq,d}^3}{t_2 + 2\Gamma t_{s1}}}$$

$t_{eq,d}$: Equivalent thickness for deflection as obtained from the following formula:

$$t_{1eq,d} = \sqrt[3]{t_1^3 + t_2^3 + 12\Gamma I_s}$$

Γ : Shear transfer coefficient as obtained from the following formula, without being taken less than 0 (independent plies behaviour) and more than 1,0 (monolithic behaviour):

$$\Gamma = \frac{1}{1 + 9{,}6\,\frac{E}{G} \cdot \frac{I_s}{hs^2} \cdot \frac{t_l}{s^2} \cdot \frac{1}{10^6}}$$

$$t_{s1} = \frac{hs \cdot t_1}{t_1 + t_2}$$

$$t_{s2} = \frac{hs \cdot t_2}{t_1 + t_2}$$

$$I_s = t_1 t_{s2}^2 + t_2 t_{s1}^2$$

$$hs = 0{,}5(t_1 + t_2) + t_l$$

G : Shear modulus of the interlayer at 25 °C, in N/mm², generally taken equal to 1,6 N/mm² for polyvinyl butyral (PVB).

For other interlayer materials the shear modulus value at 25 °C for short time duration load (60 s) shall be declared by the interlayer material manufacturer

E : Young's modulus of the plies, in N/mm²

s : Shorter side, in m, of rectangular window or sidescuttle.

In case of multiple (more than two plies) laminates the calculation is to be iterated. The iteration is to start from the outer ply (the one directly loaded by water pressure) and end with the inner ply.

3.3.8 Thickness of laminated window with plies of different materials

The equivalent thickness t_{eq}, in mm, of laminates made of n plies of different materials, of thicknesses $t_{p,1}$, $t_{p,2}$, …, $t_{p,n}$ and of Young's modulus $E_{p,1}$, $E_{p,2}$, ..., $E_{p,n}$ is to comply with the following formula:

$t_{eq} \geq t$

where:

$t_{eq} = min[t_{eq,j}]$

$$t_{eq,j} = \sqrt{\frac{\sum_{j=1}^{n} E_{p,j} t_{p,j}^3}{E_{p,j} t_{p,j}}}$$

j : Ply index, ranging from 1 to n

t : Thickness, in mm, of a monolithic window, calculated according to [3.3.4] for the same material than the ply giving the minimum value of $t_{eq,j}$.

3.3.9 Thickness of double windows

Double windows are glass windows made of two plies of glass separated by an hermetically sealed spacebar.

The thickness of the ply exposed to the loads defined in [3.3.2] is to be calculated as per monolithic windows according to [3.3.4].

3.3.10 Thickness of glasses forming screen bulkheads or internal boundaries of deckhouses

The thickness of glasses forming screen bulkheads on the side of enclosed promenade spaces and that for rectangular windows in the internal boundaries of deckhouses which are protected by such screen bulkheads are considered by the Society on a case by case basis.

The Society may require both limitations on the size of rectangular windows and the use of glasses of increased thickness in way of front bulkheads which are particularly exposed to heavy sea.

3.3.11 Thickness of glasses subjected to weapon firing loads

The scantling of windows and side-scuttles exposed to weapon firing dynamic loads is to be as per [3.3.3], with pressure p, in kN/m², being taken equal to the relevant pressure calculated according to Ch 5, Sec 6, [9].

3.4 Deadlight arrangement

3.4.1 General

Sidescuttles to the following spaces are to be fitted with efficient, hinged inside deadlights:

- spaces within the first tier of enclosed superstructures
- first tier deckhouses on the watertight deck protecting openings leading below or considered buoyant in stability calculations.

3.4.2 Watertight deadlights

Efficient, hinged inside deadlights so arranged that they can be easily and effectively closed and secured watertight, are to be fitted to all sidescuttles except that abaft one eighth of the ship's length from the forward perpendicular and above a line drawn parallel to the bulkhead deck at side and having its lowest point at a height of (3,7 + 0,025 B) m above the deepest subdivision load line.

3.4.3 Openings at the side shell in the second tier

Sidescuttles and windows at the side shell in the second tier, protecting direct access below or considered buoyant in the stability calculations, are to be provided with efficient, hinged inside deadlights capable of being effectively closed and secured weathertight.

3.4.4 Openings set inboard in the second tier

Sidescuttles and windows set inboard from the side shell in the second tier, protecting direct access below to spaces listed in [3.4.1] are to be provided with either efficient, hinged inside deadlights or, where they are accessible, permanently attached external storm covers of approved design and substantial construction capable of being effectively closed and secured weathertight.

Cabin bulkheads and doors in the second tier separating sidescuttles and windows from a direct access leading below may be accepted in place of fitted deadlights or storm covers.

Note 1: Deadlights in accordance with recognized standards are fitted to the inside of windows and sidescuttles, while storm covers of comparable specifications to deadlights are fitted to the outside of windows, where accessible, and may be hinged or portable.

3.4.5 Deckhouses on superstructures of less than standard height

Deckhouses situated on a raised quarterdeck or on a superstructure of less than standard height may be treated as being on the second tier as far as the provision of deadlights is concerned, provided the height of the raised quarterdeck or superstructure is not less than the standard quarterdeck height.

3.4.6 Openings protected by a deckhouse

Where an opening in a superstructure deck or in the top of a deckhouse on the deck which gives access to a space below the waterteight deck or to a space within an enclosed superstructure is protected by a deckhouse, then it is considered that only those sidescuttles fitted in spaces which give direct access to an open stairway need to be fitted with deadlights.

4 Discharges

4.1 Arrangement of discharges

4.1.1 Inlets and discharges

All inlets and discharges in the shell plating are to be fitted with efficient and accessible arrangements for preventing the accidental admission of water into the ship.

4.1.2 Inboard opening of ash-chute, rubbish-chute, etc.

The inboard opening of each ash-shoot, rubbish-shoot, etc. is to be fitted with an efficient cover.

If the inboard opening is situated below the watertight deck, the cover is to be watertight, and in addition an automatic non-return valve is to be fitted in the chute in an easily accessible position above the deepest subdivision load line . When the chute is not in use, both the cover and the valve are to be kept closed and secured.

4.2 Arrangement of garbage chutes

4.2.1 Inboard end above the waterline

The inboard end is to be located above the waterline formed by an 8,5° heel, to port or starboard, at a draught corresponding deepest subdivision load line , but not less than 1000 mm above the deepest subdivision load line. Where the inboard end of the garbage chute exceeds 0,01 L above the deepest subdivision load line, valve control from the watertight deck is not required, provided the inboard gate valve is always accessible under service conditions.

4.2.2 Inboard end below the waterline

Where the inboard end of a garbage chute is below the margin line or the Vline then:

- the inboard end hinged cover/valve is to be watertight
- the valve is to be a screw-down non-return valve fitted in an easily accessible position above the deepest subdivision load line
- the screw-down non-return valve is to be controlled from a position above the watertight deck and provided with open/shut indicators. The valve control is to be clearly marked: “Keep closed when not in use”.

4.2.3 Gate valves

For garbage chutes, two gate valves controlled from the working deck of the chute may be accepted instead of a non-return valve with a positive means of closing it from a position above the watertight deck. In addition, the lower gate valve is to be controlled from a position above the watertight deck. An interlock system between the two valves is to be arranged.

The distance between the two gate valves is to be adequate to allow the smooth operation of the interlock system.

4.2.4 Hinged cover and discharge flap

The upper gate valve, as required in [4.2.3], may be replaced by a hinged weathertight cover at the inboard end of the chute together with a discharge flap which replaces the lower gate valve.

The cover and discharge flap are to be arranged with an interlock so that the flap cannot be operated until the hopper cover is closed.

4.2.5 Marking of valve and hinged cover

The gate valve controls and/or hinged cover are to be clearly marked: “Keep closed when not in use”.

4.3 Scantlings of garbage chutes

4.3.1 Material

The chute is to be constructed of steel. Other equivalent materials are considered by the Society on a case-by-case basis.

4.3.2 Wall thickness

The wall thickness of the chute up to, and including, the cover is to be not less than that obtained, in mm, from Tab 4.

Table 4 : Wall thickness of garbage chutes

External diameter d, in mm	Thickness, in mm
$d \leq 80$	7,0
$80 < d < 180$	7,0 + 0,03 (d – 80)
$180 \leq d \leq 220$	10,0 + 0,063 (d – 180)

5 Freeing ports

5.1 General provisions

5.1.1 General

Where bulwarks on the weather portions of watertight or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of water and for draining them.

A well is any area on the deck exposed to the weather, where water may be entrapped. Wells are considered to be deck areas bounded on four sides by deck structures; however, depending on their configuration, deck areas bounded on three or even two sides by deck structures may be deemed wells.

5.1.2 Freeing port areas

The minimum required freeing port areas in bulwarks on the watertight deck are specified in Tab 5.

5.1.3 Freeing port arrangement

Where a sheer is provided, two thirds of the freeing port area required is to be provided in the half of the well nearer the lowest point of the sheer curve.

Where the exposed watertight deck or an exposed superstructure deck has little or no sheer, the freeing port area is to be spread along the length of the well.

However, bulwarks may not have substantial openings or accesses near the breaks of superstructures, unless they are effectively detached from the superstructure sides.

5.1.4 Freeing port positioning

The lower edge of freeing ports is to be as near the deck as practicable, at not more than 100 mm above the deck.

All the openings in the bulwark are to be protected by rails or bars spaced approximately 230 mm apart.

Table 5 : Freeing port area in bulwark located on watertight deck

Ship types or ship particulars	Area A of freeing ports, in m^2	Applicable requirement
Ships fitted with a trunk having breadth ≥ 0,6 B	$0,33\ \ell_B\ h_B$	[5.3.1]
Ships fitted with continuous or substantially continuous trunk and/or hatch coamings	A_2	[5.3.1]
Ships fitted with non-continuous trunk and/ or hatch coamings	A_3	[5.3.2]
Ships fitted with open superstructure	A_S for superstructures A_W for wells	[5.4.2] [5.4.3]
Other ships	A_1	[5.2.1]

Note 1:

ℓ_B : Length, in m, of bulwark in a well at one side of the ship

h_B : Mean height, in m, of bulwark in a well of length ℓ_B.

5.1.5 Freeing port closures

If shutters or closures are fitted to freeing ports, ample clearance is to be provided to prevent jamming. Hinges are to have pins or bearings of non-corrodible material. If shutters are fitted with securing appliances, these appliances are to be of approved construction.

5.1.6 Gutter bars

Gutter bars greater than 300 mm in height fitted around the weather decks are to be treated as bulwarks. The freeing port area is to be calculated in accordance with the applicable requirements of this Section.

5.2 Freeing port area in a well not adjacent to a trunk or hatchways

5.2.1 Freeing port area A_1

Where the sheer in way of the well is standard or greater than the standard, the freeing port area on each side of the ship for each well is to be not less than that obtained, in m^2, in Tab 6.

In ships with no sheer, the above area is to be increased by 50%. Where the sheer is less than the standard, the percentage of increase is to be obtained by linear interpolation.

5.2.2 Minimum freeing port area for a deckhouse having a breadth not less than 0,8 B

Where a flush deck ship is fitted amidships with a deckhouse having a breadth not less than 0,8 B and the width of the passageways along the side of the ship less than 1,5 m, the freeing port area is to be calculated for two separate wells, before and abaft the deckhouse. For each of these wells, the freeing port area is to be obtained from Tab 5, where ℓ_B is to be taken equal to the actual length of the well considered (in this case the limitation $\ell_B \le 0,7\ L$ may not be applied).

5.2.3 Minimum freeing port area for screen bulkhead

Where a screen bulkhead is fitted across the full breadth of the ship at the fore end of a midship deckhouse, the weather deck is to be considered as divided into two wells, irrespective of the width of the deckhouse, and the freeing port area is to be obtained in accordance with [4.1.2].

Table 6 : Freeing port area A_1 in a well not adjacent to a trunk or hatchways

Location	Freeing port area A_1, in m^2	
	$\ell_B \le 20$	$\ell_B > 20$
Watertight deck and raised quarterdecks	$0,7 + 0,035\ell_B + A_C$	$0,070\ell_B + A_C$
Superstructure decks	$0,35 + 0,0175\ell_B + 0,5A_C$	$0,035\ell_B + 0,5A_C$

Note 1:

ℓ_B : Length, in m, of bulwark in the well, to be taken not greater than 0,7 L

A_C : Area, in m^2, to be taken, with its sign, equal to:

$$A_C = \frac{\ell_W}{25}(h_B - 1,2) \text{ for } h_B > 1,2$$

$$A_C = 0 \text{ for } 0,9 \le h_B \le 1,2$$

$$A_C = \frac{\ell_W}{25}(h_B - 0,9) \text{ for } h_B < 0,9$$

h_B : Mean height, in m, of the bulwark in a well of length ℓ_B.

5.3 Freeing port area in a well contiguous to a trunk or hatchways

5.3.1 Freeing port area A2 for a continuous trunk or continuous hatchway coamings

Where the ship is fitted with a continuous trunk not included in the stability calculation or where continuous or substantially continuous hatchway side coamings are fitted between detached superstructures, the freeing port area is to be not less than that obtained, in m^2, from Tab 7.

Where the ship is fitted with a continuous trunk having breadth not less than 0,6 B, included in the stability calculation and where open rails on the weather parts of the watertight deck in way of the trunk for at least half the length of these exposed parts are not fitted, the freeing port area in the well contiguous to the trunk is to be not less than 33% of the total area of the bulwarks.

Table 7 : Freeing port area A_2 in a well contiguous to a continuous trunk or continuous hatchway coamings

Breadth B_H, in m	Freeing port area A_2, in m^2
$B_H \leq 0,4\ B$	$0,2\ \ell_B\ h_B$
$0,4\ B < B_H < 0,75\ B$	$\left[0,2 - 0,286\left(\frac{B_H}{B} - 0,4\right)\right]\ell_B h_B$
$B_H \geq 0,75\ B$	$0,1\ \ell_B\ h_B$
Note 1: B_H : Breadth of the trunk or the hatchway, in m ℓ_B : Length, in m, of bulwark in a well at one side of the ship h_B : Mean height, in m, of bulwark in a well of length ℓ_B.	

5.3.2 Freeing port area A_3 for a non-continuous trunk or non-continuous hatchway coamings

Where the free flow of water across the deck of the ship is impeded due to the presence of a non-continuous trunk, hatchway coaming or deckhouse in the whole length of the well considered, the freeing port area in the bulwark of this well is to be not less than that obtained, in m^2, from Tab 8.

Table 8 : Freeing port area A_3 in a well contiguous to a non-continuous trunk or non-continuous hatchway coamings

Free flow area f_P, in m^2	Freeing port area A_3, in m^2
$f_p \leq A_1$	A_2
$A_1 < f_P < A_2$	$A_1 + A_2 - f_P$
$f_P \geq A_2$	A_1
Note 1: f_P : Free flow area on deck, equal to the net area of gaps between hatchways, and between hatchways and superstructures and deckhouses up to the actual height of the bulwark A_1, A_2 : Freeing port areas, in m^2, to be obtained from, respectively, Tab 6 and Tab 7.	

5.4 Freeing port area in an open space within superstructures

5.4.1 General

In ships having superstructures on the watertight or superstructure decks, which are open at either or both ends to wells formed by bulwarks on the open decks, adequate provision for freeing the open spaces within the superstructures is to be provided.

5.4.2 Freeing port area A_S for open superstructures

The freeing port area on each side of the ship for the open superstructure is to be not less than that obtained, in m^2, from the following formula:

$$A_S = A_1 c_{SH}\left[1 - \left(\frac{\ell_W}{\ell_T}\right)^2\right]\left(\frac{b_0 h_S}{2\,\ell_T h_W}\right)$$

where:

ℓ_T : Total well length, in m, to be taken equal to: $\ell_T = \ell_W + \ell_S$

ℓ_W : Length, in m, of the open deck enclosed by bulwarks

ℓ_S : Length, in m, of the common space within the open superstructures

A_1 : Freeing port area, in m^2, required for an open well of length ℓ_T, in accordance with Tab 6, where A_C is to be taken equal to zero

c_{SH} : Coefficient which accounts for the absence of sheer, if applicable, to be taken equal to:

- $c_{SH} = 1,0$ in the case of standard sheer or sheer greater than standard sheer
- $c_{SH} = 1,5$ in the case of no sheer

b_0 : Breadth, in m, of the openings in the end bulkhead of enclosed superstructures

h_S : Standard superstructure height, in m, defined in [1.2.1]

h_W : Distance, in m, of the well deck above the watertight deck.

5.4.3 Freeing port area A_W for open well

The freeing port area on each side of the ship for the open well is to be not less than that obtained, in m^2, from the following formula:

$$A_W = A_1 c_{SH}\left(\frac{h_S}{2h_W}\right)$$

where:

A_1 : Freeing port area, in m^2, required for an open well of length ℓ_W, in accordance with Tab 6

c_{SH}, h_S, h_W, ℓ_W: Defined in [5.4.2].

5.4.4 The resulting freeing port areas for the open superstructure A_S and for the open well A_W are to be provided along each side of the open space covered by the open superstructure and each side of the open well, respectively.

6 Machinery space openings

6.1 Engine room skylights

6.1.1 Engine room skylights in position 1 or 2 are to be properly framed, securely attached to the deck and efficiently enclosed by steel casings of suitable strength. Where the casings are not protected by other structures, their strength will be considered by the Society on a case-by-case basis.

Skylights, where fitted with openings for light and air, are to have coamings of a height not less than:

- 900 mm, if in position 1
- 760 mm, if in position 2.

6.2 Closing devices

6.2.1 Machinery casings

Openings in machinery space casings in position 1 or 2 are to be fitted with doors of steel or other equivalent materials, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead and weathertight when closed. The doors are to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.

Other openings in such casings are to be fitted with equivalent covers, permanently attached in their proper position.

6.2.2 Height of the sill of the door

The height of the sill of the door is generally to be not less than:

- 600 mm above the deck if in position 1
- 380 mm above the deck if in position 2
- 230 mm in all the other cases.

However, height of coamings are to be compatible with use at sea and are not to be less than 300mm in position 1 and 150mm in position 2 in any case.

6.2.3 Double doors

Where casings are not protected by other structures, double doors (i.e. inner and outer doors) are required. An inner sill of 230 mm in conjunction with the outer sill of 600 mm is normally to be provided.

However, the height of this sill is to be compatible with use at sea and is not to be less than 300mm in position 1 and 150mm in position 2 in any case.

6.2.4 Fiddly openings

Fiddly openings are to be fitted with strong covers of steel or other equivalent material permanently attached in their proper positions and capable of being secured weathertight.

6.3 Coamings

6.3.1 Coamings of any fiddly, funnel or machinery space ventilator in an exposed position on the watertight deck or superstructure deck are to be as high above the deck as is reasonable and practicable.

In general, ventilators necessary to continuously supply the machinery space and, on demand, the emergency generator room are to have coamings whose height is in compliance with [8.1.3], but need not be fitted with weathertight closing appliances.

Where, due to the ship size and arrangement, this is not practicable, lesser heights for machinery space and emergency generator room ventilator coamings, fitted with weathertight closing appliances in accordance with [8.1.2], may be permitted by the

Society in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

7 Companionway

7.1 General

7.1.1 Openings in watertight deck

Openings in watertight deck other than hatchways, machinery space openings, manholes and flush scuttles are to be protected by an enclosed superstructure or by a deckhouse or companionway of equivalent strength and weathertightness.

7.1.2 Openings in superstructures

Openings in an exposed superstructure deck or in the top of a deckhouse on the watertight deck which give access to a space below the watertight deck or a space within an enclosed superstructure are to be protected by an efficient deckhouse or companionway.

7.1.3 Openings in superstructures having a height less than standard height

Openings in the top of a deckhouse on a raised quarterdeck or superstructure of less than standard height, having a height equal to or greater than the standard quarterdeck height are to be provided with an acceptable means of closing but need not be protected by an efficient deckhouse or companionway provided the height of the deckhouse is at least the height of the superstructure.

7.2 Scantlings

7.2.1 Companionways on exposed decks protecting openings leading into enclosed spaces are to be of steel or equivalent material and strongly attached to the deck and are to have adequate scantlings.

7.3 Closing devices

7.3.1 Doors

Doorways in deckhouses or companionways leading to or giving access to spaces below the watertight deck or to enclosed superstructures are to be fitted with weathertight doors. The doors are to be made of steel or equivalent material, to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.

Alternatively, if stairways within a deckhouse are enclosed within properly constructed companionways fitted with weathertight doors, the external door need not be watertight.

Where the closing appliances of access openings in superstructures and deckhouses are not weathertight, interior deck openings are to be considered exposed, i.e. situated in the open deck.

7.3.2 Height of sills

The height above the deck of sills to the doorways in companionways is to be not less than:

- 600 mm in position 1
- 380 mm in position 2.

Where access is not provided from above, the height of the sills to doorways in a poop bridge or deckhouse on the watertight deck is to be 600 mm.

Where access is provided to spaces inside a bridge or poop from the deck as an alternative to access from the watertight deck, the height of the sills into the bridge or poop is to be 380 mm. This also applies to deckhouses on the exposed deck.

However, height of sills are to be compatible with use at sea and are not to be less than 300mm in position 1 and 150 mm in position 2 in any case.

8 Ventilators

8.1 Closing appliances

8.1.1 General

Ventilator openings are to be provided with efficient weathertight closing appliances of steel or other equivalent material, designed to offer equivalent strength compared to the adjacent bulkhead or coaming in which they are fitted.

8.1.2 Closing appliance exemption

Ventilators need not be fitted with closing appliances, unless specifically required by the Society, if the coamings extend for more than:

- 4,5 m above the deck in position 1
- 2,3 m above the deck in position 2.

8.1.3 Closing appliances for ships not greater than 100 m in length

In ships not greater than 100 m in length, the closing appliances are to be permanently attached to the ventilator coamings.

8.1.4 Closing appliances for ships greater than 100 m in length

Where, in ships greater than 100 m in length, the closing appliances are not permanently attached, they are to be conveniently stowed near the ventilators to which they are to be fitted.

8.1.5 Ventilation of machinery spaces and emergency generator room

In order to satisfactorily ensure, in all weather conditions:

- the continuous ventilation of machinery spaces, and
- when necessary, the immediate ventilation of the emergency generator room,

the ventilators serving such spaces are to comply with [8.1.2], i.e. their openings are to be so located that they do not require closing appliances.

8.1.6 Reduced height of ventilator coamings for machinery spaces and emergency generator room

Where, due to the ship size and arrangement, the requirements in [8.1.5] are not practicable, lesser heights may be accepted for machinery space and emergency generator room ventilator coamings fitted with weathertight closing appliances in accordance with [8.1.1], [8.1.3] and [8.1.4] in combination with other suitable arrangements, such as separators fitted with drains, to ensure an uninterrupted, adequate supply of ventilation to these spaces.

8.1.7 Closing arrangements of ventilators led overboard or through enclosed superstructures

Closing arrangements of ventilators led overboard to the ship side or through enclosed superstructures are considered by the Society on a case-by-case basis. If such ventilators are led overboard more than 4,5 m above the watertight deck, closing appliances may be omitted provided that satisfactory baffles and drainage arrangements are fitted.

8.2 Coamings

8.2.1 General

Ventilators in position 1 or 2 to spaces below watertight decks or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck.

Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the watertight deck.

8.2.2 Scantlings

The scantlings of ventilator coamings exposed to the weather are to be not less than those obtained from Tab 9.

In exposed locations or for the purpose of compliance with buoyancy calculations, the height of coamings may be required to be increased to the satisfaction of the Society.

Table 9 : Scantlings of ventilator coamings

Feature	Scantlings
Height of the coaming above the deck	h = 900 mm in position 1 h = 760 mm in position 2
Thickness of the coaming, in mm **(1)**	$t = 5,5 + 0,01\ d_V$ with $7,5 \le t \le 10,0$
Support	If h > 900 mm, the coaming is to be suitably stiffened or supported by stays
(1) Where the height of the ventilator exceeds the height h, the thickness of the coaming may be gradually reduced, above that height, to a minimum of 6,5 mm. **Note 1:** d_V : Internal diameter of the ventilator, in mm.	

9 Tank cleaning openings

9.1 General

9.1.1 Ullage plugs, sighting ports and tank cleaning openings may not be arranged in enclosed spaces.

Section 11 Helicopter Decks, Helicopter Platforms and Hangar Decks

Symbols

E : Young's modulus, in N/mm^2, of the material of the plating or stiffener, as defined in Ch 4, Sec 3

g : Gravity acceleration, in m/s^2:

g = 9,81 m/s^2

k : Material factor for steel, defined in Ch 4, Sec 1, [2.3]

M_H : Mass corresponding to the maximum all-up weight of the helicopter, in t

M_P : Mass corresponding to the parking weight of the helicopter, in t

R_{eH} : Minimum guaranteed yield stress, in N/mm^2, of the material

R_y : Minimum yield stress, in N/mm^2, of the material, to be taken equal to 235/k N/mm^2, unless otherwise specified.

1 General

1.1 Application

1.1.1 The requirements of this Section apply to structure in:

- areas equipped for the landing and take-off of helicopters or other applicable vertical take-off and landing aircraft (refer to [1.1.6]), and located on a deck or on a platform permanently connected to the hull structure
- areas intended for the storage or handling of helicopters or other applicable aircraft.

1.1.2 In the case of helicopter platforms, the requirements apply to the ship hull structure to which the platform is attached, as well as to the platform deck itself and the platform supporting structure. Additional checks to those indicated in this Section may be required for the platform supporting structure, to the satisfaction of the Society.

1.1.3 The requirements in this Section are to be considered in addition to other relevant requirements defined elsewhere in the Rules. In particular, the scantlings are to be evaluated for other relevant loads defined in Part B, Chapter 5 according to the requirements of Part B, Chapter 7.

1.1.4 Helicopter decks or platforms intended for the landing of helicopters having landing devices other than wheels or skids are to be examined by the Society on a case-by-case basis.

1.1.5 All scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The net scantlings are obtained as specified in Ch 4, Sec 2.

1.1.6 Where the term 'helicopter' is used in this section, it is to be understood as being interchangeable with any other specific aircraft type that conducts vertical take-off and landing using rotor power.

1.2 Definitions

1.2.1 Final approach and take-off area

The deck area bounded by the perimeter line and perimeter lighting. This includes the zone under the final approach and take-off paths, accounting for permitted manoeuvring.

1.2.2 Handling zone

The area of a deck used for the storage or handling of helicopters. Any area where helicopters may be secured for parking or otherwise handled, including areas overlapping the landing zone or on aircraft elevators, is to be treated as a handling zone. The structure of this zone is dimensioned to withstand loads related to storage or handling of helicopters.

1.2.3 Hangar deck

An enclosed deck area used for the storage, preparation or maintenance of helicopters. In this Section the deck area within hangars is to comply with the requirements for hangar decks.

1.2.4 Helicopter deck

An upper deck forming part of the ship hull or superstructure, used as a helicopter landing zone and which may include a dedicated parking zone.

1.2.5 Helicopter platform

A structure intended for the landing and take-off of helicopters which is permanently attached to, but does not form part of, the ship hull or superstructure. In general, a helicopter platform consists of a platform deck supported by platform supporting structure (e.g. pillars, diagonals).

1.2.6 Landing gear

The undercarriage of an aircraft, with the function of supporting the weight of a helicopter during take-off and landing or when not in flight.

Landing gear relying upon one or two wheels are referred to as single wheel landing gear and dual wheel landing gear respectively.

Landing skids are landing gear not relying upon wheels and typically consisting of rigid structure.

Where a helicopter's individual landing gear have differing characteristics, main landing gear are the principal gear that support the larger proportion of the helicopter mass. Secondary landing gear are smaller gear sized to support the remaining portion of the helicopter mass.

1.2.7 Landing zone

The area of a deck where a helicopter landing may occur, including during emergencies and special operations. This zone is to include at least those parts of the final approach and take-off area where landings could occur. The structure within this zone is dimensioned to withstand the landing loads.

1.2.8 Recovery assist device

A system that interfaces a landing or landed helicopter with the ship, to assist with on-deck handling and securing of the helicopter.

2 General arrangement

2.1 General

2.1.1 The Designer is to specify the boundaries of the landing zone, its location on board, as well as the boundaries of the final approach and take-off area according to the definitions and applicable requirements of the National or other Authorities, or contractual specifications.

2.2 Final approach and take-off area

2.2.1 The final approach and take-off area is to be free of obstructions above the height of the landing zone, defined as the vertical level coinciding with the height of the deck or platform at the position of the aiming point for a normal touchdown.

Note 1: The following items may exceed this height, but not by more than 100 mm:

- guttering or slightly raised kerb
- lightning equipment
- outboard edge of the safety net
- foam monitors
- those handrails and other items associated with the landing area which are incapable of complete retraction or lowering for helicopter operations.

2.3 Safety nets

2.3.1 Safety nets are to be provided at the sides of the deck or the platform.

2.4 Drainage system

2.4.1 Drainage facilities complying with the requirements of Pt C, Ch 4, Sec 10, [3.2] are to be fitted.

3 Design principles

3.1 Partial safety factors

3.1.1 The partial safety factors to be considered for checking of helicopter deck, helicopter platform and hangar deck structures for the loads defined in this Section are specified in Tab 1.

Table 1 : Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors			
	Symbol	Plating	Ordinary stiffeners	Primary supporting members
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave pressure **(1)**	γ_{W2}	1,20	1,20	1,20
Material	γ_m	1,02	1,02	1,02
Resistance – normal landing loads	γ_R	1,02	1,02	As defined in Ch 7, Sec 3
Resistance – emergency landing loads		1,00	1,00	
Resistance – parking loads		1,02	1,02	
Resistance – sea pressure		1,02	1,02	
Resistance – specific loads for helicopter platforms		1,02	1,02	
(1) Value of 1,1 may be considered instead of 1,2 when the deck is not located on the aft or the fore part of the ship				

4 Design loads

4.1 Application

4.1.1 Helicopter decks

Landing zones are to be assessed independently for the normal and emergency landing loads defined in [4.2], and for sea pressure defined in [4.4].

Handling zones, are to be assessed for the parking loads defined in [4.3], and for sea pressure defined in [4.4].

4.1.2 Helicopter platforms

Helicopter platform deck structure is to be assessed for the loads detailed in [4.1.1] for helicopter decks.

Helicopter platform supporting structure is to be assessed independently for:

- the specific loads defined in [4.5]
- the normal and emergency landing loads defined in [4.2], in the landing zone
- sea pressure defined in [4.4].

The ship hull structure is to be assessed for the reactions to these loads, at the interfaces with the helicopter platform.

4.1.3 Hangar decks

Handling zones are to be assessed for the parking loads defined in [4.3].

4.1.4 Special cases

In case of helicopters having landing devices other than wheels (e.g. landing skids), the landing loads and the parking loads, if any, along with the corresponding load prints, will be examined by the Society on a case-by-case basis. In the absence of data from the helicopter manufacturer for such cases, the loads defined in this Section are to be applied.

If a helicopter having landing skids is fitted with wheels for handling purposes, the wheeled loads during handling operations are to be taken into account as per [4.3] for wheeled landing gear.

4.2 Landing loads

4.2.1 Normal landing

The normal landing force F_{NL} transmitted through a single main landing gear, or single skid print, is to be obtained, in kN, from the following formula:

$F_{NL} = M_H\, g$

4.2.2 Emergency landing

The emergency landing force F_{EL} transmitted through a single main landing gear, or single skid print, is to be obtained, in kN, from the following formula:

$F_{EL} = (1{,}75 - f)\, M_H\, g$

where:

$f = \text{Min}(0{,}5\ ;\ 0{,}032\ M_H)$

4.3 Parking loads

4.3.1 The still water and inertial forces, F_S and $F_{W,Z}$, transmitted via the landing gear, in kN, are to be obtained as specified in Ch 5, Sec 6, [4.1.1], where M, in t, is to be taken as follows:

- for helicopters with wheeled landing gear, M is the mass acting on each landing gear
- for helicopters with landing skids, M is the mass acting on each skid print.

The values of M are to be determined on the basis of data obtained from the helicopter manufacturer and provided by the Designer, accounting for the position of the helicopter's centre of gravity.

If the mass per wheeled landing gear, or skid print, is not known, M is to be taken equal to:

$$M = \frac{1,25}{n} M_P$$

where n is the total number of landing gear, or skid prints, as applicable.

4.4 Sea pressure

4.4.1 The sea pressure to be considered in unprotected areas is to be obtained according to Ch 5, Sec 5, [3.2].

4.5 Specific loads acting on helicopter platform supporting structure

4.5.1 The total still water and inertial forces accounting for the combination of the self-weight of the helicopter platform and the helicopter mass under the action of ship accelerations, as well as wind loading, are to be determined as specified in Tab 2.

Table 2 : Helicopter platforms - Still water and inertial forces

Ship condition	Load case	Still water force F_S and inertial force F_W, in kN **(1)**		
		Acting at the centre of gravity of the helicopter **(2) (3)**	Acting at the centre of gravity of the platfor **(4)**	Direction of application
Still water condition		$F_S = M_P g$	$F_S = M_S g$	in z direction
Upright condition	"a"	No inertial force		
	"b"	$F_{W,X} = M_P a_{X1}$	$F_{W,X} = M_S a_{X1} + 1,2 A_{SX}$	in x direction
		$F_{W,Z} = M_P a_{Z1}$	$F_{W,Z} = M_S a_{Z1}$	in z direction
Inclined condition (negative roll angle)	"c"	$F_{W,Y} = M_P a_{Y2} C_{FA}$	$F_{W,Y} = M_S a_{Y2} C_{FA} + 1,2 A_{SY}$	in y direction
	"d"	$F_{W,Z} = M_P a_{Z2} C_{FA}$	$F_{W,Z} = M_S a_{Z2} C_{FA}$	in z direction

(1) For each ship condition and load case, the forces at the centre of gravity of the helicopter and at the centre of gravity of the platform are to be applied simultaneously.

(2) The checks are to consider the range of possible helicopter positions. The positions are to be taken so as to produce the most severe response within the structural elements.

(3) The vertical position of the helicopter centre of gravity relative to the platform deck is to be determined on the basis of data from the helicopter manufacturer, to be provided by the Designer.

(4) The structural mass M_S is to be distributed appropriately in the model and subjected to the accelerations determined at the centre of gravity of the platform.

Note 1:

A_S : Area, in m^2, of the platform deck

M_S : Structural mass of the helicopter platform, in t, to be taken not less than the value obtained from the following formula: $M_S = 0,2\ A_S$

a_{X1} , a_{Z1} : Accelerations, in m/s^2, determined at the centre of gravity of the platform or helicopter, as appropriate, for the upright ship condition, and defined in Ch 5, Sec 3, [3.4]

a_{Y2} , a_{Z2} : Accelerations, in m/s^2, determined at the centre of gravity of the platform or helicopter, as appropriate, for the inclined ship condition, and defined in Ch 5, Sec 3, [3.4]

A_{SX} , A_{SY} : Projected areas, in m^2, of the helicopter platform in x and y directions respectively. If not otherwise specified, A_{SX} and A_{SY} may be taken equal to $A_S / 3$

C_{FA} : Combination factor, to be taken equal to:

- $C_{FA} = 0,7$ for load case "c"
- $C_{FA} = 1,0$ for load case "d"

4.6 Load patch dimensions

4.6.1 General

The dimensions of load patches, when taken into account, are to be determined on the basis of landing gear tyre prints or skid prints, as appropriate, for each landing and parking load.

Landing gear tyre prints and skid prints are to be modelled as rectangular in shape, with dimensions as follows:

A : Dimension, in m, parallel to the helicopter's longitudinal axis

B : Dimension, in m, perpendicular to the helicopter's longitudinal axis

Dimensions A and B are to be used to define load patches for application in the scantling formulas in Article [5] as follows:

- For helicopter landing, load patch dimensions A′ and B′ which take into account the landing orientation, for the checking of plating and stiffeners, are to be determined as per Tab 3.
- For helicopter parking, load patch surface area $A_T = A' \times B'$ for the checking of plating, is to be determined considering load patch dimensions A′ and B′ defined in Tab 4.

The dimensions A and B of a single tyre print or skid print, or the data necessary to calculate these dimensions, for all loads to be assessed, are to be obtained from the helicopter manufacturer and provided to the Society by the Designer.

4.6.2 Wheeled landing gear

The data defining the tyre prints is to describe the relationship between print dimensions and applied load. The dimensions taken into account for any particular load are not to exceed those corresponding to the tyre bottoming load specified by the helicopter manufacturer.

For landing gear having dual wheels, the calculation of tyre print dimensions is to consider that the landing gear loads are distributed uniformly across both wheels.

4.6.3 Landing skids

The skid print dimensions are not to vary with the applied load or type of load.

In the case of a helicopter with two parallel skids, it is to be assumed that load transfer to the deck occurs along partial lengths of skid beneath each of the skids' attachments to the helicopter fuselage. In this case, the longer dimension of the print is not to exceed 0,2 m.

For consideration of landing loads, the single skid print that is most heavily loaded during landing is to be considered.

Particular cases will be considered by the Society on the basis of supporting information provided by the Designer.

Table 3 : Design load and load patch characteristics for landing of helicopters

Landing gear type	Helicopter landing orientation	Patch dimension		Load	
		A′	B′	P_T	P_0
Single wheel landing gear	Aligned perpendicular to stiffener	B	A	F_L	F_L
	Aligned parallel to stiffener	A	B	F_L	F_L
Dual wheel landing gear	Aligned perpendicular to stiffener	B + c	A	0,5 F_L	F_L
	Aligned parallel to stiffener	A	B	0,5 F_L	0,5 F_L
Landing skids	Aligned perpendicular to stiffener	B	A	–	F_L
	Aligned parallel to stiffener	A	B	–	F_L

Note 1:

A, B : Dimensions, in m, of the tyre print or skid print as defined in [4.6.1]

A′, B′ : Dimensions, in m, of the load patch where A′ is parallel to the stiffener and B′ is perpendicular to the stiffener

c : Centre-to-centre distance, in m, between wheels on an axle

F_L : Landing load, in kN, to be taken as follows
- $F_L = F_{NL}$ as defined in [4.2.1] for normal landing
- $F_L = F_{EL}$ as defined in [4.2.2] for emergency landing

P_0 : Design load, in kN, to be considered for normal and emergency landing in [5.1.1] and [5.2.1] for plating and stiffeners respectively

P_T : Load, in kN, used to determine the tyre print or skid print dimensions, A and B

Table 4 : Load patch characteristics for parking loads of helicopters

Landing gear type	Patch dimension		Load
	A′	B′	P_T
Single wheel landing gear	A	B	P_0
Dual wheel landing gear	A	B + c	0,5 P_0
Landing skids	A	B	P_0

Note 1:

A, B : Dimensions, in m, of the tyre print or skid print as defined in [4.6.1]

c : Centre-to-centre distance, in m, between wheels on an axle

P_0 : Design load, in kN, calculated as per [5.1.2]

P_T : Load, in kN, used to determine the tyre print or skid print dimensions, A and B

5 Scantlings

5.1 Plating

5.1.1 Load model – landing zone

The following loads are to be considered independently in the landing zone:

- P_0 as defined for normal landing according to Tab 3
- P_0 as defined for emergency landing according to Tab 3
- sea pressure obtained as per [4.4].

Each load P_0 is considered as acting over a load patch having corresponding dimensions A′ and B′ as defined in [4.6] and Tab 3 for each case.

5.1.2 Load model – handling zone

The following loads are to be considered independently in handling zones:

- $P_0 = \gamma_{s2} F_s + \gamma_{w2} F_{w,z}$
  where F_s and $F_{w,z}$ are the forces corresponding to the parking loads, as defined in [4.3] and γ_{s2} and γ_{w2} are to be taken as per Tab 1.
- sea pressure obtained as per [4.4].

The load P_0 is considered as acting over a load patch having area A_T = A′ x B′ as defined in [4.6].

5.1.3 Plating subjected to landing loads

The net thickness of plating subjected to landing loads is to be not less than the value obtained, in mm, from the following formula:

$$t = \alpha_{WP}\beta_P\sqrt{\frac{P_0}{\lambda R_Y}}$$

where:

α_{WP} : Dual wheel landing gear factor, to be taken as follows:
- α_{WP} = 1,0 for single wheel landing gear or landing skids
- taken as per Tab 5 for dual wheel landing gear

β_P : Coefficient to be taken from Tab 6

P_0 : Design load, in kN, defined in [5.1.1]

R_Y : Minimum yield stress, in N/mm^2, to be taken as follows:
- $R_Y = 235/k$ for normal landing
- $R_Y = R_{eH}$ for emergency landing

λ : Coefficient to be taken as follows, with σ_{X1} as per Ch 7, Sec 1, [3.2.6] and considering Note 1:
- for longitudinally framed plating of helicopter decks:
  $\lambda = \lambda_L$ as defined in Ch 7, Sec 1, [3.3.1]
- for transversely framed plating of helicopter decks:
  $\lambda = \lambda_T$ as defined in Ch 7, Sec 1, [3.4.1]
- for helicopter platform decks:
  λ = 1,0

Note 1: For evaluation of emergency landing, the contribution from the wave bending moment is to be excluded. As such, the hull girder stress, σ_{X1} , considered for emergency landing is to be calculated with C_{FV} and C_{FH} taken equal to 0.

Table 5 : Coefficient α_{WP} for dual wheel landing gear

		B′ / s				
		0,1	0,2	0,3	0,4	0,5
c / s	0,10	1,408	–	–	–	–
	0,15	1,301	–	–	–	–
	0,20	1,229	1,339	–	–	–
	0,25	1,175	1,261	–	–	–
	0,30	1,135	1,201	1,272	–	–
	0,35	1,099	1,152	1,207	1,266	–
	0,40	1,069	1,111	1,155	1,196	–
	0,45	1,044	1,078	1,110	1,142	1,173
	0,50	1,024	1,046	1,071	1,095	1,118
	0,55	1,004	1,021	1,039	1,053	1,068
	0,60	0,985	0,998	1,009	1,018	1,027
	0,65	0,973	0,979	0,983	0,985	0,987
	0,70	0,956	0,956	0,956	0,956	0,956
	0,75	0,945	0,941	0,934	0,930	0,924
	0,80	0,936	0,926	0,919	0,910	0,894

Note 1: Intermediate values may be obtained by linear interpolation
B′ : Load patch dimension for landing, in m, to be taken as per Tab 3
c : the centre-to-centre distance, in m, between wheels on an axle
s : stiffener spacing, in m

Table 6 : Coefficient β_p

		A′ / s										
		0,0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0
B′ / s	0,0	19,74	19,19	18,68	18,20	17,75	17,34	17,04	16,66	16,24	15,79	15,34
	0,1	19,14	18,60	18,10	17,63	17,20	16,79	16,50	16,13	15,72	15,28	14,84
	0,2	18,54	18,01	17,52	17,07	16,64	16,24	15,95	15,60	15,19	14,77	14,33
	0,3	17,93	17,42	16,94	16,49	16,08	15,69	15,41	15,06	14,67	14,25	13,83
	0,4	17,32	16,82	16,35	15,92	15,51	15,13	14,86	14,52	14,14	13,73	13,32
	0,5	16,70	16,21	15,76	15,33	14,94	14,57	14,31	13,98	13,61	13,21	12,81
	0,6	16,07	15,60	15,16	14,75	14,37	14,01	13,75	13,43	13,07	12,69	12,31
	0,7	15,43	14,98	14,55	14,16	13,79	13,44	13,19	12,89	12,54	12,17	11,80
	0,8	14,79	14,35	13,94	13,56	13,20	12,87	12,63	12,33	12,00	11,64	11,28
	0,9	14,13	13,71	13,31	12,95	12,61	12,29	12,06	11,78	11,45	11,11	10,77
	1,0	13,46	13,06	12,68	12,33	12,01	11,70	11,49	11,21	10,91	10,58	10,25

Note 1: Intermediate values may be obtained by linear interpolation
A′, B′ : Load patch dimensions for landing, in m, to be taken as per Tab 3
s : Stiffener spacing, in m

5.1.4 Plating subjected to parking loads

The net thickness of plating subjected to parking loads is to be not less than the values obtained according to Ch 7, Sec 1, [4.3], considering:

- P_0 as per [5.1.2]
- Load patch surface area A_T defined as per [4.6.1]
- λ equal to 1,0 in the particular case of a helicopter platform.

5.1.5 Plating subjected to sea pressure

The net thickness of plating subjected to sea pressure is to be not less than the values obtained according to Ch 7, Sec 1, [3].

5.2 Ordinary stiffeners

5.2.1 Load model – landing zone

The following loads are to be considered independently in the landing zone:

- P_0 as defined for normal landing according to Tab 3
- P_0 as defined for emergency landing according to Tab 3
- sea pressure as defined in [4.4].

Each load P_0 is considered as acting over a load patch having corresponding dimensions A′ and B′ as defined in [4.6] and Tab 3 for each case. Helicopter landing orientations parallel and perpendicular to the stiffeners are to be independently assessed.

5.2.2 Load model – handling zone

The following load is to be considered in handling zones:

- $P_0 = \gamma_{s2} F_s + \gamma_{w2} F_{w,z}$

  where F_s and $F_{w,z}$ are the forces corresponding to the parking loads, as defined in [4.3] and γ_{s2} and γ_{w2} are to be taken as per Tab 1.

In unprotected areas, sea pressure obtained as per [4.4] is to be considered simultaneously with the load defined above.

5.2.3 Net section modulus and net shear sectional area of ordinary stiffeners subjected to landing loads

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of longitudinal or transverse ordinary stiffeners subjected to normal and emergency landing loads are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \frac{\alpha_{WS} \beta_M C_{WPD} C_S P_0 \ell}{5{,}85\ (R_Y - \gamma_R \gamma_m \sigma_{X1,WH})} 10^3$$

$$A_{Sh} = 20 \gamma_R \gamma_m \frac{\alpha_{WS} \beta_V C_{WPD} C_S P_0}{R_Y}$$

where:

α_{WS} : Dual wheel landing gear factor, to be taken as follows:
- $\alpha_{WS} = 1{,}0$ for single wheel landing gear or landing skids
- taken as per Tab 7 for dual wheel landing gear

β_M : Moment coefficient, to be calculated according to the following formula:

$$\beta_M = 1 - 0{,}732 \frac{A'}{\ell} + 0{,}155 \left(\frac{A'}{\ell}\right)^2$$

β_V : Shear coefficient, to be calculated according to the following formula:

$$\beta_V = 1 - 0{,}732 \left(\frac{A'}{\ell}\right)^2 + 0{,}299 \left(\frac{A'}{\ell}\right)^3$$

γ_m , γ_R : Partial safety factors to be taken as per Tab 1

ℓ : Span length, in m, of the stiffener

$\sigma_{X1,WH}$: Hull girder normal stress, in N/mm^2, to be determined as follows:
- for longitudinal stiffeners contributing to the hull girder longitudinal strength and subjected to wheeled loads:
  - Normal landing: calculated according to Ch 7, Sec 2, [3.3.7]
  - Emergency landing: calculated according to Ch 7, Sec 2, [3.3.7] except that C_{FV}, C_{FH} and $C_{F\Omega}$ are to be taken equal to 0
- for other cases including stiffeners of helicopter platform decks:

  $\sigma_{X1,WH} = 0$

C_{WPD} : Patch width distribution factor, to be calculated according to the following formula:

$$C_{WPD} = 1 - 0{,}183 \left(\frac{B'}{s}\right)^2 + 0{,}0374 \left(\frac{B'}{s}\right)^3 \qquad \text{for } \frac{B'}{s} \leq 2$$

C_S : Plating load distribution factor, to be calculated as follows:
- $C_S = 1$ in cases where the stiffener spans are of unequal length
- $C_S = 1 + \eta\zeta$ in other cases

  where:

$$\eta = \frac{t_0^3}{455 l_w s^3} \left(\frac{\ell}{\pi}\right)^4$$

$$\zeta = \frac{2}{v_1 v_2} \left(v_1 - 7 - \frac{v_1^2 - 6v_1 + v_1 v_2 + v_2 + 1}{1 + v_1 + v_2}\right)$$

$$v_1 = \sqrt{\frac{1+48\eta}{3}}$$

$$v_2 = \sqrt{\frac{4}{3}+2v_1}$$

I_w : net moment of inertia of a stiffener, with attached plating having an effective width s_e, about its neutral axis parallel to the plating, in cm^4

s : stiffener spacing, in m

s_e : effective width of attached plating, in m, as follows:

$$s_e = Min(s, 0{,}363\ell, \sqrt{E/R_{eH}}10^3)$$

t_0 : rounded net thickness of plating, in mm, as defined in Ch 1, Sec 1, [3.1.1]

P_0 : Design load, in kN, defined in [5.2.1]

R_Y : Minimum yield stress, in N/mm^2, as follows:

- $R_Y = 235/k$ for normal landing
- $R_Y = R_{eH}$ for emergency landing

Table 7 : Coefficient α_{ws}

c/s	0,0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	0,974
α_{WS}	2,000	1,935	1,831	1,723	1,618	1,510	1,406	1,298	1,190	1,083	1,000
Note 1: Intermediate values may be obtained by linear interpolation											

5.2.4 Normal and shear stresses in stiffeners subjected to parking loads

Normal and shear stresses induced by parking loads in an ordinary stiffener are to be obtained according to Ch 7, Sec 2, [3.5].

The hull girder stresses are to be taken into account for assessment of longitudinal stiffeners contributing to the hull girder longitudinal strength.

In unprotected areas, the normal and shear stresses induced by sea pressures are to be obtained according to Ch 7, Sec 2, [3.4.2], with $\sigma_{X1} = 0$, and added to the corresponding stresses induced by the parking loads as calculated above.

5.2.5 Checking criteria

It is to be checked that the normal stress σ and the shear stress τ calculated according to [5.2.4] fulfil the following conditions:

$$\sigma \le \frac{R_Y}{\gamma_R \gamma_m}$$

$$\tau \le 0{,}5\frac{R_Y}{\gamma_R \gamma_m}$$

where γ_m and γ_R are to be taken as per Tab 1.

5.3 Primary supporting members

5.3.1 Load model – landing zone

The following loads are to be considered independently in the landing zone:

- $P_0 = F_{NL}$

  where F_{NL} is the force corresponding to the normal landing load, as defined in [4.2.1]

- $P_0 = F_{EL}$

  where F_{EL} is the force corresponding to the emergency landing load, as defined in [4.2.2]

- sea pressure obtained as per [4.4].

The load P_0 is to be considered as a concentrated load.

The point of application of the design loads is to be taken so as to produce the most severe response within the structure. Multiple load cases may therefore need to be considered.

5.3.2 Load model – handling zone

The following loads are to be considered in handling zones:

- $P_0 = \gamma_{s2} F_s + \gamma_{w2} F_{w,z}$

  where F_s and $F_{w,z}$ are the forces corresponding to the parking loads for each landing gear considered, as defined in [4.3] and γ_{s2} and γ_{w2} are to be taken as per Tab 1.

The load P_0 is to be considered as a concentrated load.

The most unfavourable cases are to be considered, i.e. where the maximum number of landing gear with the largest loads are located on the same primary supporting members, taking into account the distribution of concentrated loads transmitted via the landing gear.

In unprotected areas, sea pressure obtained as per [4.4] is to be considered simultaneously with the loads defined above.

5.3.3 Load model – specific considerations for helicopter platforms

The ship hull structures are to be assessed for the reaction loads at the attachment points due to the specific loads acting on helicopter platforms, defined in [4.5].

The helicopter platform supporting structure is to be assessed taking into account the specific loads acting on helicopter platforms, defined in [4.5].

The loads F_s and F_w defined in [4.5] are to be considered simultaneously and multiplied by γ_{s2} and γ_{w2} respectively, where γ_{s2} and γ_{w2} are to be taken as per Tab 1.

5.3.4 Normal and shear stresses

Normal and shear stresses induced by loads and pressures in primary supporting members are to be obtained according to Ch 7, App 2, [5], considering:

- for analyses based on finite element models:

  $\sigma = \sigma_{VM}$

  where σ_{VM} is the Von Mises equivalent stress calculated according to Ch 7, App 2, [5.2.1]
- for analyses based on beam models:

  $\sigma = \sigma_1$ and $\tau = \tau_{12}$

The stresses calculated are to include the contribution of hull girder loads. For evaluation of emergency landing, the contribution from the wave bending moment is to be excluded.

5.3.5 Checking criteria

It is to be checked that the normal stress σ and the shear stress τ calculated according to [5.3.4] fulfil the following conditions:

$$\sigma \leq \frac{R_y}{\gamma_R \gamma_m}$$

$$\tau \leq 0,5 \frac{R_y}{\gamma_R \gamma_m}$$

where:

γ_m , γ_R : Partial safety factors to be taken as per Tab 1

R_Y : $R_Y = 235/k$ except in the case of emergency landing loads where $R_Y = R_{eH}$ may be considered.

6 Lashing

6.1 General

6.1.1 Where lashing pots are fitted, the strength of the structure in way of the lashing pots is to be assessed according to this Article.

6.1.2 The strength checks are to consider cases that are representative of the arrangement of all lashing pots. Where calculation results are not satisfactory for particular lashing pots, the fitting of additional stiffening may be required.

6.2 Documentation to be submitted

6.2.1 The following documentation is to be submitted to the Society for information:

- lashing arrangement showing clearly the lashing forces transmitted to the hull structures and pre-tensioning forces, if any
- Safe Working Load (SWL) and Breaking Load (BL) of the fixed and portable lashing devices
- details of welding between fixed lashing devices and deck structure.

In the absence of other information, the lashing force transmitted through one single lashing device may be taken equal to 50 kN acting at 45° with respect to the deck plane, in the most severe direction.

6.3 Design Load

6.3.1 The design load to be considered for the structural assessment of the deck structure in way of lashing devices is to be taken equal to 1,1 SWL.

6.4 Checking criteria

6.4.1 It is to be checked that the normal stress σ and the shear stress τ in way of all structure elements supporting lashing forces fulfil the following conditions:

$$\sigma \leq \frac{R_y}{\gamma_R \gamma_m}$$

$$\tau \leq 0,5 \frac{R_y}{\gamma_R \gamma_m}$$

where:

γ_m : Partial safety factor covering uncertainties on the material, to be taken equal to 1,02

γ_R : Partial safety factor covering uncertainties on the resistance, to be taken as specified in Ch 7, Sec 3.

6.4.2 Additional checks may be requested by the Society, depending upon the arrangement of lashing pots and their integration in the structure.

7 Recovery assist devices

7.1 Documentation to be submitted

7.1.1 The following documentation is to be submitted to the Society for information:

- General arrangement showing the maximum reaction loads induced by the recovery device on the deck structure
- Drawing of the integration of the system within the ship structure, including scantling and welding details.

7.2 Checking criteria

7.2.1 It is to be checked that the normal stress σ and the shear stress τ in way of all structure elements subjected to loads induced by the recovery assist device fulfil the following conditions:

$$\sigma \leq \frac{R_y}{\gamma_R \gamma_m}$$

$$\tau \leq 0,5 \frac{R_y}{\gamma_R \gamma_m}$$

where:

γ_m : Partial safety factor covering uncertainties on the material, to be taken equal to 1,02

γ_R : Partial safety factor covering uncertainties on the resistance, to be taken as specified in Ch 7, Sec 3.

CHAPTER 9
HULL OUTFITTING

Section 1 Rudders

Section 2 Bulwarks and Guard Rails

Section 3 Propeller Shaft Brackets

Section 4 Equipment

Section 5 Masts and Other Outfitting Components

Appendix 1 Criteria for Direct Calculation of Rudder Loads

Section 1 Rudders

Symbols

V_{AV} : Maximum ahead speed, in knots, with the ship on full load waterline; if V_{AV} is less than 10 knots, the maximum service speed is to be taken not less than the value obtained from the following formula:

$$V_{MIN} = \frac{V_{AV} + 20}{3}$$

V_{AD} : Maximum astern speed, in knots, to be taken not less than minimum value between 0,5 V_{AV} and the astern speed corresponding to the maximum permissible astern power (MPAP) as defined in Pt C, Ch 1, Sec 1, [2.7.1].

A : Total area of the rudder blade, in m^2, bounded by the blade external contour, including the mainpiece and the part forward of the centreline of the rudder pintles, if any

k_1 : Material factor, defined in [1.4.1]

k : Material factor, defined in Ch 4, Sec 1, [2.3] (see also [1.4.5])

C_R : Rudder force, in N, acting on the rudder blade, defined in [2.1.2] and [2.2.2]

M_{TR} : Rudder torque, in N.m, acting on the rudder blade, defined in [2.1.3] and [2.2.3]

M_B : Bending moment, in N.m, in the rudder stock, defined in [4.1].

1 General

1.1 Application

1.1.1 Ordinary profile rudders

The requirements of this Section apply to ordinary profile rudders, without any special arrangement for increasing the rudder force, whose maximum orientation at maximum ship speed is limited to 35° on each side.

In general, an orientation greater than 35° is accepted for manoeuvres or navigation at very low speed.

When the maximum orientation at maximum speed is limited to angle smaller than 35° by physical or software devices, the Society may accept reductions, on a case-by-case basis.

1.1.2 High lift profiles

The requirements of this Section also apply to rudders fitted with flaps to increase rudder efficiency. For these rudder types, an orientation at maximum speed less than 35° may be accepted. In these cases, the rudder forces are to be calculated by the Designer for the most severe combinations between orientation angle and ship speed. These calculations are to be considered by the Society on a case-by-case basis.

The rudder scantlings are to be designed so as to be able to sustain possible failures of the orientation control system, or, alternatively, redundancy of the system itself may be required.

1.1.3 Steering nozzles

The requirements for steering nozzles are given in Article [10].

1.1.4 Special rudder types

Rudders others than those in [1.1.1], [1.1.2] and [1.1.3] will be considered by the Society on a case-by-case basis.

1.1.5 Materials

The requirements of the present section apply to rudders made of steel. Rudders made of other materials are to be considered on a case-by-case basis.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangements

1.3.1 Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure, e.g. by means of a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

1.3.2 Suitable arrangements are to be provided to prevent the rudder from lifting.

In addition, structural rudder stops of suitable strength are to be provided, except where the steering gear is provided with its own rudder stopping devices, as detailed in Pt C, Ch 1, Sec 12.

1.3.3 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided.

1.4 Materials

1.4.1 Rudder stocks, pintles, coupling bolts, keys and cast parts of rudders are to be made of rolled steel, steel forgings or steel castings according to the applicable requirements in NR216 Materials and Welding, Chapter 2.

1.4.2 The material used for rudder stocks, pintles, keys and bolts is to have a minimum yield stress not less than 200 N/mm^2.

1.4.3 The requirements relevant to the determination of scantlings contained in this Section apply to steels having a minimum yield stress equal to 235 N/mm^2.

Where the material used for rudder stocks, pintles, coupling bolts, keys and cast parts of rudders has a yield stress different from 235 N/mm^2, the scantlings calculated with the formulae contained in the requirements of this Section are to be modified, as indicated, depending on the material factor k_1, to be obtained from the following formula:

$$k_1 = \left(\frac{235}{R_{eH}}\right)^n$$

where:

R_{eH} : Yield stress, in N/mm^2, of the steel used, and not exceeding the lower of 0,7 R_m and 450 N/mm^2

R_m : Minimum ultimate tensile strength, in N/mm^2 of the steel used,

n : Coefficient to be taken equal to:

- for $R_{eH} > 235$ N/mm^2:

  n = 0,75
- for $R_{eH} \leq 235$ N/mm^2:

  n = 1,00

1.4.4 Significant reductions in rudder stock diameter due to the application of steels with yield stresses greater than 235 N/mm^2 may be accepted by the Society subject to the results of a check calculation of the rudder stock deformations.

Large rudder stock deformations are to be avoided in order to avoid excessive edge pressures in way of bearings.

1.4.5 Welded parts of rudders are to be made of approved rolled hull materials. For these members, the material factor k defined in Ch 4, Sec 1, [2.3] is to be used.

2 Force and torque acting on the rudder

2.1 Rudder blade without cut-outs

2.1.1 Rudder blade description

A rudder blade without cut-outs may have trapezoidal or rectangular contour.

2.1.2 Rudder force

The rudder force C_R is to be obtained, in N, from the following formula:

$$C_R = 132\, n_R\, A\, V^2\, r_1\, r_2\, r_3$$

where:

n_R : Navigation coefficient, defined in Tab 1

V : V_{AV} or V_{AD}, depending on the condition under consideration (for high lift profiles, see [1.1.2])

r_1 : Shape factor, to be taken equal to:

$$r_1 = \frac{\lambda + 2}{3}$$

λ : Coefficient, to be taken equal to:

$$\lambda = \frac{h^2}{A_T}$$

and not greater than 2,0

h : Mean height, in m, of the rudder area to be taken equal to (see Fig 1):

$$h = \frac{z_3 + z_4 - z_2}{2}$$

A_T : Area, in m^2, to be calculated by adding the rudder blade area A to the area of the rudder post or rudder horn, if any, up to the height h

r_2 : Coefficient to be obtained from Tab 2. For other profiles than those defined in Tab 2, the value of r_2 is defined by the Society on a case-by-case basis

r_3 : Coefficient to be taken equal to:

- for rudders outside the propeller jet (centre rudders on twin screw ships, or similar cases):
  $r_3 = 0,8$
- for rudders behind a fixed propeller nozzle:
  $r_3 = 1,15$
- in other cases:
  $r_3 = 1,0$

Figure 1 : Geometry of rudder blade without cut-outs

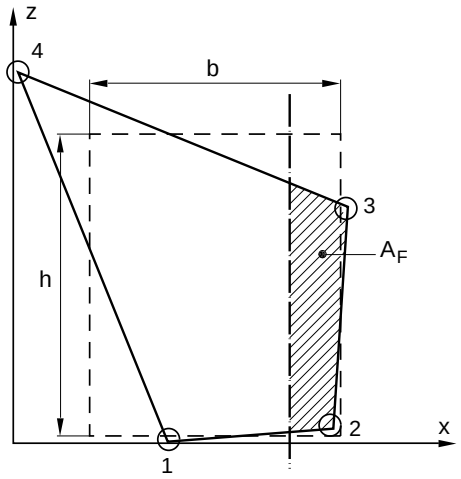
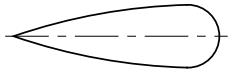
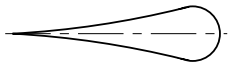
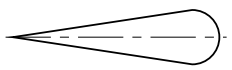
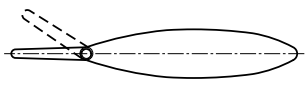
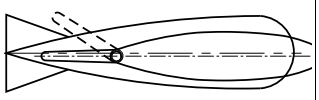
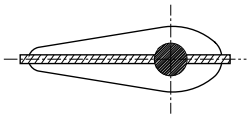


Table 1 : Navigation coefficient n_R

Navigation notation	Navigation coefficient n_R
unrestricted navigation	1,00
coastal area	0,85
sheltered area	0,75

Table 2 : Values of coefficient r_2

Rudder profile type	r_2 for ahead condition	r_2 for astern condition
NACA 00 - Goettingen 	1,10	0,80
Hollow 	1,35	0,90
Flat side 	1,10	0,90

Rudder profile type	r_2 for ahead condition	r_2 for astern condition
High lift 	1,70	1,30
Fish tail 	1,40	0,80
Single plate 	1,00	1,00

2.1.3 Rudder torque

The rudder torque M_{TR}, for both ahead and astern conditions, is to be obtained, in N.m, from the following formula:

$M_{TR} = C_R\, r$

where:

r : Lever of force C_R, in m, equal to:

$$r = b\left(\alpha - \frac{A_F}{A}\right)$$

and to be taken not less than 0,1 b for the ahead condition

b : Mean breadth, in m, of rudder area to be taken equal to (see Fig 1):

$$b = \frac{x_2 + x_3 - x_1}{2}$$

α : Coefficient to be taken equal to:

- $\alpha = 0{,}33$ for ahead condition
- $\alpha = 0{,}66$ for astern condition

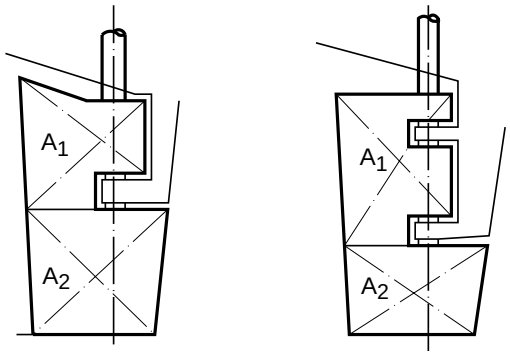
A_F : Area, in m^2, of the rudder blade portion afore the centreline of rudder stock (see Fig 1).

2.2 Rudder blade with cut-outs (semi-spade rudders)

2.2.1 Rudder blade description

A rudder blade with cut-outs may have trapezoidal or rectangular contour, as indicated in Fig 2.

Figure 2 : Rudder blades with cut-outs



Trapezoidal rudder blade
Semi-spade rudder with
rudder horn - 2 bearings

Trapezoidal rudder blade
Semi-spade rudder with
rudder horn - 3 bearings

2.2.2 Rudder force

The rudder force C_R, in N, acting on the blade is to be calculated in accordance with [2.1.2].

2.2.3 Rudder torque

The rudder torque M_{TR}, in N·m, is to be calculated in accordance with the following procedure.

The rudder blade area A is to be divided into two rectangular or trapezoidal parts having areas A_1 and A_2, defined in Fig 2, so that:

$A = A_1 + A_2$

The rudder forces C_{R1} and C_{R2}, acting on each part A_1 and A_2 of the rudder blade, respectively, are to be obtained, in N, from the following formulae:

$$C_{R1} = C_R \frac{A_1}{A}$$

$$C_{R2} = C_R \frac{A_2}{A}$$

The levers r_1 and r_2 of the forces C_{R1} and C_{R2}, respectively, are to be obtained, in m, from the following formulae:

$$r_1 = b_1\left(\alpha - \frac{A_{1F}}{A_1}\right)$$

$$r_2 = b_2\left(\alpha - \frac{A_{2F}}{A_2}\right)$$

where:

b_1, b_2 : Mean breadths of the rudder blade parts having areas A_1 and A_2, respectively, to be determined according to [2.1.3]

A_{1F} , A_{2F} : Areas, in m^2, of the rudder blade parts, defined in Fig 3

α : Coefficient to be taken equal to:

- $\alpha = 0,33$ for ahead condition
- $\alpha = 0,66$ for astern condition

For rudder parts located behind a fixed structure such as a rudder horn, α is to be taken equal to:

- $\alpha = 0,25$ for ahead condition
- $\alpha = 0,55$ for astern condition.

The torques M_{TR1} and M_{TR2} , relevant to the rudder blade parts A_1 and A_2 respectively, are to be obtained, in N.m, from the following formulae:

$$M_{TR1} = C_{R1}\, r_1$$

$$M_{TR2} = C_{R2}\, r_2$$

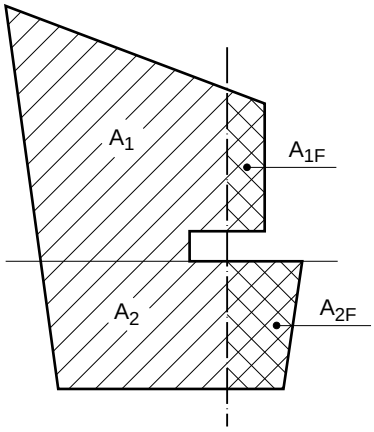
The total torque M_{TR} acting on the rudder stock, for both ahead and astern conditions, is to be obtained, in N.m, from the following formula:

$$M_{TR} = M_{TR1} + M_{TR2}$$

For the ahead condition only, M_{TR} is to be taken not less than the value obtained, in N.m, from the following formula:

$$M_{TR,MIN} = 0,1 C_R \frac{A_1 b_1 + A_2 b_2}{A}$$

Figure 3 : Geometry of rudder blade with cut-outs



3 Loads acting on the rudder structure

3.1 General

3.1.1 Loads

The force and torque acting on the rudder, defined in Article [2], induce in the rudder structure the following loads:

- bending moment and torque in the rudder stock
- support forces
- bending moment, shear force and torque in the rudder body
- bending moment, shear force and torque in rudder horns and solepieces.

3.1.2 Direct load calculations

The bending moment in the rudder stock, the support forces, and the bending moment and shear force in the rudder body are to be determined through direct calculations to be performed in accordance to the static schemes and the load conditions specified in Ch 9, App 1.

For rudders with solepiece or rudder horns these structures are to be included in the calculation model in order to account for the elastic support of the rudder body.

The other loads (i.e. the torque in the rudder stock and in the rudder body and the loads in rudder horns and sole-pieces) are to be calculated as indicated in the relevant requirements of this Section.

3.1.3 Simplified methods for load calculation

For ordinary rudder types, the bending moment in the rudder stock, the support forces, and the bending moment and shear force in the rudder body may be determined through approximate methods specified in the relevant requirements of this Section.

The other loads (i.e. the torque in the rudder stock and in the rudder body and the loads in rudder horns and sole-pieces) are to be calculated as indicated in the relevant requirements of this Section.

4 Rudder stock scantlings

4.1 Bending moment

4.1.1 General

The bending moment M_B in the rudder stock is to be obtained as follows:

- for spade rudders, 2 bearing rudders with solepiece and 2 bearing semi-spade rudders with rudder horn:

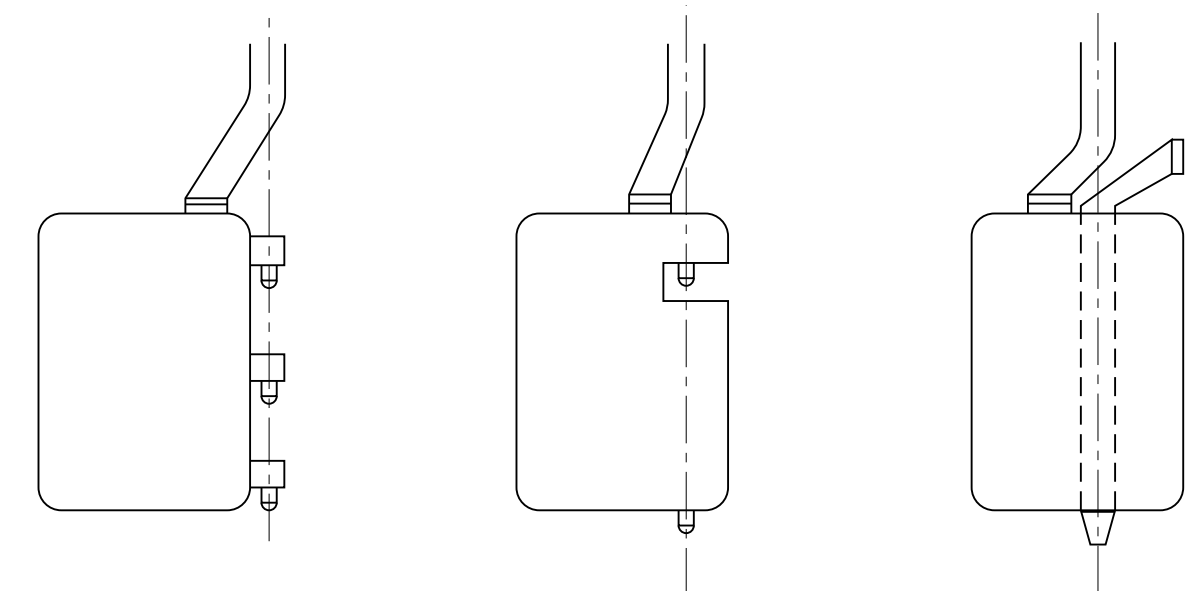
  M_B is to be calculated according to:

  - [4.1.2] through a direct calculation, or
  - [4.1.3] through a simplified method

- for 3 bearing semi-spade rudders with rudder horn and for the rudder types shown in Fig 4:

  M_B may be taken equal to zero.

Figure 4 : Rudder types



Hinged rudder with three bearings | Hinged rudder with three bearings | Simplex-type rudder

4.1.2 Bending moment calculated through a direct calculation

For spade rudders, 2 bearing rudders with solepiece and 2 bearing semi-spade rudders with rudder horn, where a direct calculation according to the static schemes and the load conditions specified in Ch 9, App 1 is carried out, the bending moment in the rudder stock is to be obtained as specified in Ch 9, App 1.

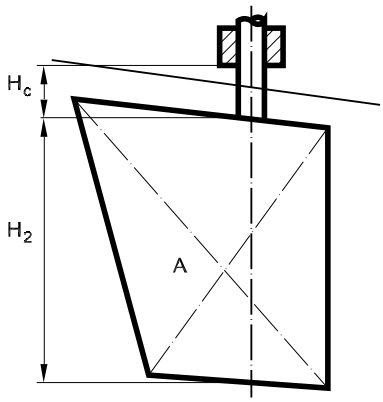
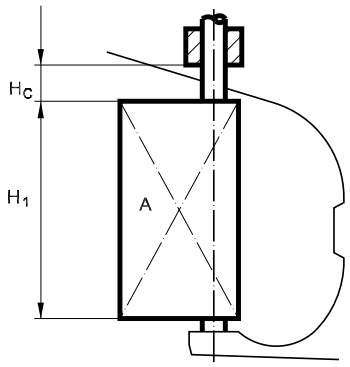
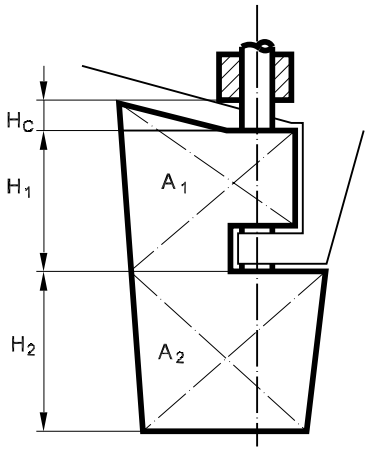
4.1.3 Bending moment calculated through a simplified method

For spade rudders, 2 bearing rudders with solepiece and 2 bearing semi-spade rudders with rudder horn, where a direct calculation according to the static schemes and the load conditions specified in Ch 9, App 1 is not carried out, the bending moment M_B in the rudder stock is to be obtained, in N.m, from the following formula:

$$M_B = 0{,}866\frac{HC_R}{A}$$

where H is defined, in m^3, in Tab 3.

Table 3 : Factor H, in m³

Spade rudders	2 bearing rudders with solepiece	2 bearing semi-spade rudders with rudder horn
		
$H = A\left(H_C + \frac{H_2}{2}\right)$	$H = A\ a_1\ u\ H_1$	H = 0,83 B **(1)**

(1) B is the greater of the absolute values obtained from the following formulae:

- $B = A_1\ u\ H_1 + A_2\ (v\ H_1 + w\ H_2)$
- $B = A_1\ a_2\ H_1 - A_2\ (a_3\ H_1 + 0,5\ H_2)$

where a_1, a_2, a_3, u, v and w are defined in Tab 4.

Table 4 : Coefficients for calculating the bending moment in the rudder stock

Coefficient	Value
a_1	$2,55 - 1,75\ c$
a_2	$1,75\ c^2 - 3,9\ c + 2,35$
a_3	$2,65\ c^2 - 5,9\ c + 3,25$
u	$1,10\ c^2 - 2,05\ c + 1,175$
v	$1,15\ c^2 - 1,85\ c + 1,025$
w	$-3,05\ c^4 + 8,14\ c^3 - 8,15\ c^2 + 3,81\ c - 0,735$

Note 1:

$c = \frac{H_1}{H_1 + H_C}$

H_1, H_C : As defined in Tab 3, as applicable.

4.2 Scantlings

4.2.1 Rudder stock subjected to torque only

For rudder stocks subjected to torque only (3 bearing semi-spade rudders with rudder horn in Fig 2 and the rudder types shown in Fig 4), it is to be checked that the torsional shear stress τ, in N/mm², induced by the torque M_{TR} is in compliance with the following formula:

$\tau \leq \tau_{ALL}$

where:

τ_{ALL} : Allowable torsional shear stress, in N/mm²: $\tau_{ALL} = 68 / k_1$

For this purpose, the rudder stock diameter is to be not less than the value obtained, in mm, from the following formula:

$d_T = 4,2\ (M_{TR}\ k_1)^{1/3}$

4.2.2 Rudder stock subjected to combined torque and bending

For rudder stocks subjected to combined torque and bending (spade rudders, 2 bearing rudders with solepiece and 2 bearing semi-spade rudders with rudder horn in Tab 3), it is to be checked that the equivalent stress σ_E induced by the bending moment M_B and the torque M_{TR} is in compliance with the following formula:

$\sigma_E \leq \sigma_{E,ALL}$

where:

σ_E : Equivalent stress to be obtained, in N/mm^2, from the following formula:

$$\sigma_E = \sqrt{\sigma_B^2 + 3\tau_T^2}$$

σ_B : Bending stress to be obtained, in N/mm^2, from the following formula:

$$\sigma_B = 10^3 \frac{10,2 M_B}{d_{TF}^3}$$

τ_T : Torsional stress to be obtained, in N/mm^2, from the following formula:

$$\tau_T = 10^3 \frac{5,1 M_{TR}}{d_{TF}^3}$$

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm^2, equal to:

$\sigma_{E,ALL} = 118/k_1$ N/mm^2

For this purpose, the rudder stock diameter is to be not less than the value obtained, in mm, from the following formula:

$$d_{TF} = 4,2 (M_{TR} k_1)^{1/3} \left[1 + \frac{4}{3}\left(\frac{M_B}{M_{TR}}\right)^2\right]^{1/6}$$

In general, the diameter of a rudder stock subjected to torque and bending may be gradually tapered above the lower stock bearing so as to reach, from the diameter d_{TF}, the value of d_T in way of the quadrant or the tiller.

5 Rudder stock couplings

5.1 General

5.1.1 Cone coupling fitting

The following checks apply to cone couplings at the connection of rudder stocks to tillers or rudder blades, in addition to applicable requirements in [5.3] and [5.4] respectively.

Before final fit up, the initial fit is to be checked to ascertain that the actual surface contact:

- is evenly distributed across the bearing surfaces
- is at least 80% of the theoretical bearing area.

Note 1: The reference position from which the push-up length is to be measured is to correspond to a relative positioning of the two parts which satisfies the initial fitting criteria specified above.

Following final fit up, checking of the push-up length is to be conducted after releasing the hydraulic pressure applied in the hydraulic nut and in the assembly.

5.1.2 Entrance edges

The entrance edge of the tiller bore, of the rudder stock housing and that of the rudder stock cone are to be rounded or bevelled.

5.2 Horizontal flange couplings

5.2.1 General

In general, the coupling flange and the rudder stock are to be forged from a solid piece. A shoulder radius as large as practicable is to be provided for between the rudder stock and the coupling flange. This radius is to be not less than 0,13 d_1, where d_1 is the greater of the rudder stock diameters d_T and d_{TF}, in mm, to be calculated in compliance with the requirements in [4.2.1] and [4.2.2], respectively.

Where the rudder stock diameter does not exceed 350 mm, the coupling flange may be welded onto the stock provided that its thickness is increased by 10%, and that the weld extends through the full thickness of the coupling flange and that the assembly obtained is subjected to heat treatment. This heat treatment is not required if the diameter of the rudder stock is less than 75 mm.

Where the coupling flange is welded, the grade of the steel used is to be of weldable quality, particularly with a carbon content not greater than 0,25% and the welding conditions (preparation before welding, choice of electrodes, pre and post heating, inspection after welding) are to be defined to the satisfaction of the Society. The throat weld at the top of the flange is to be concave shaped to give a fillet shoulder radius as large as practicable. This radius is to be not less than 0,13 d_1, where d_1 is defined above.

5.2.2 Bolts

Horizontal flange couplings are to be connected by fitted bolts having a diameter not less than the value obtained, in mm, from the following formula:

$$d_B = 0,62 \sqrt{\frac{d_1^3 k_{1B}}{n_B e_M k_{1S}}}$$

where:

d_1 : Rudder stock diameter, in mm, defined in [5.2.1]

k_{1S} : Material factor k_1 for the steel used for the rudder stock

k_{1B} : Material factor k_1 for the steel used for the bolts

e_M : Mean distance, in mm, from the bolt axes to the longitudinal axis through the coupling centre (i.e. the centre of the bolt system)

n_B : Total number of bolts, which is to be not less than 6.

Non-fitted bolts may be used provided that, in way of the mating plane of the coupling flanges, a key is fitted having a section of $(0,25d_T \times 0,10d_T)$ mm^2 and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.

The distance from the bolt axes to the external edge of the coupling flange is to be not less than $1,2\ d_B$.

5.2.3 Coupling flange

The thickness of the coupling flange is to be not less than the value obtained, in mm, from the following formula:

$$t_P = d_B \sqrt{\frac{k_{1F}}{k_{1B}}}$$

where:

d_B : Bolt diameter, in mm, calculated in accordance with [5.2.2], where the number of bolts n_B is to be taken not greater than 8

k_{1F} : Material factor k_1 for the steel used for the flange

k_{1B} : Material factor k_1 for the steel used for the bolts.

In any case, the thickness t_P is to be not less than $0,9\ d_B$.

5.2.4 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

5.3 Couplings between rudder stocks and tillers

5.3.1 Application

The requirements of this sub-Article apply in addition to those specified in Pt C, Ch 1, Sec 12.

The requirements specified in [5.3.2] and [5.3.3] apply to solid rudder stocks in steel and to tiller bosses, either in steel or in SG iron, with constant external diameter. Solid rudder stocks others than those above will be considered by the Society on a case-by-case basis, provided that the relevant calculations, to be based on the following criteria, are submitted to the Society:

- Young's modulus:
  - $E = 2,06.10^5$ N/mm^2 for steel
  - $E = 1,67.10^5$ N/mm^2 for SG iron
- Poisson's ratio:
  - $\nu = 0,30$ for steel
  - $\nu = 0,28$ for SG iron
- frictional coefficient:
  - $\mu = 0,15$ for contact steel/steel
  - $\mu = 0,13$ for contact steel/SG iron
- torque C_T transmissible through friction:

  $C_T \geq \eta\ M_{TR}$

  where η is defined in [5.3.2]
- combined stress in the boss:

  $$\sqrt{\sigma_R^2 + \sigma_T^2 - \sigma_R\sigma_T} \leq (0,5\ + 0,2\ \eta)R_{eH}$$

  where σ_R and σ_T are, in N/mm^2, the radial compression stress and tangent tensile stress, respectively, induced by the grip pressure, considered as positive, and calculated at the bore surface ($\sigma_R = p_F$, where p_F is the grip pressure in the considered horizontal cross-section of the boss)
- where the rudder stock is hollow, the following strength criterion is to be complied with at any point of the rudder stock cross-section:

  $$\sqrt{\sigma_R^2 + \sigma_T^2 - \sigma_R\sigma_T + 3\tau^2} \leq 0,7\ R_{eH}$$

  where:

  σ_R, σ_T : Radial and tangent compressive stress, respectively, in N/mm^2, induced by the grip pressure, considered as positive

  τ : Shear stress, in N/mm^2, induced by the torque M_{TR}.

5.3.2 Push up length of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push up length Δ_E of the rudder stock tapered part into the tiller boss is in compliance with the following formula:

$\Delta_0 \leq \Delta_E \leq \Delta_1$

where:

$$\Delta_0 = 6,2 \frac{M_{TR} \eta \gamma}{c d_M t_S \mu_A \beta} 10^{-3}$$

$$\Delta_1 = \frac{2\eta + 5}{1,8} \cdot \frac{\gamma d_0 R_{eH}}{c} 10^{-6}$$

η : Coefficient to be taken equal to:

- $\eta = 1$ for keyed connections
- $\eta = 2$ for keyless connections

c : Taper of conical coupling measured on diameter, to be obtained from the following formula:

$c = (d_U - d_0) / t_S$

t_S, d_U, d_0 : Geometrical parameters of the coupling, defined in Fig 5

β : Coefficient to be taken equal to:

$$\beta = 1 - \left(\frac{d_M}{d_E}\right)^2$$

d_M : Mean diameter, in mm, of the conical bore, to be obtained from the following formula:

$d_M = d_U - 0,5\, c\, t_S$

d_E : External boss diameter, in mm

μ_A : Coefficient to be taken equal to:

$$\mu_A = \sqrt{\mu^2 - 0,25 c^2}$$

μ, γ : Coefficients to be taken equal to:

- for rudder stocks and bosses made of steel:
  $\mu = 0,15$
  $\gamma = 1,00$
- for rudder stocks made of steel and bosses made of SG iron:
  $\mu = 0,13$
  $\gamma = 1,24 - 0,1\, \beta$

R_{eH} : Defined in [1.4.3].

5.3.3 Boss of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

The scantlings of the boss are to comply with the following formula:

$$\frac{1,8}{2\eta + 5} \frac{\Delta_E c}{\gamma d_0} 10^6 \leq R_{eH}$$

where:

Δ_E : Push-up length adopted, in mm

c, η, γ : Defined in [5.3.2]

d_0 : Defined in Fig 5

R_{eH} : Defined in [1.4.3].

5.3.4 Cylindrical couplings by shrink fit

It is to be checked that the diametral shrinkage allowance δ_E is in compliance with the following formula:

$\delta_0 \leq \delta_E \leq \delta_1$

where:

$$\delta_0 = 6,2 \frac{M_{TR} \eta \gamma}{d_U t_S \mu \beta_1}$$

$$\delta_1 = \frac{2\eta + 5}{1,8} \gamma d_U R_{eH} 10^{-6}$$

η, μ, γ, c: Defined in [5.3.2]

d_U : Defined in Fig 5

β_1 : Coefficient to be taken equal to:

$$\beta_1 = 1 - \left(\frac{d_U}{d_E}\right)^2$$

R_{eH} : Defined in [1.4.3].

5.3.5 Keyless couplings through special devices

The use of special devices for frictional connections, such as expansible rings, may be accepted by the Society on a case-by-case basis provided that the following conditions are complied with:

- evidence that the device is efficient (theoretical calculations and results of experimental tests, references of behaviour during service, etc.) are to be submitted to the Society
- the torque transmissible by friction is to be not less than 2 M_{TR}
- design conditions [5.3.1]
- instructions provided by the manufacturer are to be complied with, notably concerning the pre-stressing of the tightening screws.

5.4 Cone couplings between rudder stocks and rudder blades

5.4.1 Taper on diameter

The taper on diameter of the cone couplings is to be in compliance with the following formulae:

- for cone couplings without hydraulic arrangements for assembling and disassembling the coupling:

$$\frac{1}{12} \leq \frac{d_U - d_0}{t_S} \leq \frac{1}{8}$$

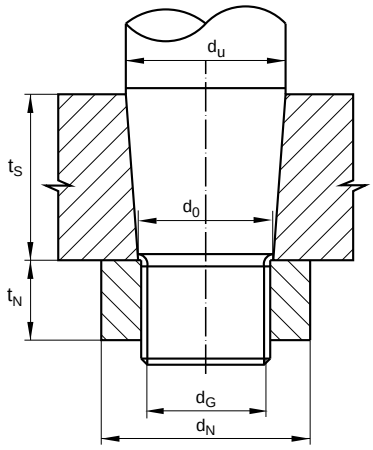
- for cone couplings with hydraulic arrangements for assembling and disassembling the coupling (assembling with oil injection and hydraulic nut):

$$\frac{1}{20} \leq \frac{d_U - d_0}{t_S} \leq \frac{1}{12}$$

where:

d_U, t_S, d_0: Geometrical parameters of the coupling, defined in Fig 5.

Figure 5 : Geometry of cone coupling



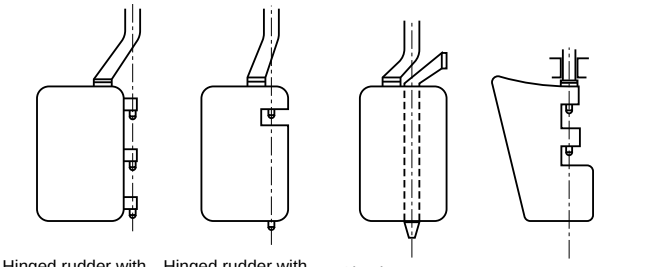
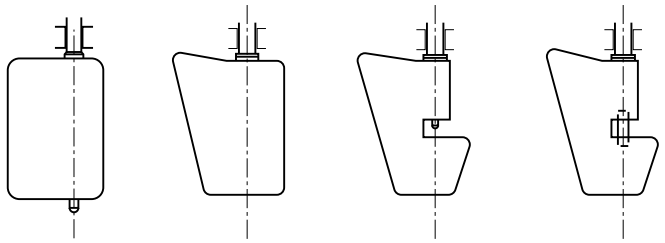
5.4.2 Push up length of cone coupling with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push up length Δ_E of the rudder stock tapered part into the boss is in compliance with the following formula:

$$\Delta_0 \leq \Delta_E \leq \Delta_1$$

where Δ_0 and Δ_1 are to be obtained from the formulae in Tab 5.

Table 5 : Push up length values

Rudder type	Δ_0	Δ_1
 Hinged rudder with three bearings; Hinged rudder with two bearings; Simplex - type; 3 bearings semi-spade rudders with rudder horn	$6,2\frac{M_{TR}\eta\gamma}{cd_M t_S \mu_A \beta}$	$\frac{2\eta+5}{1,8}\frac{\gamma d_0 R_{eH}}{10^6 c}$
 Spade rudder; Simple pintle; Inserted pintle	the greater of: • $6,2\frac{M_{TR}\eta\gamma}{cd_M t_S \mu_A \beta}$ • $16\frac{M_{TR}\eta\gamma}{ct_S^2\beta}\sqrt{\frac{d_{1L}^6 - d_{1S}^6}{d_{1S}^6}}$	$\frac{2\eta+5}{1,8}\frac{\gamma d_0 R_{eH}}{10^6 c(1+\rho_1)}$
High lift profile and special rudder types	the greater of: • $6,2\frac{M_{TR}\eta\gamma}{cd_M t_S \mu_A \beta}$ • $16\frac{M_{TR}\eta\gamma}{ct_S^2\beta}\sqrt{\frac{d_{1L}^6 - d_{1S}^6}{d_{1S}^6}}$ • $6,2\frac{M_T\eta\gamma}{cd_M t_S \mu_A \beta}$ • $18,4\frac{M_F\eta\gamma}{ct_S^2\beta}$	the greater of: • $\frac{2\eta+5}{1,8}\frac{\gamma d_0 R_{eH}}{10^6 c(1+\rho_1)}$ • $\frac{2\eta+5}{1,8}\frac{\gamma d_0 R_{eH}}{10^6 c(1+\rho_2)}$

Note 1:

$$\rho_1 = \frac{80\sqrt{d_{1L}^6 - d_{1S}^6}}{R_{eH} d_M t_S^2 \left[1 - \left(\frac{d_0}{d_E}\right)^2\right]}$$

$$\rho_2 = \frac{7,4 M_F \cdot 10^6}{R_{eH} d_M t_S^2 \left[1 - \left(\frac{d_0}{d_E}\right)^2\right]}$$

R_{eH} : Defined in [1.4.3]

M_F, M_T : Bending moment and torsional moment, respectively, in kN.m, provided by the manufacturer

d_{1L} : The greater of the rudder stock diameters d_T and d_{TF}, in mm, calculated in way of the lower part of the rudder stock (between the top of the rudder plate and the lower bearing of the rudder stock) in compliance with the requirements in [4.2.1] and [4.2.2], respectively, considering $k_1 = 1$

d_{1S} : The greater of the rudder stock diameters d_T and d_{TF}, in mm, calculated in way of the upper part of the rudder stock (at tiller level) in compliance with the requirements in [4.2.1] and [4.2.2], respectively, considering $k_1 = 1$

η, c, β, d_M, d_E, μ_A, μ, γ : Defined in [5.3.2]

t_S, d_U, d_0 : Defined in Fig 5.

5.4.3 Slogging nut

The coupling is to be secured by a slugging nut, whose dimensions are to be in accordance with the following formulae:

$t_S \geq 1,5\ d_1$

$d_G \geq 0,65\ d_1$

$t_N \geq 0,60\ d_G$

$d_N \geq 1,2\ d_0$ and, in any case, $d_N \geq 1,5\ d_G$

where:

t_S, d_G, t_N, d_N, d_1, d_0: Geometrical parameters of the coupling, defined in Fig 5.

The above minimum dimensions of the locking nut are only given for guidance, the determination of adequate scantlings being left to the Designer.

5.4.4 Washer

For cone couplings with hydraulic arrangements for assembling and disassembling the coupling, a washer is to be fitted between the nut and the rudder gudgeon, having a thickness not less than $0,13\ d_G$ and an outer diameter not less than $0,13\ d_0$ or $1,6\ d_G$, whichever is the greater.

5.4.5 Key

For cone couplings without hydraulic arrangements for assembling and disassembling the coupling, a key is to be fitted having a section of $(0,25\ d_T \times 0,10\ d_T)$ mm^2 and keyways in both the tapered part and the rudder gudgeon.

The key is to be machined and located on the fore or aft part of the rudder. The key is to be inserted at half-thickness into stock and into the solid part of the rudder.

For cone couplings with hydraulic arrangements for assembling and disassembling the coupling, the key may be omitted. In this case the designer is to submit to the Society shrinkage calculations supplying all data necessary for the relevant check.

5.4.6 Instructions

All necessary instructions for hydraulic assembly and disassembly of the nut, including indication of the values of all relevant parameters, are to be available on board.

5.5 Vertical flange couplings

5.5.1 Vertical flange couplings are to be connected by fitted bolts having a diameter not less than the value obtained, in mm, from the following formula:

$$d_B = \frac{0,81\,d_1}{\sqrt{n_B}}\sqrt{\frac{k_{1B}}{k_{1S}}}$$

where:

d_1 : Rudder stock diameter, in mm, defined in [5.2.1]

k_{1S}, k_{1B} : Material factors, defined in [5.2.2]

n_B : Total number of bolts, which is to be not less than 8.

5.5.2 The first moment of area of the sectional area of bolts about the vertical axis through the centre of the coupling is to be not less than the value obtained, in cm^3, from the following formula:

$M_S = 0,43\ d_1^3 \cdot 10^{-6}$

where:

d_1 : Rudder stock diameter, in mm, defined in [5.2.1].

5.5.3 The thickness of the coupling flange, in mm, is to be not less than d_B, defined in [5.5.1].

5.5.4 The distance, in mm, from the bolt axes to the external edge of the coupling flange is to be not less than $1,2\ d_B$, where d_B is defined in [5.5.1].

5.5.5 A suitable locking device is to be provided to prevent the accidental loosening of nuts.

5.6 Couplings by continuous rudder stock welded to the rudder blade

5.6.1 When the rudder stock extends through the upper plate of the rudder blade and is welded to it, the thickness of this plate in the vicinity of the rudder stock is to be not less than $0,20\ d_1$, where d_1 is defined in [5.2.1].

5.6.2 The welding of the upper plate of the rudder blade with the rudder stock is to be made with a full penetration weld and is to be subjected to non-destructive inspection through dye penetrant or magnetic particle test and ultrasonic testing.

The throat weld at the top of the rudder upper plate is to be concave shaped to give a fillet shoulder radius as large as practicable. This radius is to be not less than $0,20\ d_1$, where d_1 is defined in [5.2.1].

5.7 Skeg connected with rudder trunk

5.7.1 In case of a rudder trunk connected with the bottom of a skeg, the throat weld is to be concave shaped to give a fillet shoulder radius as large as practicable. This radius is considered by the Society on a case-by-case basis.

6 Rudder stock and pintle bearings

6.1 Forces on rudder stock and pintle bearings

6.1.1 Where a direct calculation according to the static schemes and the load conditions specified in Ch 9, App 1 is carried out, the support forces are to be obtained as specified in Ch 9, App 1.

Where such a direct calculation is not carried out, the support forces F_{A1} and F_{A2} acting on the rudder stock bearing and on the pintle bearing, respectively, are to be obtained, in N, from the following formulae:

$$F_{A1} = \left(\frac{A_{G1}}{A} + 0,87\frac{h_0}{H_0}\right)C_R$$

$$F_{A2} = \frac{A_{G2}}{A}C_R$$

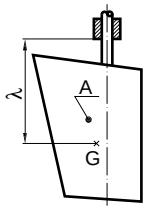
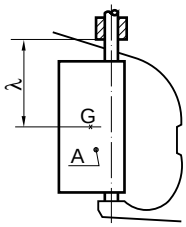
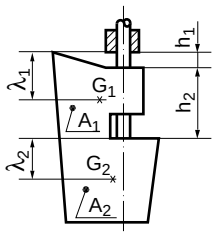
where:

A_{G1} , A_{G2} : Portions of the rudder blade area A, in m^2, supported by the rudder stock bearing and by the pintle bearing respectively, to be not less than the value obtained from Tab 6

h_0 : Coefficient defined in Tab 6

H_0 : Distance, in m, between the points at mid-height of the upper and lower rudder stock bearings.

Table 6 : Areas A_{G1} , A_{G2} and h_0

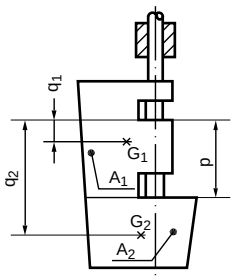
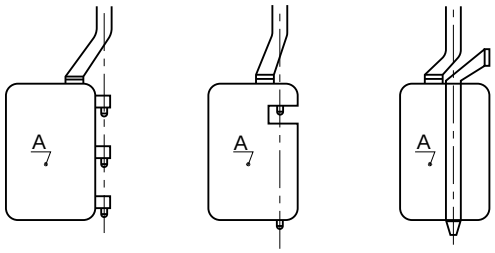
Rudder type	A_{G1} , in m^2	A_{G2} , in m^2	h_0 , in m
spade rudders 	A	0	1,15 λ
2 bearing rudders with solepiece 	Rudder blade area above a horizontal line equally spaced from the upper and the lower edges	Rudder blade area below a horizontal line equally spaced from the upper and the lower edges	0,30 λ
2 bearing semi-spade rudders with rudder horn 	$\frac{A_1\lambda_1 h_2^2}{(h_1 + h_2)^3}$	the greater of: • $\frac{\lambda A}{h_1 + h_2}$ • A	the greater of: • $0,19\frac{A_1\lambda_1}{A}$ • $\left\lvert 0,3\frac{A_1\lambda_1 - 2A_2\lambda_2}{A}\right\rvert$

Note 1:

G, G_1 , G_2 : Centres of gravity of area A, A_1 and A_2 respectively

$$\lambda = \frac{(\lambda_2 + h_2 + h_1)A_2 + \lambda_1 A_1}{A}$$

n : Number of pintles.

Rudder type	A_{G1}, in m^2	A_{G2}, in m^2	h_0, in m
3 bearing semi-spade rudders with rudder horn 	0	• Lower pintle: $\frac{A_1q_1 + A_2q_2}{p}$ • Upper pintle: the greater of: $A_1 + A_2 - \frac{A_1q_1 + A_2q_2}{p}$; $0,5\frac{A_1q_1 + A_2q_2}{p}$	0
Hinged rudders and Simplex type rudders 	0	$\frac{A}{n}$	0

Note 1:

G, G_1, G_2: Centres of gravity of area A, A_1 and A_2 respectively

$$\lambda = \frac{(\lambda_2 + h_2 + h_1)A_2 + \lambda_1 A_1}{A}$$

n : Number of pintles.

6.2 Rudder stock bearing

6.2.1 The mean bearing pressure acting on the rudder stock bearing is to be in compliance with the following formula:

$p_F \leq p_{F,ALL}$

where:

p_F : Mean bearing pressure acting on the rudder stock bearings, in N/mm^2, equal to:

$$p_F = \frac{F_{A1}}{d_m h_m}$$

F_{A1} : Force acting on the rudder stock bearing, in N, calculated as specified in [6.1.1]

d_m : Actual inner diameter, in mm, of the rudder stock bearings

h_m : Bearing length, in mm. For the purpose of this calculation, h_m is to be taken not greater than:

- 1,2 d_m for spade rudders
- d_m for rudder of other types

$p_{F,ALL}$: Allowable bearing pressure, in N/mm^2, defined in Tab 7.

Values greater than those given in Tab 7 may be accepted by the Society on the basis of specific tests.

6.2.2 An adequate lubrication of the bearing surface is to be ensured.

6.3 Pintle bearings

6.3.1 The mean bearing pressure acting on the gudgeons is to be in compliance with the following formula:

$p_F \leq p_{F,ALL}$

where:

p_F : Mean bearing pressure acting on the gudgeons, in N/mm^2, equal to:

$$p_F = \frac{F_{A2}}{d_A h_L}$$

F_{A2} : Force acting on the pintle, in N, calculated as specified in [6.1.1]

d_A : Actual diameter, in mm, of the rudder pintles

h_L : Bearing length, in mm (see [6.3.3])

$p_{F,ALL}$: Allowable bearing pressure, in N/mm², defined in Tab 7.

Values greater than those given in Tab 7 may be accepted by the Society on the basis of specific tests.

6.3.2 An adequate lubrication of the bearing surface is to be ensured.

6.3.3 The bearing length h_L, in mm, is to be not less than d_A, where d_A is defined in [6.4.1]. For the purpose of the calculation in [6.3.1], the bearing length is to be taken not greater than 1,2 d_A.

6.3.4 The manufacturing tolerance t_0 on the diameter of metallic supports is to be not less than the value obtained, in mm, from the following formula:

$$t_0 = \frac{d_A}{1000} + 1$$

In the case of non-metallic supports, the tolerances are to be carefully evaluated on the basis of the thermal and distortion properties of the materials employed.

In any case, the tolerance on support diameter is to be not less than 1,5 mm.

Table 7 : Allowable bearing pressure $p_{F,ALL}$

Bearing material	$p_{F,ALL}$, in N/mm²
Lignum vitae	2,5
White metal, oil lubricated	4,5
Synthetic material with hardness between 60 and 70 Shore D**(1)**	5,5
Steel, bronze and hot-pressed bronze-graphite materials**(2)**	7,0
(1) Indentation hardness test at 23°C and with 50% moisture to be performed according to a recognised standard. Type of synthetic bearing materials is to be approved by the Society. **(2)** Stainless and wear-resistant steel in combination with stock liner approved by the Society.	

6.4 Pintles

6.4.1 Rudder pintles are to have a diameter not less than the value obtained, in mm, from the following formula:

$$d_A = \frac{0{,}38 V_{AV}}{V_{AV} + 3} \sqrt{F_{A2} k_1} + f_C$$

where:

F_{A2} : Force, in N, acting on the pintle, calculated as specified in [6.1.1]

f_C : Coefficient depending on corrosion, whose value may generally be obtained from the following formula:

$$f_C = 30 \sqrt{k_1}$$

The Society may accept lower values of f_C, considering the ship dimensions and satisfactory service experience of corrosion control systems adopted.

6.4.2 Provision is to be made for a suitable locking device to prevent the accidental loosening of pintles.

6.4.3 The pintles are to have a conical coupling with a taper on diameter in accordance with [5.4.1].

The conical coupling is to be secured by a nut, whose dimensions are to be in accordance with [5.4.3].

6.4.4 The length of the pintle housing in the gudgeon is to be not less than the value obtained, in mm, from the following formula:

$$h_L = 0{,}35 \sqrt{F_{A2} k_1}$$

where:

F_{A2} : Force, in N, acting on the pintle, calculated as specified in [6.1.1].

The thickness of pintle housing in the gudgeon, in mm, is to be not less than 0,25 d_A, where d_A is defined in [6.4.1].

7 Rudder blade scantlings

7.1 General

7.1.1 Application

The requirements in [7.1] to [7.6] apply to streamlined rudders and, when applicable, to rudder blades of single plate rudders.

7.1.2 Rudder blade structure

The structure of the rudder blade is to be such that stresses are correctly transmitted to the rudder stock and pintles. To this end, horizontal and vertical web plates are to be provided.

Horizontal and vertical webs acting as main bending girders of the rudder blade are to be suitably reinforced.

7.1.3 Access openings

Streamlined rudders, including those filled with pitch, cork or foam, are to be fitted with plug-holes and the necessary devices to allow their mounting and dismounting.

Access openings to the pintles are to be provided. If necessary, the rudder blade plating is to be strengthened in way of these openings.

The corners of openings intended for the passage of the rudder horn heel and for the dismantling of pintle or stock nuts are to be rounded off with a radius as large as practicable.

Where the access to the rudder stock nut is closed with a welded plate, a full penetration weld is to be provided.

7.1.4 Connection of the rudder blade to the trailing edge for rudder blade area greater than 6 m²

Where the rudder blade area is greater than 6 m², the connection of the rudder blade plating to the trailing edge is, in general, to be made by means of a forged or cast steel fashion piece, a flat or a round bar.

Other arrangements proposed by the shipyard may be accepted by the Society, on a case-by-case basis.

7.2 Strength checks

7.2.1 Bending stresses

For the generic horizontal section of the rudder blade, it is to be checked that the bending stress σ, in N/mm², induced by the loads defined in [3.1], is in compliance with the following formula:

$$\sigma \leq \sigma_{ALL}$$

where:

σ_{ALL} : Allowable bending stress, in N/mm², specified in Tab 8.

Table 8 : Allowable stresses for rudder blade scantlings

Type of rudder blade	Allowable bending stress σ_{ALL}, in N/mm²	Allowable shear stress τ_{ALL}, in N/mm²	Allowable equivalent stress $\sigma_{E,ALL}$, in N/mm²
Without cut-outs	110/k	50/k	120/k
With cut-outs (see Fig 2)	75/k	50/k	100/k

7.2.2 Shear stresses

For the generic horizontal section of the rudder blade it is to be checked that the shear stress τ, in N/mm², induced by the loads defined in [3.1], is in compliance with the following formula:

$$\tau \leq \tau_{ALL}$$

where:

τ_{ALL} : Allowable shear stress, in N/mm², specified in Tab 8.

7.2.3 Combined bending and shear stresses

For the generic horizontal section of the rudder blade, it is to be checked that the equivalent stress σ_E is in compliance with the following formula:

$$\sigma_E \leq \sigma_{E,ALL}$$

where:

σ_E : Equivalent stress induced by the loads defined in [3.1], to be obtained, in N/mm², from the following formula:

$$\sigma_E = \sqrt{\sigma^2 + 3\tau^2}$$

Where unusual rudder blade geometries make it practically impossible to adopt ample corner radiuses or generous tapering between the various structural elements, the equivalent stress σ_E is to be obtained by means of direct calculations aiming at assessing the rudder blade areas where the maximum stresses, induced by the loads defined in [3.1], occur

σ : Bending stress, in N/mm²

τ : Shear stress, in N/mm²

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm², specified in Tab 8.

7.3 Rudder blade plating

7.3.1 Plate thickness

The thickness of each rudder blade plate panel is to be not less than the value obtained, in mm, from the following formula:

$$t_F = \left(5{,}5 s\beta\sqrt{T + \frac{C_R 10^{-4}}{A}} + 2{,}5\right)\sqrt{k}$$

where:

β : Coefficient equal to:

$$\beta = \sqrt{1{,}1 - 0{,}5\left(\frac{s}{b_L}\right)^2}$$

to be taken not greater than 1,0 if $b_L/s > 2{,}5$

s : Length, in m, of the shorter side of the plate panel

b_L : Length, in m, of the longer side of the plate panel.

7.3.2 Thickness of the top and bottom plates of the rudder blade

The thickness of the top and bottom plates of the rudder blade is to be not less than the thickness t_F defined in [7.3.1] for the attached side plating.

Where the rudder is connected to the rudder stock with a coupling flange, the thickness of the top plate which is welded in extension of the rudder flange is to be not less than 1,1 times the thickness calculated above.

7.3.3 Web spacing

The spacing between horizontal web plates is to be not greater than 1,20 m.

Vertical webs are to have spacing not greater than twice that of horizontal webs.

7.3.4 Web thickness

Web thickness is to be at least 70% of that required for rudder plating and in no case is it to be less than 8 mm, except for the upper and lower horizontal webs, for which the requirements in [7.3.2] apply.

When the design of the rudder does not incorporate a mainpiece, this is to be replaced by two vertical webs closely spaced, having thickness not less than that obtained from Tab 9. In rudders having area less than 6 m^2, one vertical web only may be accepted provided its thickness is at least twice that of normal webs.

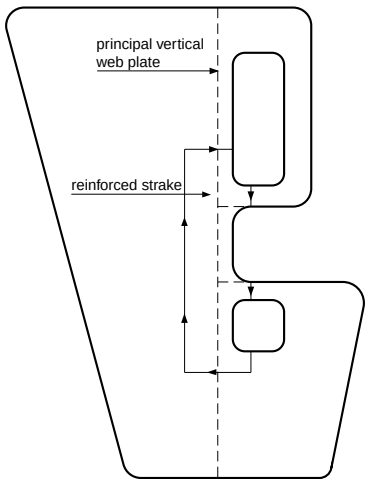
7.3.5 Thickness of side plating and vertical web plates welded to solid part or to rudder flange

The thickness, in mm, of the vertical web plates welded to the solid part where the rudder stock is housed, or welded to the rudder flange, as well as the thickness of the rudder side plating under this solid part, or under the rudder coupling flange, is to be not less than the value obtained, in mm, from Tab 9.

7.3.6 Reinforced strake of semi-spade rudders

A reinforced strake is to be provided in the lower pintle zone of semi-spade rudders. Its thickness is to be not less than 1,6 t_F, where t_F is defined in [7.3.1]. This strake is to be extended forward of the main vertical web plate (see Fig 6).

Figure 6 : Reinforced strake extension for semi-spade rudders



7.3.7 Main vertical webs of semi-spade rudders

The thickness of the main vertical web plate in the area between the rudder blade upper part and the pintle housing of semi-spade rudders is to be not less than 2,6 t_F, where t_F is defined in [7.3.1].

Under the pintle housing, the thickness of this web is to be not less than the value obtained from Tab 9.

Where two main vertical webs are fitted, the thicknesses of these webs are to be not less than the values obtained from Tab 9 depending on whether the web is fitted in a rudder blade area without opening or if the web is along the recess cut in the rudder for the passage of the rudder horn heel.

7.3.8 Welding

The welded connections of blade plating to vertical and horizontal webs are to be in compliance with the applicable requirements of NR216 Materials and Welding.

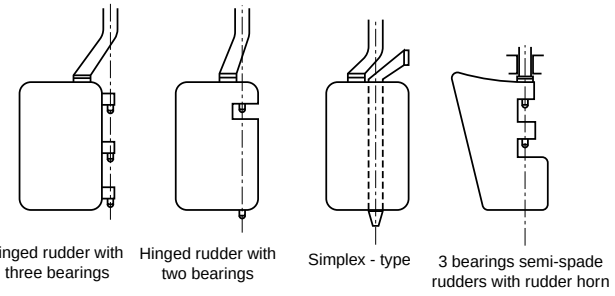
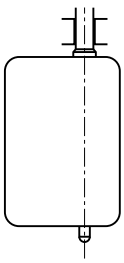
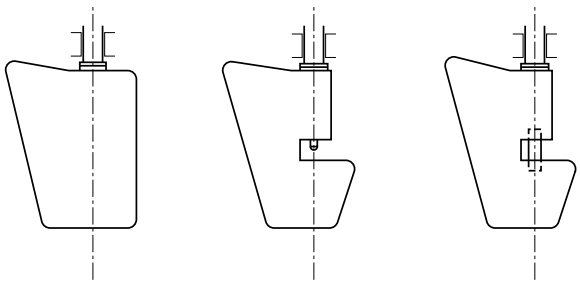
Where the welds of the rudder blade are accessible only from outside of the rudder, slots on a flat bar welded to the webs are to be provided to support the weld root, to be cut on one side of the rudder only.

7.3.9 Rudder nose plate thickness

Rudder nose plates are to have a thickness not less than 1,25 t_F, where t_F is defined in [7.3.1].

In general this thickness need not exceed 22 mm, unless otherwise required in special cases to be considered individually by the Society.

Table 9 : Thickness of the vertical webs and rudder side plating welded to solid part or to rudder flange

Type of rudder	Thickness of vertical web plates, in mm		Thickness of rudder plating, in mm	
	Rudder blade without opening	At opening boundary	Rudder blade without opening	Area with opening
Hinged rudders, Simplex type rudders and semi-spade with three bearings rudders  Hinged rudder with three bearings; Hinged rudder with two bearings; Simplex - type; 3 bearings semi-spade rudders with rudder horn	t_F	1,3 t_F	t_F	1,2 t_F
Rudder without intermediate pintles 	1,2 t_F	1,6 t_F	1,2 t_F	1,4 t_F
Spade and one bearing rudders  Spade rudder; Simple pintle; Inserted pintle	1,4 t_F	2,0 t_F	1,3 t_F	1,6 t_F

Note 1:

t_F : Defined in [7.3.1].

7.4 Connections of rudder blade structure with solid parts in forged or cast steel

7.4.1 General

Solid parts in forged or cast steel which ensure the housing of the rudder stock or of the pintle are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

7.4.2 Minimum section modulus of the connection with the rudder stock housing

The section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed, which is made by vertical web plates and rudder plating, is to be not less than that obtained, in cm^3, from the following formula:

$$w_S = c_S d_1^3 \left(\frac{H_E - H_X}{H_E}\right)^2 \frac{k}{k_1} 10^{-4}$$

where:

c_S : Coefficient, to be taken equal to:

- $c_S = 1,0$ if there is no opening in the rudder plating
- $c_S = 1,5$ if there is an opening in the considered cross-section of the rudder

d_1 : Rudder stock diameter, in mm, defined in [5.2.1]

H_E : Vertical distance, in m, between the lower edge of the rudder blade and the upper edge of the solid part

H_X : Vertical distance, in m, between the considered cross-section and the upper edge of the solid part

k, k_1 : Material factors, defined in [1.4], for the rudder blade plating and the rudder stock, respectively.

7.4.3 Calculation of the actual section modulus of the connection with the rudder stock housing

The actual section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed is to be calculated with respect to the symmetrical axis of the rudder.

The breadth of the rudder plating to be considered for the calculation of this actual section modulus is to be not greater than that obtained, in m, from the following formula:

$$b = s_V + 2\frac{H_X}{m}$$

where:

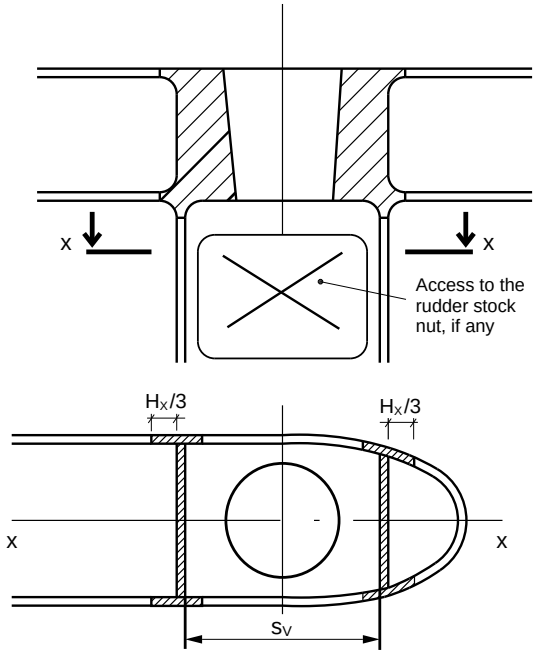
s_V : Spacing, in m, between the two vertical webs (see Fig 7)

H_X : Distance defined in [7.4.2]

m : Coefficient to be taken, in general, equal to 3.

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate according to [7.1.3], they are to be deducted (see Fig 7).

Figure 7 : Cross-section of the connection between rudder blade structure and rudder stock housing



Section x-x

7.4.4 Thickness of horizontal web plates

In the vicinity of the solid parts, the thickness of the horizontal web plates, as well as that of the rudder blade plating between these webs, is to be not less than the greater of the values obtained, in mm, from the following formulae:

$t_H = 1,2\ t_F$

$$t_H = 0,045\frac{d_S^2}{s_H}$$

where:

t_F : Defined in [7.3.1]

d_S : Diameter, in mm, to be taken equal to:

- d_1 for the solid part connected to the rudder stock
- d_A for the solid part connected to the pintle

d_1 : Rudder stock diameter, in mm, defined in [5.2.1]

d_A : Pintle diameter, in mm, defined in [6.4.1]

s_H : Spacing, in mm, between the two horizontal web plates.

Different thickness may be accepted when justified on the basis of direct calculations submitted to the Society for approval.

7.4.5 Thickness of side plating and vertical web plates welded to the solid part

The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained, in mm, from Tab 9.

7.4.6 Solid part protrusions

The solid parts are to be provided with protrusions. Vertical and horizontal web plates of the rudder are to be butt welded to these protrusions.

These protrusions are not required when the web plate thickness is less than:

- 10 mm for web plates welded to the solid part on which the lower pintle of a semi-spade rudder is housed and for vertical web plates welded to the solid part of the rudder stock coupling of spade rudders
- 20 mm for the other web plates.

If no protrusions are provided, vertical and horizontal webs are to be welded by full penetration welds. Particular precautions are to be taken for these welds. The Society may request full Non Destructive Testing to be carried out on the concerned welds, and machining of welds if necessary.

7.5 Connection of the rudder blade with the rudder stock by means of horizontal flanges

7.5.1 Minimum section modulus of the connection

The section modulus of the cross-section of the structure of the rudder blade which is directly connected with the flange, which is made by vertical web plates and rudder blade plating, is to be not less than the value obtained, in cm^3, from the following formula:

$w_S = 1,3\ d_1^3\ 10^{-4}$

where d_1 is the greater of the rudder stock diameters d_T and d_{TF}, in mm, to be calculated in compliance with the requirements in [4.2.1] and [4.2.2], respectively, taken k_1 equal to 1.

7.5.2 Actual section modulus of the connection

The section modulus of the cross-section of the structure of the rudder blade which is directly connected with the flange is to be calculated with respect to the symmetrical axis of the rudder.

For the calculation of this actual section modulus, the length of the rudder cross-section equal to the length of the rudder flange is to be considered.

Where the rudder plating is provided with an opening under the rudder flange, the actual section modulus of the rudder blade is to be calculated in compliance with [7.4.3].

7.5.3 Welding of the rudder blade structure to the rudder blade flange

The welds between the rudder blade structure and the rudder blade flange are to be full penetrated (or of equivalent strength) and are to be 100% inspected by means of non-destructive tests.

Where the full penetration welds of the rudder blade are accessible only from outside of the rudder, a backing flat bar is to be provided to support the weld root.

The external fillet welds between the rudder blade plating and the rudder flange are to be of concave shape and their throat thickness is to be at least equal to 0,5 times the rudder blade thickness.

Moreover, the rudder flange is to be checked before welding by non-destructive inspection for lamination and inclusion detection in order to reduce the risk of lamellar tearing.

7.5.4 Thickness of side plating and vertical web plates welded to the rudder flange

The thickness of the vertical web plates directly welded to the rudder flange as well as the plating thickness of the rudder blade upper strake in the area of the connection with the rudder flange is to be not less than the values obtained, in mm, from Tab 9.

7.6 Single plate rudders

7.6.1 Mainpiece diameter

The mainpiece diameter is to be obtained from the formulae in [4.2].

In any case, the mainpiece diameter is to be not less than the stock diameter.

For spade rudders the lower third may taper down to 0,75 times the stock diameter.

7.6.2 Blade thickness

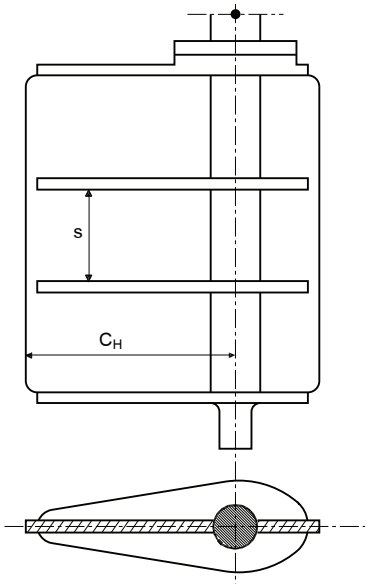
The blade thickness is to be not less than the value obtained, in mm, from the following formula:

$$t_B = (1,5 s V_{AV} + 2,5)\sqrt{k}$$

where:

s : Spacing of stiffening arms, in m, to be taken not greater than 1 m (see Fig 8).

Figure 8 : Single plate rudder



7.6.3 Arms

The thickness of the arms is to be not less than the blade thickness.

The section modulus of the generic section is to be not less than the value obtained, in cm^3, from the following formula:

$$Z_A = 0,5\ s\ C_H^2\ V_{AV}^2\ k$$

where (see Fig 8):

C_H : Horizontal distance, in m, from the aft edge of the rudder to the centreline of the rudder stock

s : Defined in [7.6.2].

8 Rudder horn and solepiece scantlings

8.1 General

8.1.1 The weight of the rudder is normally supported by a carrier bearing inside the rudder trunk.

In the case of unbalanced rudders having more than one pintle, the weight of the rudder may be supported by a suitable disc fitted in the solepiece gudgeon.

Robust and effective structural rudder stops are to be fitted, except where adequate positive stopping arrangements are provided in the steering gear, in compliance with the applicable requirements of Pt C, Ch 1, Sec 12.

8.2 Rudder horn

8.2.1 General

When the connection between the rudder horn and the hull structure is designed as a curved transition into the hull plating, special consideration is to be paid to the effectiveness of the rudder horn plate in bending and to the stresses in the transverse web plates.

8.2.2 Loads

The following loads acting on the generic section of the rudder horn are to be considered:

- bending moment
- shear force
- torque.

The requirements in [8.2.3], [8.2.4] and [8.2.5] apply for calculating the above loads in the case of 2 bearing semi-spade rudders.

In the case of 3 bearing semi-spade rudders, these loads are to be calculated on the basis of the support forces at the lower and upper pintles, obtained according to [6.1].

8.2.3 Bending moment

For 2 bearing semi-spade rudders, the bending moment acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formula:

$M_H = F_{A1}\, z$

where:

F_{A1} : Support force, in N, to be determined through a direct calculation to be performed in accordance with the static schemes and the load conditions specified in Ch 9, App 1. As an alternative, it may to be obtained from the following formula:

$$F_{A1} = C_R \frac{b}{\ell_{20} + \ell_{30}}$$

b, ℓ_{20}, ℓ_{30} : Distances, in m, defined in Fig 9

z : Distance, in m, defined in Fig 10, in any case to be taken less than the distance d, in m, defined in the same figure.

Figure 9 : Geometrical parameters for the calculation of the bending moment in rudder horn

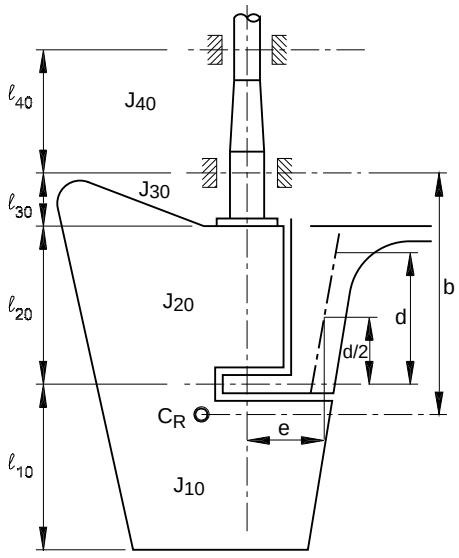
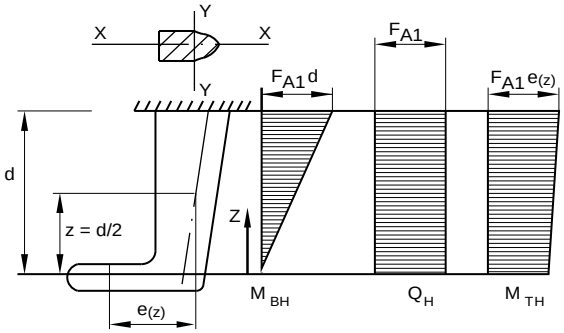


Figure 10 : Rudder horn geometry



8.2.4 Shear force

The shear force Q_H acting on the generic section of the rudder horn is to be obtained, in N, from the following formula:

$Q_H = F_{A1}$

where:

F_{A1} : Force, in N, defined in [8.2.3].

8.2.5 Torque

The torque acting on the generic section of the rudder horn is to be obtained, in N.m, from the following formula:

$M_T = F_{A1}\, e$

where:

F_{A1} : Force, in N, defined in [8.2.3]

e : Distance, in m, defined in Fig 10.

8.2.6 Shear stress check

For the generic section of the rudder horn it is to be checked that:

$\tau_S + \tau_T \leq \tau_{ALL}$

where:

τ_S : Shear stress to be obtained, in N/mm^2, from the following formula:

$$\tau_S = \frac{F_{A1}}{A_H}$$

F_{A1} : Force, in N, defined in [8.2.3]

A_H : Shear sectional area of the rudder horn in Y direction, in mm^2

τ_T : Torsional stress to be obtained for hollow rudder horn, in N/mm^2, from the following formula:

$$\tau_T = \frac{M_T 10^3}{2 A_T t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case-by-case basis

M_T : Torque, in N·m, defined in [8.2.5]

A_T : Area of the horizontal section enclosed by the rudder horn, in mm^2

t_H : Plate thickness of rudder horn, in mm

τ_{ALL} : Allowable torsional shear stress, in N/mm^2:

$\tau_{ALL} = 48 / k_1$

8.2.7 Combined stress strength check

For the generic section of the rudder horn within the length d, defined in Fig 10, it is to be checked that:

$\sigma_E \leq \sigma_{E,ALL}$

$\sigma_B \leq \sigma_{B,ALL}$

where:

σ_E : Equivalent stress to be obtained, in N/mm^2, from the following formula:

$$\sigma_E = \sqrt{\sigma_B^2 + 3(\tau_S^2 + \tau_T^2)}$$

Where unusual rudder horn geometries make it practically impossible to adopt ample corner radiuses or generous tapering between the various structural elements, the equivalent stress s_E is to be obtained by means of direct calculations aiming at assessing the rudder horn areas where the maximum stresses, induced by the loads defined in [3.1], occur

σ_B : Bending stress to be obtained, in N/mm^2, from the following formula:

$$\sigma_B = \frac{M_H}{W_X}$$

M_H : Bending moment at the section considered, in N·m, defined in [8.2.3]

W_X : Section modulus, in cm^3, around the horizontal axis X (see Fig 10)

τ_S , τ_T : Shear and torsional stresses, in N/mm^2, defined in [8.2.6]

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm^2, equal to:

$\sigma_{E,ALL} = 120/k_1$

$\sigma_{B,ALL}$: Allowable bending stress, in N/mm^2, equal to:

$\sigma_{B,ALL} = 67/k_1$.

8.3 Solepieces

8.3.1 Bending moment

The bending moment acting on the generic section of the solepiece is to be obtained, in N·m, from the following formula:

$M_S = F_{A1}\ x$

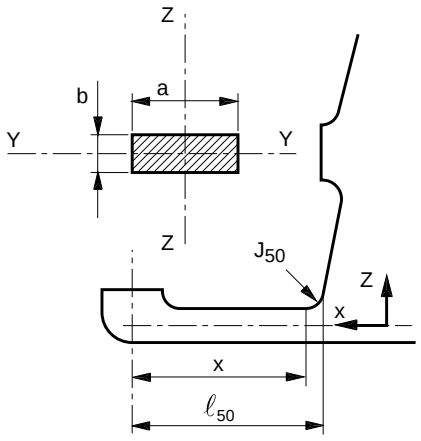
where:

F_{A1} : Supporting force, in N, in the pintle bearing, to be determined through a direct calculation to be performed in accordance with the static schemes and the load conditions specified in Ch 9, App 1; where such a direct calculation is not carried out, this force may be taken equal to:

$$F_{A1} = \frac{C_R}{2}$$

x : Distance, in m, defined in Fig 11.

Figure 11 : Solepiece geometry



8.3.2 Strength checks

For the generic section of the solepiece within the length ℓ_{50}, defined in Fig 11, it is to be checked that

$\sigma_E \leq \sigma_{E,ALL}$

$\sigma_B \leq \sigma_{B,ALL}$

$\tau \leq \tau_{ALL}$

where:

σ_E : Equivalent stress to be obtained, in N/mm^2, from the following formula:

$$\sigma_E = \sqrt{\sigma_B^2 + 3\tau^2}$$

σ_B : Bending stress to be obtained, in N/mm^2, from the following formula:

$$\sigma_B = \frac{M_S}{W_Z}$$

τ : Shear stress to be obtained, in N/mm^2, from the following formula:

$$\tau = \frac{F_{A1}}{A_S}$$

M_S : Bending moment at the section considered, in N·m, defined in [8.3.1]

F_{A1} : Force, in N, defined in [8.3.1]

W_Z : Section modulus, in cm^3, around the vertical axis Z (see Fig 11)

A_S : Shear sectional area in Y direction, in mm^2

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm^2, equal to:

$\sigma_{E,ALL} = 115/k_1$

$\sigma_{B,ALL}$: Allowable bending stress, in N/mm^2, equal to:

$\sigma_{B,ALL} = 80/k_1$

τ_{ALL} : Allowable shear stress, in N/mm^2, equal to:

$\tau_{ALL} = 48/k_1$.

8.3.3 Minimum section modulus around the horizontal axis

The section modulus around the horizontal axis Y (see Fig 11) is to be not less than the value obtained, in cm^3, from the following formula:

$W_Y = 0,5\ W_Z$

where:

W_Z : Section modulus, in cm^3, around the vertical axis Z (see Fig 11).

9 Simplex rudder shaft

9.1 Scantlings

9.1.1 Diameter of the rudder shaft

The rudder shaft diameter is to be not less than the value obtained, in mm, from the following formula:

$$d = 17,9\left(\frac{\alpha A(V_{AV}+2)^2}{\ell}\right)^{1/3}$$

where:

α : Coefficient equal to:

- if $a \le b$:

  $\alpha = b\ (\ell - b + a)$

- if $a > b$:

  $\alpha = a\ (\ell - a + b)$

a, b, ℓ : Geometrical parameters, in m, defined in Fig 12.

9.1.2 Sectional area of rudder shaft

The overall sectional area of the rudder shaft is to be not less than the greater of the following values:

- 70% of the sectional area for the propeller post defined in Ch 8, Sec 2, [6.3]
- value of the sectional area of the pintle supporting half the rudder blade, whose diameter is to be calculated from the formula in [6.4.1].

If the latter value is the greater, it is to be applied only where the rudder bears on the rudder shaft; in such case, it is recommended that an overthickness or a bush is provided in way of the bearing areas.

9.1.3 Bearings

The bearing length of the rudder shaft is to be not less than 1,2 d, where d is the shaft diameter defined in [9.1.1].

The mean pressure acting on the bearings is not to exceed the relevant allowable values, defined in Tab 7.

9.2 Connections

9.2.1 Connection with the hull

The shaft is to be connected with the hull by means of a vertical coupling flange having thickness at least equal to d/4, where d is the shaft diameter, obtained from the formula in [9.1.1] (see Fig 12).

The coupling flange is to be secured by means of six fitted bolts. The shank diameter of the bolts is to be not less than the coupling flange thickness defined above.

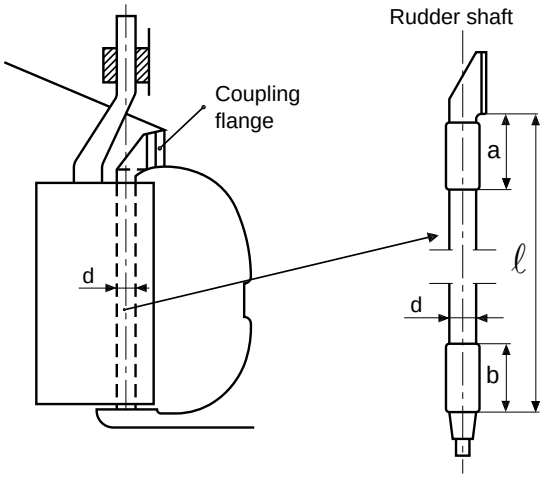
The distance from the bolt centre lines to the coupling flange edge is to be not less than 1,17 times the bolt diameter defined above.

9.2.2 Connection with the solepiece

The rudder shaft is to be connected with the solepiece by means of a cone coupling, having a taper on the radius equal to about 1/10 and housing length not less than 1,1 d, where d is obtained from the formula in [9.1.1] (See Fig 12).

The mean pressure exerted by the rudder shaft on the bearing is to be not greater than the relevant allowable bearing pressure, defined in Tab 6 assuming a rudder with two pintles.

Figure 12 : Simplex rudder shaft geometry



10 Steering nozzles

10.1 General

10.1.1 The requirements of this Article apply to scantling steering nozzles for which the power transmitted to the propeller is less than the value obtained, in kW, from the following formula:

$$P = \frac{16900}{d_M}$$

where:

d_M : Inner diameter of the nozzle, in m.

Nozzles for which the power transmitted is greater than the value obtained from the above formula are considered on a case-by-case basis.

The following requirements may apply also to fixed nozzle scantlings.

10.1.2 Nozzles normally consist of a double skin cylindrical structure stiffened by ring webs and other longitudinal webs placed perpendicular to the nozzle.

At least two ring webs are to be fitted, one of which, of greater thickness, is to be placed in way of the axis of rotation of the nozzle.

For nozzles with an inner diameter d_M exceeding 3 m, the number of ring webs is to be suitably increased.

10.1.3 Care is to be taken in the manufacture of the nozzle to ensure the welded connection between plating and webs.

10.1.4 The internal part of the nozzle is to be adequately protected against corrosion.

10.2 Nozzle plating and internal diaphragms

10.2.1 The thickness of the inner plating of the nozzle is to be not less than the value obtained, in mm, from the following formulae:

$$t_F = (0{,}085\sqrt{Pd_M} + 9{,}65)\sqrt{k} \qquad \text{for} \quad P \leq \frac{6100}{d_M}$$

$$t_F = (0{,}085\sqrt{Pd_M} + 11{,}65)\sqrt{k} \qquad \text{for} \quad P > \frac{6100}{d_M}$$

where:

P, d_M : Defined in [10.1.1].

The thickness t_F is to be extended to a length, across the transverse section containing the propeller blade tips, equal to one third of the total nozzle length.

Outside this length, the thickness of the inner plating is to be not less than $(t_F - 7)$ mm and, in any case, not less than 7 mm.

10.2.2 The thickness of the outer plating of the nozzle is to be not less than $(t_F - 9)$ mm, where t_F is defined in [10.2.1] and, in any case, not less than 7 mm.

10.2.3 The thicknesses of ring webs and longitudinal webs are to be not less than $(t_F - 7)$ mm, where t_F is defined in [10.2.1], and, in any case, not less than 7 mm.

However, the thickness of the ring web, in way of the headbox and pintle support structure, is to be not less than t_F.

The Society may consider reduced thicknesses where an approved stainless steel is used, in relation to its type.

10.3 Nozzle stock

10.3.1 The diameter of the nozzle stock is to be not less than the value obtained, in mm, from the following formula:

$$d_{NTF} = 64,2\ (M_T\ k_1)^{1/3}$$

where:

M_T : Torque, to be taken as the greater of those obtained, in N·m, from the following formulae:

- $M_{TAV} = 0,3\ S_{AV}\ a$
- $M_{TAD} = S_{AD}\ b$

S_{AV} : Force, in N, equal to: $S_{AV} = 150\ V^2_{AV}\ A_N$

S_{AD} : Force, in N, equal to: $S_{AD} = 200\ V^2_{AD}\ A_N$

A_N : Area, in m², equal to: $A_N = 1,35\ A_{1N} + A_{2N}$

A_{1N} : Area, in m², equal to: $A_{1N} = L_M\ d_M$

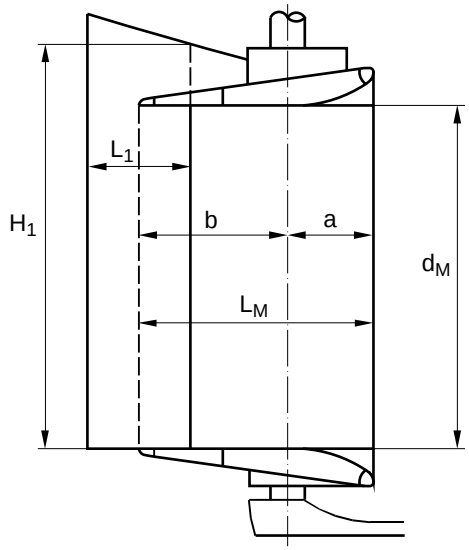
A_{2N} : Area, in m², equal to: $A_{2N} = L_1\ H_1$

a, b, L_M, d_M, L_1, H_1 : Geometrical parameters of the nozzle, in m, defined in Fig 13.

The diameter of the nozzle stock may be gradually tapered above the upper stock bearing so as to reach, in way of the tiller or quadrant, the value obtained, in mm, from the following formula:

$$d_{NT} = 0,75\ d_{NTF}$$

Figure 13 : Geometrical parameters of the nozzle



10.4 Pintles

10.4.1 The diameter of the pintles is to be not less than the value obtained, in mm, from the following formula:

$$d_A = \left(\frac{11\,V_{AV}}{V_{AV} + 3}\sqrt{S_{AV}} + 30\right)\sqrt{k_1}$$

where:

S_{AV} : Defined in [10.3.1].

10.4.2 The net pintle length h_A, in mm, is to be not less than 1,2 d_A, where d_A is defined in [10.4.1].

Smaller values of h_A may be accepted provided that the pressure on the gudgeon bearing p_F is in compliance with the following formula:

$p_F \leq p_{F,ALL}$

where:

p_F : Mean bearing pressure acting on the gudgeon, to be obtained in N/mm^2, from the following formula:

$$p_F = 10^3 \frac{0,6S'}{d'_A h'_A}$$

S' : The greater of the values S_{AV} and S_{AD}, in kN, defined in [10.3.1]

d'_A : Actual pintle diameter, in mm

h'_A : Actual bearing length of pintle, in mm

$p_{F,ALL}$: Allowable bearing pressure, in N/mm^2, defined in Tab 7.

In any case, h_A is to be not less than d_A.

10.5 Nozzle coupling

10.5.1 Diameter of coupling bolts

The diameter of the coupling bolts is to be not less than the value obtained, in mm, from the following formula:

$$d_B = 0,23 d_{NTF} \sqrt{\frac{k_{1B}}{k_{1A}}}$$

where:

d_{NTF} : Diameter of the nozzle stock, in mm, defined in [10.3.1]

k_{1A} : Material factor k_1 for the steel used for the stock

k_{1B} : Material factor k_1 for the steel used for the bolts.

Non-fitted bolts may be used provided that, in way of the mating plane of the coupling flanges, a key is fitted having a section of (0,25 d_{NT} x 0,10 d_{NT}) mm^2, where d_{NT} is defined in [10.3.1], and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.

The distance from the bolt axes to the external edge of the coupling flange is to be not less than 1,2 d_B.

10.5.2 Thickness of coupling flange

The thickness of the coupling flange is to be not less than the value obtained, in mm, from the following formula:

$$t_P = d_{NTF} \sqrt{\frac{k_{1F}}{k_{1B}}}$$

where:

d_{NTF} : Diameter of the nozzle stock, in mm, defined in [10.3.1]

k_{1B}, : Material factor k_1 for the steel used for the bolts

k_{1F} : Material factor k_1 for the steel used for the coupling flange.

10.5.3 Push up length of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push up length Δ_E of the nozzle stock tapered part into the boss is in compliance with the following formula:

$\Delta_0 \leq \Delta_E \leq \Delta_1$

where:

Δ_0 : The greater of:

- $6,2 \dfrac{M_{TR}\eta\gamma}{c d_M t_S \mu_A \beta}$
- $16 \dfrac{M_{TR}\eta\gamma}{c t_S^2 \beta} \sqrt{\dfrac{d_{NTF}^6 - d_{NT}^6}{d_{NT}^6}}$

$$\Delta_1 = \frac{2\eta + 5}{1,8} \frac{\gamma d_0 R_{eH}}{10^6 c(1+\rho_1)}$$

$$\rho_1 = \frac{80\sqrt{d_{NTF}^6 - d_{NT}^6}}{R_{eH} d_M t_S^2 \left[1 - \left(\dfrac{d_0}{d_{NTF}}\right)^2\right]}$$

d_{NTF} : Nozzle stock diameter, in mm, to be obtained from the formula in [10.3.1], considering $k_1 = 1$

d_{NT} : Nozzle stock diameter, in mm, to be obtained from the formula in [10.3.1], considering $k_1 = 1$

η, c, β, d_M, d_E, μ_A, μ, γ: Defined in [5.3.2]

t_S, d_U, d_0: Defined in Fig 5

R_{eH} : Defined in [1.4.3].

10.5.4 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

11 Azimuth propulsion system

11.1 General

11.1.1 Arrangement

The azimuth propulsion system is constituted by the following sub-systems (see Fig 14):

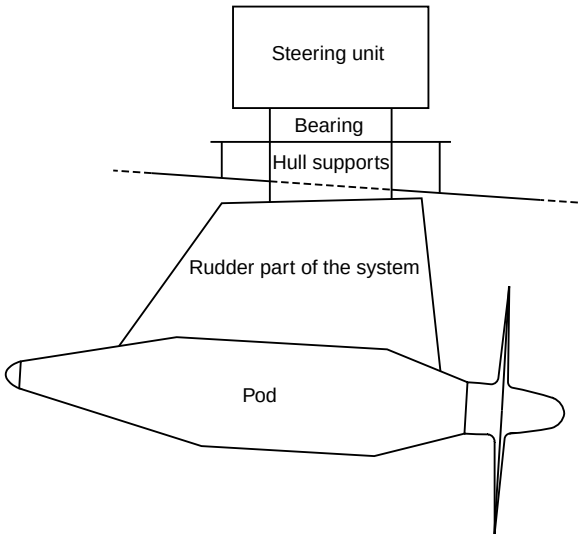
- the steering unit
- the bearing
- the hull supports
- the rudder part of the system
- the pod, which contains the electric motor in the case of a podded propulsion system.

11.1.2 Application

The requirements of this Article apply to the scantlings of the hull supports, the rudder part and the pod.

The steering unit and the bearing are to comply with the requirements in Pt C, Ch 1, Sec 12 and Pt C, Ch 1, Sec 13, respectively.

Figure 14 : Azimuth propulsion system



11.1.3 Operating conditions

The maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed is to be specified by the Designer. Such maximum angle is generally to be less than 35° on each side.

In general, orientations greater than this maximum angle may be considered by the Society for azimuth propulsion systems during manoeuvres, provided that the orientation values together with the relevant speed values are submitted to the Society for approval.

11.2 Arrangement

11.2.1 Plans to be submitted

In addition to the plans showing the structural arrangement of the pod and the rudder part of the system, the plans showing the arrangement of the azimuth propulsion system supports are to be submitted to the Society for approval. The scantlings of the supports and the maximum loads which acts on the supports are to be specified in these drawings.

11.2.2 Locking device

The azimuth propulsion system is to be mechanically lockable in a fixed position, in order to avoid rotations of the system and propulsion in undesirable directions in the event of damage.

11.3 Design loads

11.3.1 The lateral pressure to be considered for scantling of plating and ordinary stiffeners of the azimuth propulsion system is to be determined for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed.

The total force which acts on the azimuth propulsion system is to be obtained by integrating the lateral pressure on the external surface of the system.

The calculations of lateral pressure and total force are to be submitted to the Society for information.

11.4 Plating

11.4.1 Plating of the rudder part of the azimuth propulsion system

The thickness of plating of the rudder part of the azimuth propulsion system is to be not less than that obtained, in mm, from the formulae in [7.3.1], in which the term C_R/A is to be replaced by the lateral pressure calculated according to [11.3].

11.4.2 Plating of the pod

The thickness of plating of the pod is to be not less than that obtained, in mm, from the formulae in Ch 7, Sec 1, where the lateral pressure is to be calculated according to [11.3].

11.4.3 Webs

The thickness of webs of the rudder part of the azimuth propulsion system is to be determined according to [7.3.4], where the lateral pressure is to be calculated according to [11.3].

11.5 Ordinary stiffeners

11.5.1 Ordinary stiffeners of the pod

The scantlings of ordinary stiffeners of the pod are to be not less than those obtained from the formulae in Ch 7, Sec 2, where the lateral pressure is to be calculated according to [11.3].

11.6 Primary supporting members

11.6.1 Analysis criteria

The scantlings of primary supporting members of the azimuth propulsion system are to be obtained through direct calculations, to be carried out according to the following requirements:

- the structural model is to include the pod, the rudder part of the azimuth propulsion system, the bearing and the hull supports
- the boundary conditions are to represent the connections of the azimuth propulsion system to the hull structures
- the loads to be applied are those defined in [11.6.2].

The direct calculation analyses (structural model, load and stress calculation, strength checks) carried out by the Designer are to be submitted to the Society for information.

11.6.2 Loads

The following loads are to be considered in the direct calculation of the primary supporting members of the azimuth propulsion system:

- gravity loads
- buoyancy
- maximum loads calculated for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed
- maximum loads calculated for the possible orientations of the system greater than the maximum angle at the relevant speed (see [11.1.3])
- maximum loads calculated for the crash stop of the ship obtained through inversion of the propeller rotation
- maximum loads calculated for the crash stop of the ship obtained through a 180° rotation of the pod.

11.6.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_E in primary supporting members, calculated, in N/mm^2, for the load cases defined in [11.6.2], is in compliance with the following formula:

$\sigma_E \leq \sigma_{ALL}$

where:

σ_{ALL} : Allowable stress, in N/mm^2, to be taken equal to the lesser of the following values:
- $0,275\ R_m$
- $0,55\ R_{eH}$

R_m : Tensile strength, in N/mm^2, of the material, defined in Ch 4, Sec 1, [2]

R_{eH} : Minimum yield stress, in N/mm^2, of the material, defined in Ch 4, Sec 1, [2].

11.7 Hull supports of the azimuth propulsion system

11.7.1 Analysis criteria

The scantlings of hull supports of the azimuth propulsion system are to be obtained through direct calculations, to be carried out in accordance with the requirements in [11.6.1].

11.7.2 Loads

The loads to be considered in the direct calculation of the hull supports of the azimuth propulsion system are those specified in [11.6.2].

11.7.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_E in hull supports, in N/mm^2, calculated for the load cases defined in [11.6.2], is in compliance with the following formula:

$\sigma_E \leq \sigma_{ALL}$

where:

σ_{ALL} : Allowable stress, in N/mm^2, equal to:

$\sigma_{ALL} = 65/k$

k : Material factor, defined in Ch 4, Sec 1, [2.3].

Values of σ_E greater than σ_{ALL} may be accepted by the Society on a case-by-case basis, depending on the localization of σ_E and on the type of direct calculation analysis.

Section 2 Bulwarks and Guard Rails

1 General

1.1 Introduction

1.1.1 The requirements of this Section apply to the arrangement of bulwarks and guard rails provided at boundaries of the main watertight deck, superstructure decks and tops of the first tier of deckhouses located on the main watertight deck.

1.2 General

1.2.1 Efficient bulwarks or guard rails are to be fitted at the boundaries of all exposed parts of the main watertight deck and superstructure decks directly attached to the main watertight deck, as well as the first tier of deckhouses fitted on the main watertight deck and the superstructure ends.

1.2.2 The height of the bulwarks or guard rails is to be at least 1 m from the deck. However, where their height would interfere with the normal operation of the ship, a lesser height may be accepted, if adequate protection is provided.

1.2.3 Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the main watertight deck.

1.2.4 In case a freeboard calculation is undertaken, in type A and B-100 ships, open rails on the weather parts of the main watertight deck for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with Ch 8, Sec 10, [5] are to be fitted.

1.2.5 In ships with bulwarks and trunks of breadth not less than 0,6 B, which are included in the stability calculation, open rails on the weather parts of the main watertight deck in way of the trunk for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with Ch 8, Sec 10, [5.3.1] are to be fitted.

1.2.6 In ships having superstructures which are open at either or both ends, adequate provision for freeing the space within such superstructures is to be provided.

1.2.7 The freeing port area in the lower part of the bulwarks is to be in compliance with the applicable requirements of Ch 8, Sec 10, [5].

2 Bulwarks

2.1 General

2.1.1 The requirement of this Article apply to bulwarks made of steel. Bulwarks made of other material are to be examined on a case-by-case basis.

2.1.2 As a rule, plate bulwarks are to be stiffened at the upper edge by a suitable bar and supported either by stays or plate brackets spaced not more than 2,0 m apart.

Bulwarks are to be aligned with the beams located below or are to be connected to them by means of local transverse stiffeners.

As an alternative, the lower end of the stay may be supported by a longitudinal stiffener.

2.1.3 In type A, B-60 and B-100 ships, the spacing forward of 0,07 L from the fore end of brackets and stays is to be not greater than 1,2 m.

2.1.4 Where bulwarks are cut completely, the scantlings of stays or brackets are to be increased with respect to those given in [2.2].

2.1.5 As a rule, bulwarks are not to be connected either to the upper edge of the sheerstrake plate or to the stringer plate.

Failing this, the detail of the connection will be examined by the Society on a case-by-case basis.

2.2 Scantlings

2.2.1 The thickness of bulwarks on the main watertight deck not exceeding 1100 mm in height is to be not less than:

- 5,5 mm for $L \leq 30$ m
- 6,0 mm for $30 < L \leq 120$ m
- 6,5 mm for $120 < L \leq 150$ m
- 7,0 mm for $L > 150$ m.

Where the height of the bulwark is equal to or greater than 1800 mm, its thickness is to be equal to that calculated for the side of a superstructure situated in the same location as the bulwark.

For bulwarks between 1100 mm and 1800 mm in height, their thickness is to be calculated by linear interpolation.

The thickness of bulwarks not located on the main watertight deck is to be determined as for the side of a superstructure considered in the same location as the bulwark.

2.2.2 Bulwark plating and stays are to be adequately strengthened in way of eyeplates used for shrouds or other tackles in use for cargo gear operation, as well as in way of hawserholes or fairleads provided for mooring or towing.

2.2.3 At the ends of partial superstructures and for the distance over which their side plating is tapered into the bulwark, the latter is to have the same thickness as the side plating; where openings are cut in the bulwark at these positions, adequate compensation is to be provided either by increasing the thickness of the plating or by other suitable means.

2.2.4 The section modulus of stays in way of the lower part of the bulwark is to be not less than the value obtained, in cm^3, from the following formula:

$$Z = 40\ s\ (1 + 0{,}01\ L)\ h_B^2$$

where:

L : Length of ship, in m, to be assumed not greater than 100 m

s : Spacing of stays, in m

h_B : Height of bulwark, in m, measured between its upper edge and the deck.

The actual section of the connection between stays and deck structures is to be taken into account when calculating the above section modulus.

To this end, the bulb or face plate of the stay may be taken into account only where welded to the deck; in this case the beam located below is to be connected by double continuous welding.

For stays with strengthening members not connected to the deck, the calculation of the required minimum section modulus is considered by the Society on a case-by-case basis.

At the ends of the ship, where the bulwark is connected to the sheerstrake, an attached plating having width not exceeding 600 mm may also be included in the calculation of the actual section modulus of stays.

2.2.5 Openings in bulwarks are to be arranged so that the protection of the crew is to be at least equivalent to that provided by the horizontal courses in [3.1.2].

For this purpose, vertical rails or bars spaced approximately 230 mm apart may be accepted in lieu of rails or bars arranged horizontally.

2.2.6 In the case of ships intended for the carriage of timber deck cargoes, the specific provisions of the main watertight regulations are to be complied with.

2.2.7 Bulwarks located in the bow flare area as defined in Ch 8, Sec 1, [4.1.2] are to be reinforced according to Ch 8, Sec 1, [4], considering the stays as cantilever primary supporting members.

3 Guard rails

3.1

3.1.1 Where guard rails are provided, the upper edge of sheerstrake is to be kept as low as possible.

3.1.2 The opening below the lowest course is to be not more than 230 mm. The other courses are to be not more than 380 mm apart.

3.1.3 In the case of ships with rounded gunwales or sheerstrake, the stanchions are to be placed on the flat part of the deck.

3.1.4 Fixed, removable or hinged stanchions are to be fitted about 1,5 m apart. At least every third stanchion is to be supported by a bracket or stay. However, other arrangement may be considered on a case-by-case basis (e.g. stanchions directly screwed in exposed decks), when strength is deemed equivalent.

Removable or hinged stanchions are to be capable of being locked in the upright position.

3.1.5 Wire ropes may only be accepted in lieu of guard rails in special circumstances and then only in limited lengths. Wires are to be made taut by means of turnbuckles.

3.1.6 Chains may only be accepted in short lengths in lieu of guard rails if they are fitted between two fixed stanchions and/or bulwarks.

Section 3 Propeller Shaft Brackets

Symbols

θ : Angle defined in Fig 1 and Fig 2

D_e : Propeller diameter, in m

L : Bracket length, in m (see Fig 1 and Fig 2)

A : Bracket cross-sectional area, in m^2

$$K_6 = \frac{2 - \frac{\ell}{L_1} - \frac{\ell}{L_1^2}}{4\left(1 + \frac{\ell}{L_1} + \frac{\ell}{L_1^2}\right)}$$

L_1 : Length, in m, of the bracket between the hull and the intersection point with the propeller bossing, obtained as follows:

$L_1 = L - \ell$

ℓ : Distance, in m, from the above intersection point to the intersection between the barycentre axes of the brackets (see Fig 1 and Fig 2).

1 General

1.1 Bracket configuration

1.1.1 Propeller shafting is generally supported by two brackets, a main one connected to the propeller bossing and an intermediate one between the main one and the ship hull.

The main bracket is to be of double arm type, while the intermediate one may be of single arm type.

2 Double arm brackets of propeller shaft

2.1 General

2.1.1 Double arm brackets of propeller shaft are generally to be radial or tangential, as schematically shown in, respectively, Fig 1 and Fig 2. Other arrangements proposed by the shipyard may be accepted by the Society, on a case-by-case basis.

Usually, the vertical plane passing through the base chord of the bracket is parallel to the ship symmetry plane. When this is not the case, the brackets are said to be twisted and the twist angle is to be identified.

The brackets should be in a lateral plane. However, when more space is needed between the brackets and the propeller, or when brackets normal to the hull are considered, the bracket inclination angle is to be toward the aft.

Figure 1 : Radial type double arm bracket

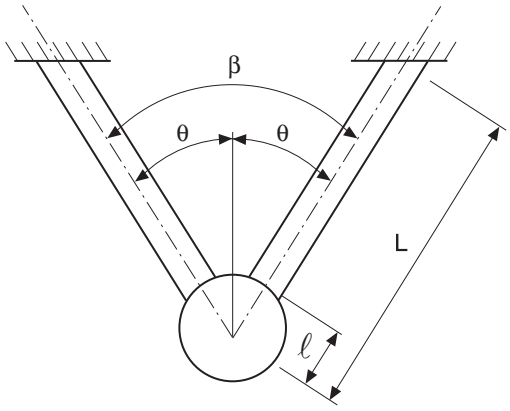
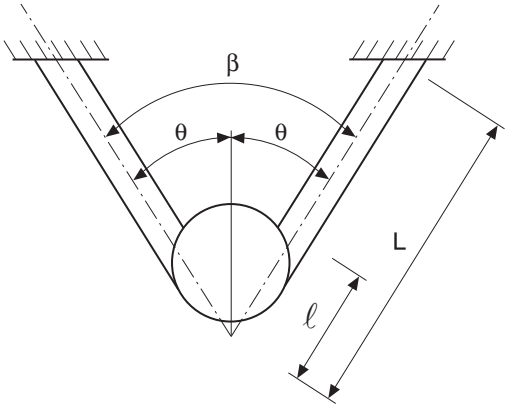


Figure 2 : Tangential type double arm bracket



2.1.2 The hull structure in the zone where the propeller brackets are attached to the hull is to be capable of completely absorbing the forces induced by the brackets; in particular, the connection with the primary longitudinal structural members is important. The connections brackets-hull and brackets-propeller bossing are to be rounded. Alternative designs of connections between internal hull structure and propeller bossing avoiding excessive stress concentration may be accepted, subject to special examination.

2.1.3 The lowest natural frequency of the brackets should exceed the blade frequency with not less than 20%.

In cases where this is not possible, the above requirement should be fulfilled for the second resonance frequency and, furthermore, the blade frequency should be at least twice the lowest natural frequency.

2.2 Limit state verification - Loss of blade

2.2.1 General

In the case of loss of a propeller blade, it is to be verified that the maximum global stress σ_{TOT} induced in the propeller brackets do not exceed the permissible stress σ_P:

$\sigma_{TOT} \leq \sigma_P$

where:

$\sigma_P = 0,48\ \sigma_y$

with:

σ_y : Yield stress of the material.

2.2.2 Maximum global stress

The maximum global stress acting on the propeller shaft bracket is to be determined as the sum of the maximum bending induced stress and the compressive stress at that instant:

$\sigma_{TOT} = \sigma_x + \sigma_c$

where:

σ_x = Max (σ_A ; σ_B), with σ_A and σ_B defined in [2.2.3]

σ_c : Compressive stress when the bending stress is maximized, defined in [2.2.4].

2.2.3 Acting bending stresses

As the brackets are subjected to combined bending (longitudinal and transverse) the stress can achieve its greatest values at two locations, A and B (see Fig 3).

The stress is therefore to be determined at both locations and the acting stress σ_x is then taken equal to the greater value.

The stress in point A is determined as follows:

$$\sigma_A = \frac{M_{L,max}}{W_{zz}}$$

where:

$M_{L,max}$: Maximum longitudinal bending moment in the bracket, defined in [2.2.5]

W_{zz} : Section modulus around z axis.

The stress in point B is determined as follows:

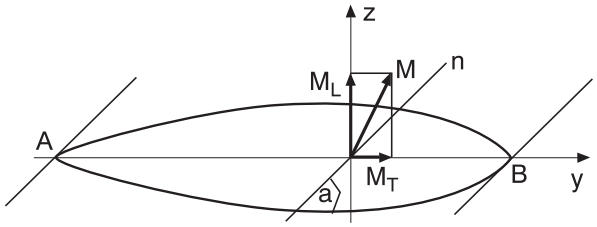
$$\sigma_B = \frac{M_{T\varphi}}{I_{yy}} Z_B + \frac{M_{L,max}}{I_{zz}} Y_B$$

where:

$M_{T\varphi}$: Transverse moment in the bracket when the longitudinal moment is maximum, as defined in [2.2.6]

I_{yy} : Sectional moment of inertia around y axis
I_{zz} : Sectional moment of inertia around z axis
Z_B : Distance from point B to the neutral axis for transverse bending
Y_B : Distance from point B to the neutral axis for longitudinal bending.

Figure 3 : Locations of maximum stress under combined bending



2.2.4 Compressive stress

The compressive stress, acting in the brackets when the longitudinal bending moment is maximized, is to be determined as follows:

$$\sigma_c = \frac{P}{2A}\left(\frac{\sin\varphi}{\sin\theta} + \frac{\cos\varphi}{\cos\theta}\right)$$

where:

P : Centrifugal force of the lost blade, in N, to be taken equal to (see Fig 4):
$P = m\,\omega^2\,\rho$
with:
m : Weight of the blade, in kg
ω : Angular velocity, in rad/s, equal to: $\omega = 2\,\pi$ RPM / 60, with:
RPM : Maximum number of revolutions per minute of the propeller
ρ : Distance from the centre of gravity of the blade to the propeller axis

φ : Phase angle for which the bending stress in the bracket is maximized.
The phase angle maximizing the bending induced stress is to be determined from:

$$\tan\varphi = \frac{2K_6}{\tan\theta}$$

2.2.5 Maximum longitudinal moment in bracket

The maximum longitudinal bending moment, in N·m, acting in the brackets is defined as follows:

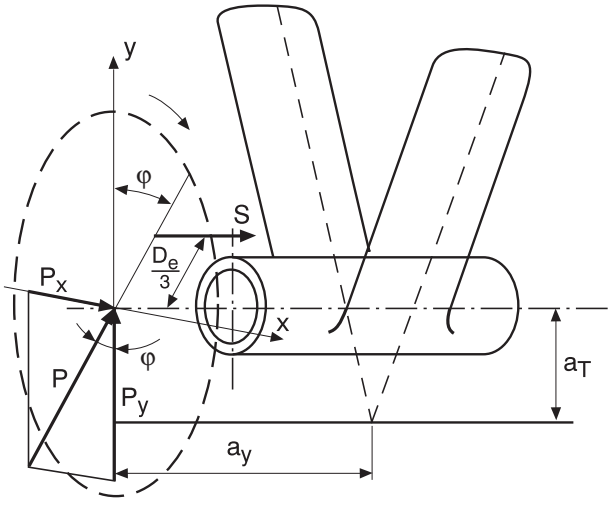
$$M_{L,max} = \frac{4K_6^2\cos\theta + \sin\theta\tan\theta}{2\sin\theta\cos\theta\sqrt{4K_6^2 + \tan^2\theta}}\left(Pa_y + \frac{SD_e}{3}\right)$$

where:

S : Thrust of the lost blade (see Fig 4), in N, to be obtained as the total thrust of the propeller divided by the number of propeller blades

a_y : Distance from the propeller to the brackets, in m (see Fig 4).

Figure 4 : Definition of forces, directions and distances



2.2.6 Maximum transverse moment in bracket

The maximum transverse bending moment, in N·m, acting in the brackets is defined as follows:

$$M_{T\varphi} = K_6 P a_T \frac{2K_6}{\sqrt{4K_6^2 + \tan^2\theta}}$$

where:

P : Defined in [2.2.4]

a_T : Defined in Fig 4, in m.

2.2.7 Resonance

In case of loss of a propeller blade, it is to be verified that the bracket lowest natural frequency f_1 is at least 20% larger than the exciting frequency of the damaged propeller f_{dam}:

$f_1 \geq 1,2\ f_{dam}$

where:

f_1 : Determined as described in [2.3.2]

f_{dam} = RPM / 60, in Hz, with:

RPM : Maximum number of revolutions per minute of the propeller.

2.3 Other verifications

2.3.1 Stability under compression

The maximum compressive stress σ_{max} acting on the brackets is defined as follows:

$$\sigma_{max} = \frac{P}{2A}\left(\frac{1}{\sin\theta\sqrt{1 + \tan^2\theta}} + \frac{\tan\theta}{\cos\theta\sqrt{1 + \tan^2\theta}}\right)$$

It is to be verified that σ_{max} does not exceed the critical instability stress σ_{cr}, in N/m^2, defined as follows:

$$\sigma_{cr} = \pi^2 \frac{EI_{min}}{0,64AL^2}$$

where:

E : Young's modulus, equal to $2,06 \cdot 10^{11}$ N/m^2 for steel

I_{min} : Minimum moment of inertia of the bracket cross-section, in m^4.

2.3.2 Resonance

In general, it is to be verified that either one of the two following conditions is satisfied:

a) the bracket lowest natural frequency f_1 exceeds with at least 20% the blade frequency f_{bl}, or

b) the blade frequency f_{bl} is at least twice as large as the bracket lowest natural frequency f_1 and 20% smaller than the second natural frequency f_2

The above conditions correspond to the two following inequalities respectively:

- $f_1 > 1,20\ f_{bl}$
- $2\ f_1 < f_{bl} < 0,8\ f_2$

where:

f_{bl} : Blade frequency, in Hz, equal to:

$f_{bl} = n \cdot RPM / 60$, with:

n : Number of blades

RPM : Maximum number of revolutions per minute of the propeller

$$f_i = \frac{\lambda_i^2}{2\pi L^2}\sqrt{\frac{EI_{min}}{w + w_e}}$$

with:

λ_1 : Factor equal to:

- 1,875 in case of a single arm bracket
- 3,927 in case of double arm brackets

λ_2 : Factor equal to:

- 4,694 in case of a single arm bracket
- 7,069 in case of double arm brackets

E, I_{min} : Defined in [2.3.1]

w : Mass of the bracket per unit length, in kg/m

w_e : Added mass of water per unit length, in kg/m.

The added mass of water is to be determined as, unless otherwise agreed with the Society:

$w_e = \rho (A_{cir} - A)$

where:

ρ : Density of sea water, equal to 1025 kg/m^3

A_{cir} : Area of the circle circumscribing the bracket profile, in m^2.

Section 4 Equipment

Symbols

EN : Equipment Number defined in [2.1]

σ_{ALL} : Allowable stress, in N/mm^2, used for the yielding check, to be taken as follows:

σ_{ALL} = Min (0,67 R_{eH} ; 0,40 R_m)

R_{eH} : Minimum yield stress, in N/mm^2, of the material, defined in Ch 4, Sec 1, [2]

R_m : Tensile strength, in N/mm^2, of the material, defined in Ch 4, Sec 1, [2].

1 General

1.1 General

1.1.1 The minimum requirements in Articles [2] to [4] apply to temporary mooring of a ship within or near harbour, or in a sheltered area, when the ship is awaiting a berth, the tide, etc.

Therefore, the equipment complying with the requirements in Articles [2] to [4] is not intended for holding a ship off fully exposed coasts in rough weather or for stopping a ship which is moving or drifting.

The requirements in Articles [2] and [4] are based on a wind speed of 25 m/s, a current speed of 2,5 m/s and a water depth of 50 m.

For a water depth greater than 50 m, a length of chain cable greater than the one obtained from Tab 1 may be accepted by the Society, on the basis of justificative calculation submitted by the shipyard.

1.1.2 The equipment complying with the requirements in Articles [2] to [4] is intended for holding a ship in good holding ground, where the conditions are such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors is to be significantly reduced.

1.1.3 It is assumed that under normal circumstances a ship will use one anchor only.

2 Equipment number

2.1 Equipment number

2.1.1 General

All ships are to be provided with equipment in anchors and chain cables (or ropes according to [3.2.5]), to be obtained from Tab 1, based on their Equipment Number EN.

In general, stockless anchors are to be adopted.

For ships with EN greater than 16000, the determination of the equipment will be considered by the Society on a case-by-case basis.

For ships of special design or ships engaged in special services or on special voyages, the Society may consider equipment other than that given in Tab 1.

2.1.2 Equipment number for ships with perpendicular superstructure front bulkhead

The equipment number EN is to be obtained from the following formula:

$EN = \Delta^{2/3} + 2\ h\ B + 0,1\ A$

where:

Δ : Moulded displacement of the ship, in t, to the full load waterline “end of life”

h : Effective height, in m, from the full load waterline to the top of the uppermost house, to be obtained in accordance with the following formula:

$h = a + \Sigma h_n$

when calculating h, sheer and trim are to be disregarded

a : Distance amidships between the full load waterline and the exposed deck, in m

h_n : Height, in m, at the centreline of tier “n” of superstructures or deckhouses having a breadth greater than B/4. Where a house having a breadth greater than B/4 is above a house with a breadth of B/4 or less, the upper house is to be included and the lower ignored

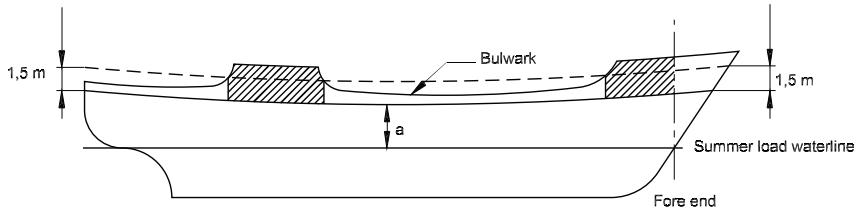
A : Area, in m^2, in profile view, of the parts of the hull, superstructures and houses above the full load waterline which are within the length L_E and also have a breadth greater than B/4

L_E : Equipment length, in m, equal to L without being taken neither less than 96% nor greater than 97% of the total length of the full load waterline.

Fixed screens or bulwarks 1,5 m or more in height are to be regarded as parts of houses when determining h and A. In particular, the hatched area shown in Fig 1 is to be included.

The height of hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A.

Figure 1 : Ships with perpendicular front bulkhead
Effective area of bulwarks or fixed screen to be included in the equipment number



2.1.3 Equipment number for ships with inclined superstructure front bulkhead

For ships having superstructures with the front bulkhead with an angle of inclination aft, the equipment number EN is to be obtained from the following formula:

$EN = \Delta^{2/3} + 2\,(a\,B + \Sigma\, b_N\, h_N \sin\theta_N) + 0{,}1\,A$

where:

Δ, a, h_N, A: Defined in [2.1.2]

θ_N : Angle of inclination aft of each front bulkhead, shown in Fig 2

b_N : Greatest breadth, in m, of each tier n of superstructures or deckhouses having a breadth greater than B/4.

Fixed screens or bulwarks 1,5 m or more in height are to be regarded as parts of houses when determining h and A. In particular, the hatched area shown in Fig 2 is to be included.

Figure 2 : Ships with inclined front bulkhead
Effective area of bulwarks or fixed screen to be included in the equipment number

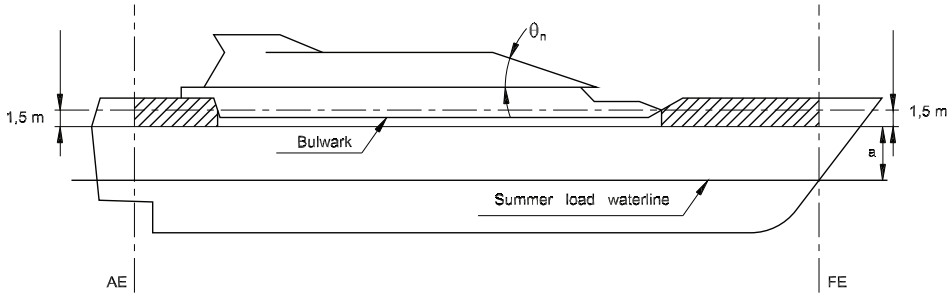


Table 1 : Equipment

Equipment number EN A < EN ≤ B		Stockless anchors		Stud link chain cables for anchors			
		N **(1)**	Mass per anchor, in kg	Total length, in m	Diameter, in mm		
A	B				Q1	Q2	Q3
50	70	2	240	220,0	16,0	14,0	
70	90	2	300	247,5	17,5	16,0	
90	110	2	360	247,5	19,0	17,5	
110	130	2	420	275,0	20,5	17,5	
130	150	2	480	275,0	22,0	19,0	
150	175	2	570	302,5	24,0	20,5	
175	205	3	660	302,5	26,0	22,0	20,5
205	240	3	780	330,0	28,0	24,0	22,0
240	280	3	900	357,5	30,0	26,0	24,0
280	320	3	1020	357,5	32,0	28,0	24,0
320	360	3	1140	385,0	34,0	30,0	26,0
360	400	3	1290	385,0	36,0	32,0	28,0
400	450	3	1440	412,5	38,0	34,0	30,0
450	500	3	1590	412,5	40,0	34,0	30,0
(1) See [3.1.4].							

Equipment number EN A < EN ≤ B		Stockless anchors		Stud link chain cables for anchors			
		N **(1)**	Mass per anchor, in kg	Total length, in m	Diameter, in mm		
A	B				Q1	Q2	Q3
500	550	3	1740	440,0	42,0	36,0	32,0
550	600	3	1920	440,0	44,0	38,0	34,0
600	660	3	2100	440,0	46,0	40,0	36,0
660	720	3	2280	467,5	48,0	42,0	36,0
720	780	3	2460	467,5	50,0	44,0	38,0
780	840	3	2640	467,5	52,0	46,0	40,0
840	910	3	2850	495,0	54,0	48,0	42,0
910	980	3	3060	495,0	56,0	50,0	44,0
980	1060	3	3300	495,0	58,0	50,0	46,0
1060	1140	3	3540	522,5	60,0	52,0	46,0
1140	1220	3	3780	522,5	62,0	54,0	48,0
1220	1300	3	4050	522,5	64,0	56,0	50,0
1300	1390	3	4320	550,0	66,0	58,0	50,0
1390	1480	3	4590	550,0	68,0	60,0	52,0
1480	1570	3	4890	550,0	70,0	62,0	54,0
1570	1670	3	5250	577,5	73,0	64,0	56,0
1670	1790	3	5610	577,5	76,0	66,0	58,0
1790	1930	3	6000	577,5	78,0	68,0	60,0
1930	2080	3	6450	605,0	81,0	70,0	62,0
2080	2230	3	6900	605,0	84,0	73,0	64,0
2230	2380	3	7350	605,0	87,0	76,0	66,0
2380	2530	3	7800	632,5	90,0	78,0	68,0
2530	2700	3	8300	632,5	92,0	81,0	70,0
2700	2870	3	8700	632,5	95,0	84,0	73,0
2870	3040	3	9300	660,0	97,0	84,0	76,0
3040	3210	3	9900	660,0	100,0	87,0	78,0
3210	3400	3	10500	660,0	102,0	90,0	78,0
3400	3600	3	11100	687,5	105,0	92,0	81,0
3600	3800	3	11700	687,5	107,0	95,0	84,0
3800	4000	3	12300	687,5	111,0	97,0	87,0
4000	4200	3	12900	715,0	114,0	100,0	87,0
4200	4400	3	13500	715,0	117,0	102,0	90,0
4400	4600	3	14100	715,0	120,0	105,0	92,0
4600	4800	3	14700	742,5	122,0	107,0	95,0
4800	5000	3	15400	742,5	124,0	111,0	97,0
5000	5200	3	16100	742,5	127,0	111,0	97,0
5200	5500	3	16900	742,5	130,0	114,0	100,0
5500	5800	3	17800	742,5	132,0	117,0	102,0
5800	6100	3	18800	742,5		120,0	107,0
6100	6500	3	20000	770,0		124,0	111,0
6500	6900	3	21500	770,0		127,0	114,0
6900	7400	3	23000	770,0		132,0	117,0
7400	7900	3	24500	770,0		137,0	122,0
7900	8400	3	26000	770,0		142,0	127,0
8400	8900	3	27500	770,0		147,0	132,0
8900	9400	3	29000	770,0		152,0	132,0
9400	10000	3	31000	770,0			137,0
10000	10700	3	33000	770,0			142,0
10700	11500	3	35500	770,0			147,0
11500	12400	3	38500	770,0			152,0
12400	13400	3	42000	770,0			157,0
13400	14600	3	46000	770,0			162,0

(1) See [3.1.4].

3 Equipment

3.1 Anchors

3.1.1 General

The scantlings of anchors are to be in compliance with the following requirements.

Anchors are to be constructed and tested in compliance with approved plans.

3.1.2 Ordinary anchors

The required mass for each anchor is to be obtained from Tab 1.

The individual mass of a main anchor may differ by ± 7% from the mass required for each anchor, provided that the total mass of anchors is not less than the total mass required in Tab 1.

The mass of the head of an ordinary stockless anchor, including pins and accessories, is to be not less than 60% of the total mass of the anchor.

Where a stock anchor is provided, the mass of the anchor, excluding the stock, is to be not less than 80% of the mass required in Tab 1 for a stockless anchor. The mass of the stock is to be not less than 25% of the mass of the anchor without the stock but including the connecting shackle.

3.1.3 High and very high holding power anchors

High holding power (HHP) and very high holding power (VHHP) anchors are anchors for which a holding power higher than that of ordinary anchors has been proven, without requiring prior adjustment or special placement on the sea bottom.

HHP and VHHP anchors are to be certified according to NR216, Ch 10, Sec 1. Their holding power is to be demonstrated through the tests described in [3.1.5] to [3.1.7].

Where HHP or VHHP anchors are used as bower anchors, the mass of each anchor is to be not less than 75% or 50%, respectively, of that required for ordinary stockless anchors in Tab 1.

The mass of VHHP anchors is to be, in general, less than or equal to 1500 kg.

3.1.4 Third anchor

Where three anchors are provided, two are to be connected to their own chain cables and positioned on board always ready for anchoring.

The third anchor is intended as a spare and is not required for the purpose of classification.

3.1.5 Test for high holding power anchors approval

For approval and/or acceptance as a HHP anchor, comparative tests are to be performed on various types of sea bottom. Such tests are to show that the holding power of the HHP anchor is at least twice the holding power of an ordinary stockless anchor of the same mass.

For approval and/or acceptance as a HHP anchor of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least two anchors of different sizes are to be tested. The mass of the maximum size to be approved is to be not greater than 10 times the maximum size tested. The mass of the smallest is to be not less than 0,1 times the minimum size tested.

3.1.6 Test for very high holding power anchors approval

For approval and/or acceptance as a VHHP anchor, comparative tests are to be performed at least on three types of sea bottom: soft mud or silt, sand or gravel and hard clay or similar compounded material. Such tests are to show that the holding power of the VHHP anchor is to be at least four times the holding power of an ordinary stockless anchor of the same mass or at least twice the holding power of a previously approved HHP anchor of the same mass.

For approval and/or acceptance as a VHHP anchor of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least three anchors of different sizes are to be tested. relevant to the bottom, middle and top of the mass range.

3.1.7 Specification for test on high holding power and very high holding power anchors

Full scale tests are to be performed on various types of sea bottom: soft mud or silt, sand or gravel and hard clay or similar compounded material.

Tests are generally to be carried out from a tug. Shore based tests may be accepted by the Society on a case-by-case basis.

The holding power test load is to be less than or equal to the proof load of the anchor, specified in NR216, Ch 10, Sec 1.

Alternatively, sea trials by comparison with a previous approved anchor of the same type (HHP or VHHP) of the one to be tested may be accepted by the Society on a case-by-case basis.

For each series of sizes, the two anchors selected for testing (ordinary stockless and HHP anchors for testing HHP anchors, ordinary stockless and VHHP anchors or, when ordinary stockless anchors are not available, HHP and VHHP anchors for testing VHHP anchors) are to have the same mass.

The length of chain cable connected to each anchor, having a diameter appropriate to its mass, is to be such that the pull on the shank remains practically horizontal. For this purpose a value of the ratio between the length of the chain cable paid out and the water depth equal to 10 is considered normal. A lower value of this ratio may be accepted by the Society on a case-by-case basis.

Three tests are to be carried out for each anchor and type of sea bottom.

The pull is to be measured by dynamometer; measurements based on the RPM/bollard pull curve of tug may, however, be accepted instead of dynamometer readings.

Note is to be taken where possible of the stability of the anchor and its ease of breaking out.

3.2 Chain cables for anchors

3.2.1 Material

The chain cables are classified as grade Q1, Q2 or Q3 depending on the type of steel used and its manufacture.

The characteristics of the steel used and the method of manufacture of chain cables are to be approved by the Society for each manufacturer. The material from which chain cables are manufactured and the completed chain cables themselves are to be tested in accordance with the applicable requirements of NR216 Materials and Welding, Ch 4, Sec 1.

Chain cables made of grade Q1 may not be used with high holding power and very high holding power anchors.

3.2.2 Stud link chain cables

The mass and geometry of stud link chain cables, including the links, are to be in compliance with the requirements in NR216 Materials and Welding, Ch 4, Sec 1.

The diameter of stud link chain cables is to be not less than the values given in Tab 1.

3.2.3 Studless link chain cables

For ships with EN less than 90, studless short link chain cables may be accepted by the Society as an alternative to stud link chain cables, provided that the equivalence in strength is based on proof load, defined in NR216 Materials and Welding, Ch 4, Sec 1, [3], and that the steel grade of the studless chain is equivalent to the steel grade of the stud chains it replaces, as defined in [3.2.1].

3.2.4 Chain cable arrangement

Chain cables are to be made by lengths of 27,5 m each, joined together by Dee or lugless shackles.

The total length of chain cable, required in Tab 1, is to be divided in approximately equal parts between the two anchors ready for use.

Where different arrangements are provided, they are considered by the Society on a case-by-case basis. In particular, different lengths of chain cable for each anchor may be accepted, provided each mooring line is appropriate for 50m water depth.

Where the ship may anchor in areas with current speed greater than 2,5 m/s, the Society may require a length of heavier chain cable to be fitted between the anchor and the rest of the chain in order to enhance anchor bedding.

3.2.5 Wire ropes

As an alternative to the stud link or short link chain cables mentioned, wire ropes may be used in the following cases:

- wire ropes for both the anchors, for ship length less than 30 m
- wire rope for one of the two anchors, for ship length between 30 m and 40 m.

The wire ropes above are to have a total length equal to 1,5 times the corresponding required length of stud link chain cables, obtained from Tab 1, and a minimum breaking load equal to that given for the corresponding stud link chain cable (see [3.2.2]).

A short length of chain cable is to be fitted between the wire rope and the anchor, having a length equal to 12,5 m or the distance from the anchor in the stowed position to the winch, whichever is the lesser.

3.3 Attachment pieces

3.3.1 General

Where the lengths of chain cable are joined to each other by means of shackles of the ordinary Dee type, the anchor may be attached directly to the end link of the first length of chain cable by a Dee type end shackle.

A detachable open link in two parts riveted together may be used in lieu of the ordinary Dee type end shackle; in such case the open end link with increased diameter, defined in [3.3.2], is to be omitted.

Where the various lengths of chain cable are joined by means of lugless shackles and therefore no special end and increased diameter links are provided, the anchor may be attached to the first length of chain cable by a special pear-shaped lugless end shackle or by fitting an attachment piece.

3.3.2 Scantlings

The diameters of the attachment pieces, in mm, are to be not less than the values indicated in Tab 2.

Attachment pieces may incorporate the following items between the increased diameter stud link and the open end link:

- swivel, having diameter equal to 1,2 d
- increased stud link, having diameter equal to 1,1 d.

Where different compositions are provided, they will be considered by the Society on a case-by-case basis.

Table 2 : Diameters of attachment pieces

Attachment piece	Diameter, in mm
End shackle	1,4 d
Open end link	1,2 d
Increased stud link	1,1 d
Common stud link	d
Lugless shackle	d
Note 1: d : Diameter, in mm, of the common link	

3.3.3 Material

Attachment pieces, joining shackles and end shackles are to be of such material and design as to provide strength equivalent to that of the attached chain cable, and are to be tested in accordance with the applicable requirements of NR216 Materials and Welding, Ch 4, Sec 1.

3.4 Towlines

3.4.1 General

The towlines are given as a guidance, but are not required as a condition of classification.

The towlines having the characteristics defined in Tab 3 are intended as those belonging to the ship to be towed by a tug or another ship.

3.4.2 Materials

Towlines may be of wire, natural or synthetic fibre or a mixture of wire and fibre.

The breaking loads defined in Tab 3 refer to steel wires or natural fibre ropes.

Steel wires and fibre ropes are to be tested in accordance with the applicable requirements in NR216 Materials and Welding, Ch 4, Sec 1.

3.4.3 Steel wires

Steel wires are to be made of flexible galvanized steel and are to be of types defined in Tab 4.

3.4.4 Synthetic fibre ropes

Where synthetic fibre ropes are adopted, their size is to be determined taking into account the type of material used and the manufacturing characteristics of the rope, as well as the different properties of such ropes in comparison with natural fibre ropes.

The breaking load of synthetic fibre ropes B_{LS} is to be not less than that obtained, in kN, from the following formula:

$B_{LS} = K\, B_{L0}$

where:

B_{L0} : Breaking load, in kN, for the towline, defined in Tab 3,

K : Coefficient to be taken equal to:

K = 1,3 for polypropylene towlines

K = 1,2 for towlines made in other synthetic material.

Fibre rope diameters are to be not less than 20 mm.

3.4.5 Equivalence between the breaking loads of synthetic and natural fibre ropes

Generally, fibre ropes are to be made of polyamide or other equivalent synthetic fibres.

The equivalence between the breaking loads of synthetic fibre ropes B_{LS} and of natural fibre ropes B_{LN} is to be obtained, in kN, from the following formula:

$B_{LS} = 7{,}4\, \delta\, B_{LN}^{8/9}$

where:

δ : Elongation to breaking of the synthetic fibre rope, to be assumed not less than 30%.

3.5 Hawse pipes

3.5.1 Hawse pipes are to be built according to sound marine practice.

Their position and slope are to be so arranged as to create an easy lead for the chain cables and efficient housing for the anchors, where the latter are of the retractable type, avoiding damage to the hull during these operations.

For this purpose chafing lips of suitable form with ample lay-up and radius adequate to the size of the chain cable are to be provided at the shell and deck. The shell plating in way of the hawse pipes is to be reinforced as necessary.

3.5.2 All mooring units and accessories, such as timbler, riding and trip stoppers are to be securely fastened, to the Surveyor's satisfaction.

Table 3 : Towlines and mooring lines

Equipment number EN A< EN ≤ B		Towlines	
A	B	Minimum length, in m	Breaking load, in kN
50	70	180	98,1
70	90	180	98,1
90	110	180	98,1
110	130	180	98,1
130	150	180	98,1
150	175	180	98,1
175	205	180	112
205	240	180	129
240	280	180	150
280	320	180	174
320	360	180	207
360	400	180	224
400	450	180	250
450	500	180	277
500	550	190	306
550	600	190	338
600	660	190	371
660	720	190	406
720	780	190	441
780	840	190	480
840	910	190	518
910	980	190	550
980	1060	200	603
1060	1140	200	647
1140	1220	200	692
1220	1300	200	739
1300	1390	200	786

Equipment number EN A< EN ≤ B		Towlines	
A	B	Minimum length, in m	Breaking load, in kN
1390	1480	200	836
1480	1570	220	889
1570	1670	220	942
1670	1790	220	1024
1790	1930	220	1109
1930	2080	220	1168
2080	2230	240	1259
2230	2380	240	1356
2380	2530	240	1453
2530	2700	260	1471
2700	2870	260	1471
2870	3040	260	1471
3040	3210	280	1471
3210	3400	280	1471
3400	3600	280	1471
3600	3800	300	1471
3800	4000	300	1471
4000	4200	300	1471
4200	4400	300	1471
4400	4600	300	1471
4600	4800	300	1471
4800	5000	300	1471
5000	5200	300	1471
5200	5500	300	1471
5500	5800	300	1471
5800	6100	300	1471

Table 4 : Steel wire composition

Breaking load B_L ,in kN	Steel wire components		
	Number of threads	Ultimate tensile strength of threads, in N/mm^2	Composition of wire
$B_L < 216$	72	1420 ÷ 1570	6 strands with 7-fibre core
$216 < B_L < 490$	144	1570 ÷ 1770	6 strands with 7-fibre core
$B_L > 490$	216 or 222	1770 ÷ 1960	6 strands with 1-fibre core

3.6 Windlass

3.6.1 General

The Rule Note NR626 “Anchor Windlass and Chain Stoppers” is to be applied, considering the windlass brake capacity defined in [3.6.2].

The deck in way of the windlass is to be suitably reinforced. The windlass, its frame and the stoppers are to be efficiently bedded to the deck.

3.6.2 Brake capacity

Based on mooring line arrangements with brakes engaged and cable lifter disengaged, the capacity HL (Holding Load), in kN, of the windlass brake is to be sufficient to withstand the following design loads without any permanent deformation of the stressed parts and without brake slip:

- 0,8 times the breaking load BL of the chain, if not combined with a chain stopper
- 0,45 times the breaking load BL of the chain, if combined with a chain stopper.

3.7 Chain stoppers

3.7.1 A chain stopper is generally to be fitted between the windlass and the hawse pipe in order to relieve the windlass of the pull of the chain cable when the ship is at anchor. The chain stopper is to comply with applicable requirements given in the Rule Note NR626 “Anchor Windlass and Chain Stoppers”.

For the same purpose, a piece of chain cable may be used with a rigging screw capable of supporting the weight of the anchor when housed in the hawse pipe or a chain tensioner. Such arrangements are not to be considered as chain stoppers.

3.7.2 Where the windlass is at a distance from the hawse pipes and no chain stoppers are fitted, suitable arrangements are to be provided to lead the chain cables to the windlass.

3.8 Chain locker

3.8.1 The capacity of the chain locker is to be adequate to stow all chain cable equipment and provide an easy direct lead to the windlass.

3.8.2 Where two chains are used, the chain lockers are to be divided into two compartments, each capable of housing the full length of one line.

3.8.3 The inboard ends of chain cables are to be secured to suitably reinforced attachments in the structure by means of end shackles, whether or not associated with attachment pieces.

Generally, such attachments are to be able to withstand a force not less than 15% of the breaking load of the chain cable.

In an emergency, the attachments are to be easily released from outside the chain locker.

3.8.4 Where the chain locker is arranged aft of the collision bulkhead, its boundary bulkheads are to be watertight and a drainage system is to be provided.

4 Mooring arrangement

4.1 General

4.1.1 The mooring lines and the hawser for mooring to a buoy are to be in accordance with the following sub-articles. The other mooring equipment are outside the scope of classification.

4.2 Mooring lines

4.2.1 Minimum breaking load

The minimum breaking load BL, in KN, of the mooring lines is given by:

$BL = FS / N$

with:

FS : Static force, in kN, induced by wind on the ship in the transverse direction given by the following formula:
$FS = 2,382\ A\ (h + 18) / (h + 60)$

h : Mean height, in m, above waterline to be taken as:
$h = 2\ A / 3\ L_E$

A : Area, in m^2, as given in [2.1.2]

L_E : Length, in m, as given in [2.1.2]

N : Number of breast lines.

4.2.2 Number

As a rule, two breast lines are to be fitted on board. However, for large ships, the number of breast lines may be increased in order to ensure that the diameter of the lines will be less than 72 mm, which is considered to be the maximum permissible diameter for handiness.

All the mooring lines are to be made of the same material and have the same diameter. However, when this diameter is greater than 63 mm, the head and stern lines will be replaced by four ones with lower diameter.

As a minimum, eight mooring lines are to be fitted on board:

- one head line and one stern line
- one forward spring and one after spring
- one forward breast line and one after breast line
- two spare lines (one breast line and one spring).

4.2.3 Length

As a rule, the length of the breast lines and the springs is to be between 0,7 L_E and L_E.

The length of head and stern lines is to be equal to 1,5 times the length of the other mooring lines.

4.2.4 Material

Mooring lines may be of natural or synthetic fibre or a mixture of wire and fibre.

4.3 Hawser for mooring to a buoy

4.3.1 Material

Each ship is to have a special hawser for mooring to a buoy. As a rule, this hawser is to be made of steel wire made of six strands with 7-fibre core.

4.3.2 Minimum breaking load

The minimum breaking load R, in daN, of the hawser is given by the relation:

$(R \cdot 10^{-3})^{0,5} > 0,17\ \Delta^{1/3} + 2$

where Delta

Δ : Displacement, in t, as given in [2.1.2].

Section 5 Masts and Other Outfitting Components

1 Masts

1.1 Application

1.1.1 The requirements of this Article apply to the arrangement of masts fitted on weather deck or on superstructure decks for supporting lights or other important fittings having significant mass with respect to the one of the mast structure.

The requirements in [1.2] apply for static analysis of masts subjected to still water, inertial and wind loads.

The requirements in [1.3] apply for the dynamic analysis of masts.

1.2 Static analysis of masts

1.2.1 General

In general, the inertial loads acting on the mast structures are to be obtained from a complete analysis of the ship motion and accelerations in irregular waves, whose results are to be submitted to the Society for approval. These loads are to be obtained as those that can be reached with a probability of 10^{-5} per cycle.

Extreme wind values are to be considered in association with these inertial loads.

However, when deemed acceptable by the Society, the design loads in [1.2.2] may be used for the structural analysis of masts.

1.2.2 Design loads

The design loads are constituted by still water, inertial and wind loads. The structural weight of the mast and the weight of the mast fittings and devices are to be taken into account when calculating the still water force F_S and the inertial force F_W, as indicated in Tab 1.

Table 1 : Still water force F_S and inertial force F_W

Ship condition	Load case	Forces F_S and F_W, in kN		
		in x direction	in y direction	in z direction
Still water condition		$F_{S,X} = 0{,}035\ g\ \Sigma_i\ W_i$ **(1)**	$F_{S,Y} = 0{,}087\ g\ \Sigma_i\ W_i$ **(2)**	$F_{S,Z} = g\ \Sigma_i\ W_i$
Upright condition	"a"	No inertial force		
	"b"	$F_{W,X} = \Sigma_i\ a_{X1,i}\ W_i$	–	$F_{W,Z} = \Sigma_i\ a_{Z1,i}\ W_i$
Inclined condition	"c"	–	$F_{W,Y} = C_{FA}\ \Sigma_i\ a_{Y2,i}\ W_i$	$F_{W,Z} = C_{FA}\ \Sigma_i\ a_{Z2,i}\ W_i$
	"d"			

(1) Still water force corresponding to a ship trim angle equal to 2°. Other trim angle values may be accepted if adequate documentation is provided to the Society

(2) Still water force corresponding to a ship heel angle equal to 5°. Other heel angle values may be accepted if adequate documentation is provided to the Society.

Note 1:

W_i : Mass, in t, of each one of the N mast components considered (i = 1 to N). It includes also the mass of mast structure and the mass of mast fittings and devices

$a_{X1,i}$, $a_{Z1,i}$: Reference values of the accelerations a_{X1} , a_{Z1} in the upright ship condition, defined in Ch 5, Sec 3, 3.4, calculated in way of the centre of gravity of each one of the N mast components considered (i = 1 to N)

$a_{Y2,i}$, $a_{Z2,i}$: Reference values of the accelerations a_{Y2} , a_{Z2} in the inclined ship condition, defined in Ch 5, Sec 3, 3.4, calculated in way of the centre of gravity of each one of the N mast components considered (i = 1 to N)

C_{FA} : Combination factor, to be taken equal to:

- $C_{FA} = 0{,}7$ for load case "c"
- $C_{FA} = 1{,}0$ for load case "d".

The wind force F_{Wind}, to be considered as being perpendicular to the surface of the mast exposed to the wind, is to be obtained, in N, from the following formula:

$F_{Wind} = 0,613\ C_S\ V^2\ A$

where:

C_S : Shape coefficient, to be taken equal to:
- $C_S = 1,6$ for lattice and flat-sided masts
- $C_S = 0,9$ for masts with circular cross-sections
- $C_S = 1,2$ for mast fittings

V : Wind speed, in m/s, to be taken, in general, not less than 63 m/s

A : Projected area, in m^2, of all the mast surfaces exposed to wind.

1.2.3 Structural analysis

In general, the structural analysis of masts is to be based on direct calculations performed through three-dimensional models. Direct calculations are to be carried out according to the following requirements:

- the structural modelling is to comply with the requirements from Ch 7, App 1, [2] to Ch 7, App 1, [4]
- the loads to be applied on the model are to comply with [1.2.1]
- the stress calculation is to comply with the requirements in Ch 7, App 1, [5].

However, structural analysis of masts based on isolate beam models, performed according to the requirements in Ch 7, Sec 3, [2], may be carried out when deemed acceptable by the Society depending on the structural typology and arrangement adopted for the mast.

When three-dimensional direct calculations are carried out, the structural model of the mast is to include a suitable portion of the hull structure supporting the mast, in order to avoid that the unavoidable inaccuracy in the modelling of the boundary conditions affect the results in the area to be analysed.

1.2.4 Strength check criteria of mast structures

The following strength checks of mast structures are to be carried out:

- yielding check, to be carried out according to Ch 7, Sec 3
- local buckling check of plate panels, to be carried out according to Ch 7, Sec 1, [5]
- column buckling check, to be carried out according to Ch 7, Sec 3, [5.2] and Ch 7, Sec 3, [5.3].

1.3 Dynamic analysis of masts

1.3.1 General

The dynamic analysis of masts is to be based on direct calculations performed through three-dimensional models.

The criteria adopted for structural modelling are to comply with the requirements specified in Ch 7, App 1.

In any case, the mesh accuracy is to be such that the stiffness and the mass distribution of the model elements of the mast, of the mast foundation and of the surrounding hull structure properly represent those of the actual structure.

1.3.2 Normal mode analysis

It is to be checked that each normal mode frequency f_{Ni}, in Hz, of the mast is in compliance with one of the following formulae:

$f_{Ni} < 0,8\ f_{E,MIN}$

$f_{Ni} > 1,2\ f_{E,MAX}$

where:

$f_{E,MIN}$, $f_{E,MAX}$:The lesser and the greater values, in Hz, respectively, among the possible excitations frequencies due to the ship motions or the propulsion system, to be calculated for the ship at the following speeds:
- cruise speed
- maximum continuous rate speed
- patrol speed.

The normal mode calculation method and the number of normal modes to be taken into account are considered by the Society on a case-by-case basis.

When at least one of the mast normal mode frequencies does not comply with the above formulae, a dynamic analysis is to be carried out according to the requirements in [1.3.2].

1.3.3 Dynamic analysis

It is to be checked that the dynamic effects induced in the mast by the ship's motions or propulsion system excitations are within the allowable limits, when this is required according to [1.3.2].

The dynamic effects are to be calculated by means of a dynamic analysis aiming at evaluating the response of the mast in the frequency domain.

When the dynamic analysis is based on normal models, their number is, in general, to be such that the modal effective mass is not less than 95% of the mass of the system constituted by the mast and its supporting structure.

The modal effective mass is defined as:

$$\sum_{i=1}^{N} \gamma_i^2$$

where γ_i is the i^{th} modal participation factor and N is the number of the considered normal modes.

The dynamic analysis criteria and the relevant allowable limits are considered by the Society on a case-by-case basis.

Where requested by the interested parties, the allowable limits may also take into account the serviceability limits of the mast fittings, i.e. the limits at which the efficiency of the mast fitting is impaired (e.g. because of excessive vibration level).

2 Outfitting components subjected to weapon firing loads

2.1 General

2.1.1 These requirements apply to the outfitting components that, because of their relative location with respect to a weapon, could be subjected to the weapon firing loads, but have not been designed to sustain them. Such components are to be completely enclosed within a protecting structure whose strength with respect to the weapon firing loads is to be checked by means of the applicable formulae in Part B, Chapter 7, where the loads are to be calculated according to Ch 5, Sec 6, [9].

If necessary, the protecting structure is to be provided with openings and closing devices. The strength of the closing devices is to be checked against the weapon firing loads as the protecting structure.

Appendix 1 Criteria for Direct Calculation of Rudder Loads

Symbols

ℓ_{10}, ℓ_{20}, ℓ_{30}, ℓ_{40}: Lengths, in m, of the individual girders of the rudder system (see Fig 1, Fig 2 and Fig 3)

ℓ_{50} : Length, in m, of the solepiece (see Fig 2 and Fig 4)

J_{10}, J_{20}, J_{30}, J_{40}: Moments of inertia about the x axis, in cm^4, of the individual girders of the rudder system having lengths ℓ_{10}, ℓ_{20}, ℓ_{30}, ℓ_{40} (see Fig 1, Fig 2 and Fig 3). For rudders supported by a solepiece only, J_{20} indicates the moment of inertia of the pintle in the sole piece

J_{50} : Moment of inertia about the z axis, in cm^4, of the solepiece (see Fig 2 and Fig 4)

C_R : Rudder force, in N, acting on the rudder blade, defined in Ch 9, Sec 1, [2.1.1]

C_{R1}, C_{R2} : Rudder forces, in N, defined in Ch 9, Sec 1, [2.2.3].

1 Criteria for direct calculation of the loads acting on the rudder structure

1.1 General

1.1.1 Application

The requirements of this Appendix apply to the following types of rudders:

- spade rudders (see Fig 1)
- 2 bearing rudders with solepiece (see Fig 2)
- 2 bearing semi-spade rudders with rudder horn (see Fig 3).

The requirements of this Appendix provide the criteria for calculating the following loads:

- bending moment M_B in the rudder stock
- support forces F_A
- bending moment M_R and shear force Q_R in the rudder body.

1.1.2 Load calculation

The loads in [1.1.1] are to be calculated through direct calculations based on the model specified in Fig 1, Fig 2 and Fig 3, depending on the type of rudder.

They are to be used for the stress analysis required in:

- Ch 9, Sec 1, [4], for the rudder stock
- Ch 9, Sec 1, [6], for the rudder pintles and the pintle bearings
- Ch 9, Sec 1, [7] for the rudder blade
- Ch 9, Sec 1, [8] for the rudder horn and the solepiece.

1.1.3 Specific case of spade rudders

For spade rudders, the results of direct calculations carried out in accordance with [1.1.2] may be expressed in an analytical form. The loads in [1.1.1] may therefore be obtained from the following formulae:

- maximum bending moment in the rudder stock, in N·m:

$$M_B = C_R\left(\ell_{20} + \frac{\ell_{10}(2C_1 + C_2)}{3(C_1 + C_2)}\right)$$

  where C_1 and C_2 are the lengths, in m, defined in Fig 1

- support forces, in N:

$$F_{A3} = \frac{M_B}{\ell_{30}}$$

$$F_{A2} = C_R + F_{A3}$$

- maximum shear force in the rudder body, in N:

$$Q_R = C_R$$

Figure 1 : Spade rudders

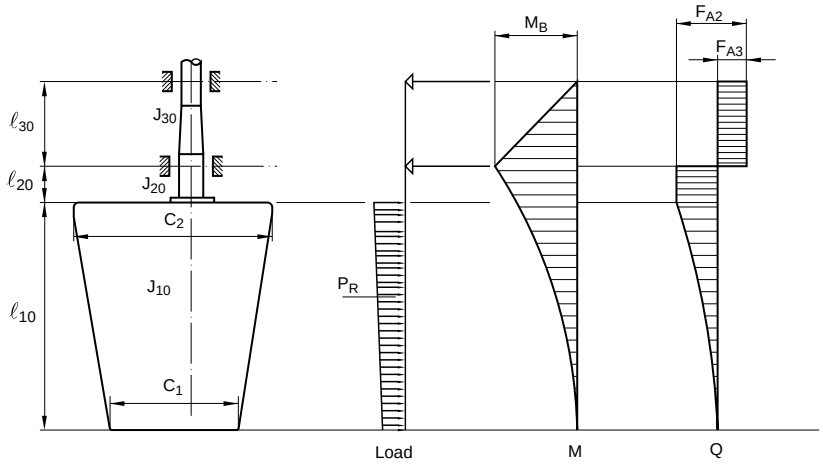


Figure 2 : 2 bearing rudders with solepiece

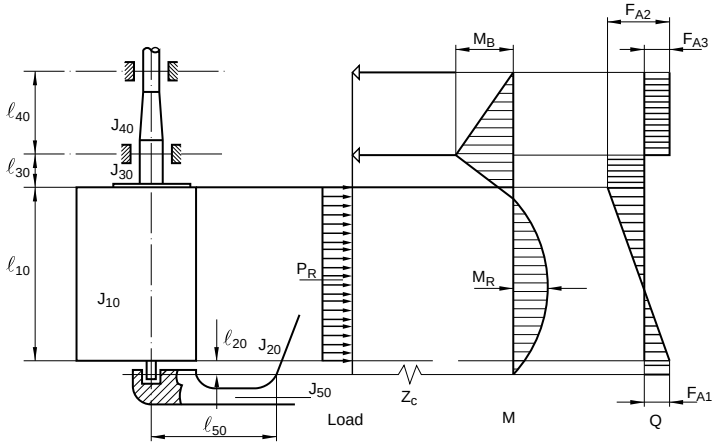


Figure 3 : 2 bearing semi-spade rudders with rudder horn

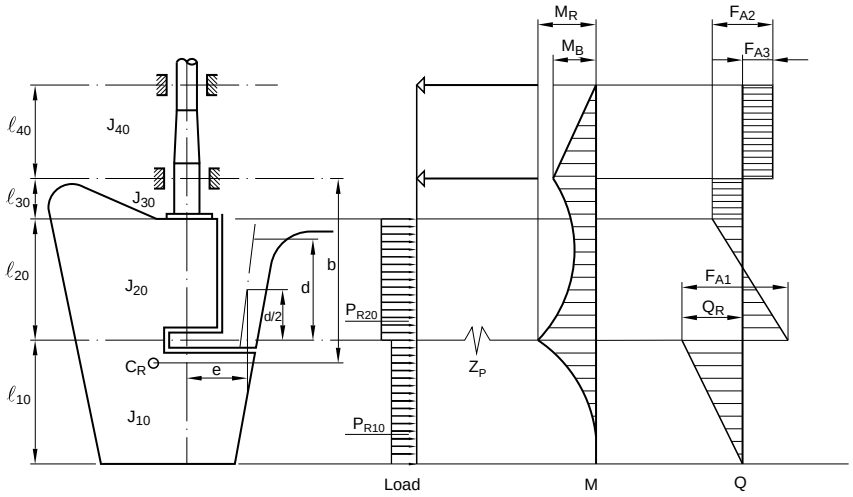
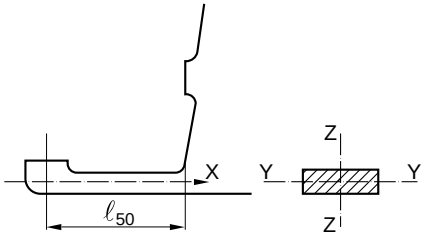


Figure 4 : Solepiece geometry



1.2 Data for the direct calculation

1.2.1 Forces per unit length

The following forces per unit length are to be calculated, in N/m, according to [1.3]:

- p_R for spade rudders and rudders with solepiece (see Fig 1 and Fig 2, respectively)
- p_{R10} and p_{R20} for semi-spade rudders with rudder horn (see Fig 3).

1.2.2 Spring constant

The following support spring constants are to be calculated, in N/m, according to [1.4]:

- Z_C for rudders with solepiece (see Fig 2)
- Z_P for semi-spade rudders with rudder horn (see Fig 3).

1.3 Force per unit length on the rudder body

1.3.1 Spade rudders and 2 bearing rudders with solepiece

The force per unit length p_R (see Fig 1 and Fig 2) acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_R = \frac{C_R}{\ell_{10}}$$

1.3.2 2 bearing semi-spade rudders with rudder horn

The forces per unit length p_{R10} and p_{R20} (see Fig 1) acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{\ell_{10}}$$

$$p_{R20} = \frac{C_{R1}}{\ell_{20}}$$

1.4 Support spring constant

1.4.1 Sole piece

The spring constant Z_C for the support in the solepiece (see Fig 2) is to be obtained, in N/m, from the following formula:

$$Z_C = \frac{6180 J_{50}}{\ell_{50}^3}$$

1.4.2 Rudder horn

The spring constant Z_P for the support in the rudder horn (see Fig 3) is to be obtained, in N/m, from the following formula:

$$Z_P = \frac{1}{f_B + f_T}$$

where:

f_B : Unit displacement of rudder horn due to a unit force of 1 N acting in the centroid of the rudder horn, to be obtained, in m/N, from the following formula:

$$f_B = 1{,}3\frac{d^3}{6180 J_N}$$

d : Height, in m, of the rudder horn, defined in Fig 3

J_N : Moment of inertia of rudder horn about the x axis, in cm^4 (see Fig 5)

f_T : Unit displacement due to torsion to be obtained, in m/N, from the following formula:

$$f_T = 10^{-8}\frac{de^2}{3140 F_T^2}\sum_i \frac{u_i}{t_i}$$

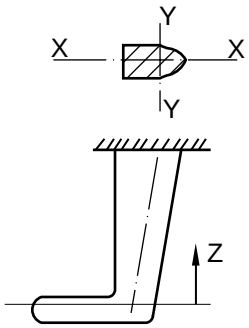
d, e : Lengths, in m, defined in Fig 3

F_T : Mean sectional area of rudder horn, in m^2

u_i : Length, in mm, of the individual plates forming the mean horn sectional area

t_i : Thickness of the individual plates mentioned above, in mm.

Figure 5 : Rudder horn geometry



Part B
Hull and Stability

CHAPTER 10
CORROSION PROTECTION AND LOADING INFORMATION

Section 1 Protection of Hull Metallic Structures

Section 2 Loading Manual and Loading Instruments

Section 1 Protection of Hull Metallic Structures

1 Protection by coating

1.1 General

1.1.1 It is the responsibility of the Shipbuilder and the Owner to choose the coating and have it applied in accordance with the manufacturer's requirements.

1.2 Structures to be protected

1.2.1 All salt water ballast spaces with boundaries formed by the hull envelope are to have a corrosion protective coating, epoxy or equivalent, applied in accordance with the manufacturer's requirements.

1.2.2 Corrosion protection of spaces other than ballast spaces is not a Class requirement.

1.2.3 Narrow spaces are generally to be filled by an efficient protective product, particularly at the ends of the ship where inspections and maintenance are not easily practicable due to their inaccessibility. Other equivalent dispositions may be accepted, such as demonstrated air watertightness without painting.

2 Cathodic protection

2.1 General

2.1.1 Internal structures in spaces intended to carry liquids may be provided with cathodic protection.

Cathodic protection may be fitted in addition to the required corrosion protective coating, if any.

2.1.2 Details concerning the type of anodes used and their location and attachment to the structure are to be submitted to the Society for approval.

2.2 Anodes

2.2.1 Magnesium or magnesium alloy anodes are not permitted in oil cargo tanks.

2.2.2 Aluminium anodes are only permitted in cargo tanks of tankers in locations where the potential energy does not exceed 28 kg·m. The height of the anode is to be measured from the bottom of the tank to the centre of the anode, and its weight is to be taken as the weight of the anode as fitted, including the fitting devices and inserts.

However, where aluminium anodes are located on horizontal surfaces such as bulkhead girders and stringers not less than 1 m wide and fitted with an upstanding flange or face flat projecting not less than 75 mm above the horizontal surface, the height of the anode may be measured from this surface.

Aluminium anodes are not to be located under tank hatches or Butterworth openings, unless protected by the adjacent structure.

2.2.3 There is no restriction on the positioning of zinc anodes.

2.2.4 Anodes are to have steel cores and are to be declared by the Manufacturer as being sufficiently rigid to avoid resonance in the anode support and designed so that they retain the anode even when it is wasted.

2.2.5 The steel inserts are to be attached to the structure by means of a continuous weld. Alternatively, they may be attached to separate supports by bolting, provided a minimum of two bolts with lock nuts are used. However, other mechanical means of clamping may be accepted.

2.2.6 The supports at each end of an anode may not be attached to separate items which are likely to move independently.

2.2.7 Where anode inserts or supports are welded to the structure, they are to be arranged by the Shipyard so that the welds are clear of stress peaks.

2.3 Impressed current systems

2.3.1 Impressed current systems are not permitted in oil cargo tanks.

3 Protection against galvanic corrosion

3.1 General

3.1.1 Non-stainless steel is to be electrically insulated from stainless steel or from aluminium alloys.

3.1.2 Where stainless steel or aluminium alloys are fitted in the same tank as non-stainless steel, a protective coating is to cover both materials.

4 Protection of bottom by ceiling

4.1 General

4.1.1 In double bottom ships, ceiling is to be laid over the inner bottom and lateral bilges, if any.

Ceiling on the inner bottom is not required where the thickness of the inner bottom is increased in accordance with Ch 7, Sec 1, [2.3.1].

4.2 Arrangement

4.2.1 Planks forming ceiling over the bilges and on the inner bottom are to be easily removable to permit access for maintenance.

4.2.2 Where the double bottom is intended to carry fuel oil, ceiling on the inner bottom is to be separated from the plating by means of battens 30 mm high, in order to facilitate the drainage of oil leakages to the bilges.

4.2.3 Where the double bottom is intended to carry water, ceiling on the inner bottom may lie next to the plating, provided a suitable protective composition is applied beforehand.

4.2.4 The Shipyard is to take care that the attachment of ceiling does not affect the tightness of the inner bottom.

4.2.5 In single bottom ships, ceiling is to be fastened to the reversed frames by galvanized steel bolts or any other equivalent detachable connection.

A similar connection is to be adopted for ceiling over the lateral bilges in double bottom ships.

4.3 Scantlings

4.3.1 The thickness of ceiling boards, when made of pine, is to be not less than 60 mm. Under cargo hatchways, the thickness of ceiling is to be increased by 15 mm.

Where the floor spacing is large, the thicknesses may be considered by the Society on a case-by-case basis.

5 Protection of decks by wood sheathing

5.1 General

5.1.1 Where decks are intended to carry specific loads, such as caterpillar trucks and unusual vehicles, the Society may require such decks wood sheathed.

5.2 Arrangement

5.2.1 Wood sheathing is to be fixed to the plating by welded studs or bolts of at least 12 mm in diameter, every second frame.

5.2.2 Before fitting the wood sheathing, deck plates are to be provided with protective coating declared to be suitable by the Shipyard.

Caulking is the Shipyard's responsibility.

5.3 Scantlings

5.3.1 The thickness of wood sheathing of decks is to be not less than:

- 65 mm for wood sheathing made of pine
- 50 mm for wood sheathing made of hardwood, such as teak.

The width of planks is not to exceed twice their thickness.

Section 2 Loading Manual and Loading Instruments

1 Definitions

1.1 Perpendiculars

1.1.1 Forward perpendicular

The forward perpendicular is the perpendicular to the waterline at the forward side of the stem on the full load waterline.

1.1.2 After perpendicular

The after perpendicular is the perpendicular to the waterline at the after side of the rudder post on the full load waterline. For ships without rudder post, the after perpendicular is the perpendicular to the waterline at the centre of the rudder stock on the full load waterline.

1.1.3 Midship perpendicular

The midship perpendicular is the perpendicular to the waterline at half the distance between forward and after perpendiculars.

2 Loading manual and loading instrument requirement criteria

2.1 General

2.1.1 The loading instrument is ship specific onboard equipment and the results of the calculations are only applicable to the ship for which it has been approved.

An approved loading instrument may not replace an approved loading manual.

3 Loading manual

3.1 Definitions

3.1.1 A loading manual is a document which describes:

- the loading conditions on which the design of the ship has been based, including permissible limits of still water bending moment and shear force
- the results of the calculations of still water bending moments, shear forces and, where applicable, limitations due to torsional and lateral loads
- the allowable local loading for the structure (hatch covers, decks, double bottom, etc.).

3.2 Conditions of approval

3.2.1 The approved loading manual is to be based on the final data of the ship. The manual is to include the design (full load and operational) loading conditions, subdivided into departure and arrival conditions as appropriate, upon which the approval of the hull scantlings is based, defined in Ch 5, Sec 2, [2.1.2].

In the case of modifications resulting in changes to the main data of the ship, a new approved loading manual is to be issued.

3.2.2 Language

The loading manual is to be prepared in a language understood by the users. If this is not English, a translation into English is to be included.

4 Loading instrument

4.1 Definitions

4.1.1 A loading instrument is an instrument which is either analog or digital and by means of which it can be easily and quickly ascertained that, at specified read-out points, the still water bending moments, shear forces and still water torsional moments and lateral loads, where applicable, in any load or ballast condition, do not exceed the specified permissible values.

An operational manual is always to be provided for the loading instrument.

Single point loading instruments are not acceptable.

4.2 Conditions of approval

4.2.1 The loading instrument is subject to approval, which is to include:

- verification of type approval, if any
- verification that the final data of the ship have been used
- acceptance of number and position of all read-out points
- acceptance of relevant limits for read-out points
- checking of proper installation and operation of the instrument on board, under agreed test conditions, and that a copy of the operation manual is available.

4.2.2 In the case of modifications implying changes in the main data of the ship, the loading instrument is to be modified accordingly and approved.

4.2.3 The operation manual and the instrument output are to be prepared in a language understood by the users. If this is not English, a translation into English is to be included.

4.2.4 The operation of the loading instrument is to be verified upon installation under the agreed test conditions. It is to be checked that the agreed test conditions and the operation manual for the instrument are available on board.

4.2.5 When the loading instrument also performs stability calculations, it is to be approved for stability purposes in accordance with the procedures indicated in [4.5] and [4.6], as applicable.

4.3 Approval procedure

4.3.1 General

The loading instrument approval process includes the following procedures for each ship:

- data verification which results in endorsed test conditions
- approval of computer hardware, where necessary, as specified in Pt C, Ch 3, Sec 6, [2.4]
- installation testing which results in an Installation Test Report.

4.3.2 Data verification approval - Endorsed test conditions

The Society is to verify the results and actual ship data used by the calculation program for the particular ship on which the program will be installed.

Upon application for data verification, the Society is to advise the applicant of a minimum of four loading conditions, taken from the ship approved loading manual, which are to be used as the test conditions. Within the range of these test conditions, each compartment is to be loaded at least once. The test conditions normally cover the range of load draughts from the deepest envisaged loaded condition to the light ballast condition. In addition, the lightship test condition is to be submitted.

When the loading instrument also performs stability calculations, the test conditions are to be taken from the ship approved trim and stability booklet.

The data indicated in [4.3.3] and contained in the loading program are to be consistent with the data specified in the approved loading manual. Particular attention is drawn to the final lightship weight and centres of gravity derived from the inclining experiment or lightweight check.

The approval of the computer application software is based on the acceptance of the results of the test conditions according to [4.4], [4.5] and [4.6] as applicable.

When the requested information has been submitted and the results of the test conditions are considered satisfactory, the Society endorses the test conditions, a copy of which is to be available on board.

4.3.3 Data to be submitted

The following data, submitted by the applicant, are to be consistent with the as-built ship:

- identification of the calculation program including the version number
- main dimensions, hydrostatic particulars and, if applicable, ship profile
- position of the forward and after perpendiculars and, if appropriate, the calculation method to derive the forward and after draughts at the actual position of the ship draught marks
- ship lightweight and lightweight distribution along the ship length
- lines plans and/or offset tables
- compartment definitions, including frame spacing and centre of volumes, together with capacity tables (sounding/ullage tables), if appropriate
- deadweight definitions for each loading condition.

4.3.4 Installation testing

During the installation test, one of the ship senior officers is to operate the loading instrument and calculate the test conditions. This operation is to be witnessed by a Surveyor of the Society. The results obtained from the loading instrument are to be identical to those stated in the endorsed test conditions. If the numerical output from the loading instrument is different from the endorsed test conditions, no approval will be confirmed.

An installation test is also to be carried out on the second nominated computer, when applicable as indicated in Pt C, Ch 3, Sec 6, [2.4], which would be used in the event of failure of the first computer. Where the installation test is carried out on a type approved computer, a second nominated computer and test are not required.

Subject to the satisfactory completion of installation tests, the Society's Surveyor endorses the test conditions, adding details of the place and the date of the installation test survey, as well as the Society stamp and the Surveyor's signature.

4.3.5 Operational manual

A uniquely identified ship specific operational manual is to be submitted to the Society for documentation.

The operational manual is to be written in a concise and unambiguous manner. The use of illustrations and flowcharts is recommended.

The operational manual is to contain:

- a general description of the program denoting identification of the program and its stated version number
- details of the hardware specification needed to run the loading program
- a description of error messages and warnings likely to be encountered, and unambiguous instructions for subsequent actions to be taken by the user in each case
- where applicable, the shear force correction factors
- where applicable, the local permissible limits for single and two adjacent hold loadings as a function of the appropriate draught and the maximum weight for each hold
- where applicable, the Society's restrictions (maximum allowable load on double bottom, maximum specific gravity allowed in liquid cargo tanks, maximum filling level or percentage in liquid cargo tanks)
- example of a calculation procedure supported by illustrations and sample computer output
- example computer output of each screen display, complete with explanatory text.

4.3.6 Calculation program specifications

The software is to be written so as to ensure that the user cannot alter the critical ship data files containing the following information:

- lightship weight and lightship weight distribution and associated centres of gravity
- the Society's structural limitations or restrictions
- geometric hull form data
- hydrostatic data and cross curves, where applicable
- compartment definitions, including frame spacing and centre of volumes, together with capacity tables (sounding/ullage tables), if appropriate.

Any changes in the software are to be made by the manufacturer or his appointed representative and the Society is to be informed immediately of such changes. Failure to advise of any modifications to the calculation program may invalidate the approval issued. In cases where the approval is considered invalid by the Society, the modified calculation program is to be re-assessed in accordance with the approval procedure.

4.3.7 Functional specification

The calculation program is to be user-friendly and designed such that it limits possible input errors by the user.

The forward, midship and after draughts, at the respective perpendiculars, are to be calculated and presented to the user on screen and hardcopy output in a clear and unambiguous manner.

It is recommended that the forward, midship and after draughts, at the actual position of the ship draught marks are calculated and presented to the user on screen and hard copy output in a clear and unambiguous manner.

The displacement is to be calculated for the specified loading condition and corresponding draught readings and presented to the user on screen and hardcopy output.

The loading instrument is to be capable of producing print-outs of the results in both numerical and graphical forms. The numerical values are to be given in both forms, as absolute values and as the percentage of the permissible values. This print-out is to include a description of the corresponding loading condition.

All screen and hardcopy output data is to be presented in a clear and unambiguous manner with an identification of the calculation program (the version number is to be stated).

4.4 Hull girder forces and moments

4.4.1 General

The loading program is to be capable of calculating the following hull girder forces and moments in accordance with Ch 5, Sec 2, [2]:

- still water shear force (SWSF) including the shear force correction, where applicable
- still water bending moment (SWBM).

The data which are to be provided to, or accepted by, the Society are specified in Tab 1.

Read-out points are usually to be selected at the position of the transverse bulkheads or other obvious boundaries.

The calculated forces and moments are to be displayed in both graphical and tabular formats, including the percentage of permissible values. The screen and hardcopy output is to display the calculated forces or moments, and the corresponding permissible limits, at each specified read-out point. Alternative limits may be considered by the Society on a case-by-case basis.

Table 1 : Data to be provided to (or accepted by) the Society

Calculation	Data
Still water shear force (SWSF)	• The read-out points (frame locations) for the SWSF calculations. These points are normally selected at the position of the transverse bulkhead or other obvious boundaries. Additional read-out points may be specified between the bulkheads of long holds or tanks or between container stacks • Shear force correction factors and method of application • The permissible seagoing and harbour SWSF limits at the read-out points. Where appropriate, additional sets of permissible SWSF values may be specified
Still water bending moment (SWBM)	• The read-out points (frame locations) for the SWBM calculations. These points are normally selected at the position of the transverse bulkhead, mid-hold or other obvious boundaries • The permissible seagoing and harbour SWBM limits at the read-out points. Where appropriate, additional sets of permissible SWBM values may be specified

4.4.2 Acceptable tolerances

The accuracy of the calculation program is to be within the acceptable tolerance band, specified in Tab 2, of the results at each read-out point obtained by the Society, using an independent program or the approved loading manual with identical input.

Table 2 : Tolerance band for the comparison of computational accuracy

Computation	Tolerance (percentage of the permissible values)
Still water shear force	± 5%
Still water bending moment	± 5%

4.4.3 Permissible limits and restrictions

The user is to be able to view the following Society structural limitations in a clear and unambiguous manner:

- all permissible still water shear forces and still water bending moments
- cargo hold weight
- ballast tank/hold capacities
- filling restrictions.

It is to be readily apparent to the user when any of the structural limits has been exceeded.

4.5 Intact stability

4.5.1 Application

The loading instrument approval for stability purposes is required when a loading instrument to be installed on board a ship performs stability calculations, as stated in [4.2.5].

4.5.2 Data verification approval - Endorsed test conditions

The requirements in [4.3.2] apply. In addition, at least one of the four loading conditions required is to show the compartments, intended for liquid loads in which the free surface effect is considerable, filled in order to have the maximum free surface moment.

The additional data necessary for the approval of the loading instrument for stability purposes are specified in [4.5.3].

In order to obtain the approval of the loading instrument, all the intact stability requirements (and relevant criteria) applicable to the ship, reported in Ch 3, Sec 2 as well as in [4.5.2], are to be available in the computer output; the lack of any one of them is sufficient to prevent the endorsement of the test conditions.

4.5.3 Additional data to be submitted

In addition to the data required in [4.3.3], the following are to be submitted:

- cross curves of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves
- capacity tables indicating, for each compartment or space, the values of the co-ordinates X_G, Y_G and Z_G of the centre of gravity, as well as the inertia, corresponding to an adequate number of filling percentages
- list of all the openings (location, tightness, means of closure), pipes or other sources which may lead to progressive flooding
- deadweight definitions for each loading condition in which, for any load taken into account, the following information is to be specified:
  - weight and centre of gravity co-ordinates
  - percentage of filling (if liquid load)
  - free surface moment (if liquid load)
- information on loading restrictions (maximum filling level or percentage in liquid cargo tanks, maximum KG or minimum GM curve or table which can be used to determine compliance with the applicable intact and damage stability criteria), when applicable
- all the intact stability criteria applicable to the ship concerned.

4.6 Damage stability

4.6.1 Application

The loading instrument approval for stability purposes is required when a loading instrument to be installed on board a ship performs damage stability calculations, as stated in [4.2.5].

In such case, the loading instrument is also to perform intact stability calculations, and therefore the approval is to be based on the requirements specified in [4.5].

Additional requirements relevant to damage stability are given in [4.6.2] and [4.6.3].

4.6.2 Data verification approval - Endorsed test conditions

The requirements specified in [4.5.2] apply.

The additional data necessary for the approval of the loading instrument for stability purposes are specified in [4.6.3].

The approval of damage stability calculations performed by a loading instrument is limited to those relevant to deterministic damage stability rules specified in Part D. In order to obtain the approval of the loading instrument, all the damage stability requirements (and relevant criteria) applicable to the ship are to be available in the computer output. The lack of any one of them is sufficient to prevent the endorsement of the test conditions.

4.6.3 Additional data to be submitted

In addition to the data required in [4.5.3], the following are to be submitted:

- list of all the damage cases which are to be considered in accordance with the relevant deterministic damage stability rules

  Each damage case is to clearly indicate all the compartments or spaces taken into account, as well as the permeability associated with each compartment or space.

  This information is to be taken from the approved damage stability documentation, and the source details are to be clearly indicated; in the case of unavailability of such documentation, the above-mentioned information may be requested from the Society.
- all the damage stability criteria applicable to the ship concerned.

CHAPTER 11
CONSTRUCTION AND TESTING

Section 1 Welding and Weld Connections

Section 2 Special Structural Details

Section 3 Testing

Appendix 1 Welding Details

Appendix 2 Reference Sheets for Special Structural Details

Section 1 Welding and Weld Connections

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the preparation, execution and inspection of welded connections in hull structures.

They are to be complemented by the criteria given in Ch 11, App 1, to which reference is made. These criteria being given as recommendations, minor departures may be accepted by the Society, on a case-by-case basis.

The general requirements relevant to fabrication by welding and qualification of welding procedures are given in NR216 Materials and Welding, Chapter 5.

1.1.2 Weld connections are to be executed according to the approved plans. Any detail not specifically represented in the plans is, if any, to comply with the applicable requirements.

1.1.3 It is understood that welding of the various types of steel is to be carried out by means of welding procedures approved for the purpose, even though an explicit indication to this effect may not appear on the approved plans.

1.1.4 The quality standard adopted by the shipyard is to be submitted to the Society and applies to all constructions unless otherwise specified on a case-by-case basis.

1.2 Base material

1.2.1 The requirements of this Section apply for the welding of hull structural steels or aluminium alloys of the types considered in NR216 Materials and Welding, or other types accepted as equivalent by the Society.

1.2.2 The service temperature is intended to be the ambient temperature, unless otherwise stated.

1.3 Documentation to be submitted

1.3.1 The structural plans to be submitted for approval, according to Ch 1, Sec 3, are to contain the necessary data relevant to the fabrication by welding of the structures and items represented as far as class is concerned.

For important structures, the main sequences of prefabrication, assembly and welding and non-destructive examination planned are also to be represented in the plans.

1.3.2 A plan showing the location of the various steel types is to be submitted at least for outer shell, deck and bulkhead structures.

1.4 Design

1.4.1 General

For the various structural details typical of welded construction in shipbuilding and not dealt with in this Section, the rules of good practice, recognized standards and past experience are to apply as agreed by the Society.

1.4.2 Plate orientation

The plates of the shell and strength deck are generally to be arranged with their length in the fore-aft direction. Possible exceptions to the above will be considered by the Society on a case-by-case basis; tests as deemed necessary (for example, transverse impact tests) may be required by the Society.

1.4.3 Overall arrangement

Particular consideration is to be given to the overall arrangement and structural details of highly stressed parts of the hull.

Drawings relevant to the special details specified in Ch 11, Sec 2 are to be submitted.

1.4.4 Prefabrication sequences

Prefabrication sequences are to be arranged so as to facilitate positioning and assembling as far as possible.

The amount of welding to be performed on board is to be limited to a minimum and restricted to easily accessible connections.

1.4.5 Distance between welds

Welds located too close to one another are to be avoided. The minimum distance between two adjacent welds is considered on a case-by-case basis, taking into account the level of stresses acting on the connected elements.

In general, the distance between two adjacent butts in the same strake of shell or deck plating is to be greater than two frame spaces.

1.5 Welding consumables and procedures

1.5.1 Approval of welding consumables and procedures

Welding consumables and welding procedures adopted are to be approved by the Society.

The requirements for the approval of welding consumables are given in NR216 Materials and Welding, Chapter 11.

The requirements for the approval of welding procedures are given in NR216 Materials and Welding, Chapter 12.

1.5.2 Consumables

For welding of hull structural steels, the minimum consumable grades to be adopted are specified in Tab 1 depending on the steel grade.

Consumables used for manual or semi-automatic welding (covered electrodes, flux-cored and flux-coated wires) of higher strength hull structural steels are to be at least of hydrogen-controlled grade H15 (H). Where the carbon equivalent C_{eq} is not more than 0,41% and the thickness is below 30 mm, any type of approved higher strength consumables may be used at the discretion of the Society.

Especially, welding consumables with hydrogen-controlled grade H15 (H) and H10 (HH) shall be used for welding hull steel forgings and castings of respectively ordinary strength level and higher strength level.

Table 1 : Consumable grades

Steel grade	Consumable minimum grade	
	Butt welding, partial and full T penetration welding	Fillet welding
A	1	1
B - D	2	
E	3	
AH32 - AH36 DH32 - DH36	2Y	2Y
EH32 - EH36	3Y	
FH32 - FH36	4Y	
AH40	2Y40	2Y40
DH40 - EH40	3Y40	
FH40	4Y40	
Note 1: Welding consumables approved for welding higher strength steels (Y) may be used in lieu of those approved for welding normal strength steels having the same or a lower grade; welding consumables approved in grade Y40 may be used in lieu of those approved in grade Y having the same or a lower grade. **Note 2:** In the case of welded connections between two hull structural steels of different grades, as regards strength or notch toughness, welding consumables appropriate to one or the other steel are to be adopted.		

1.6 Personnel and equipment

1.6.1 Welders

Manual and semi-automatic welding is to be performed by welders certified by the Society as specified in the Rule Note NR476 Approval Testing of Welders. The welders are to be employed within the limits of their respective approval.

1.6.2 Automatic welding operators

Personnel manning automatic welding machines and equipment are to be competent and sufficiently trained.

1.6.3 Organisation

The internal organization of the shipyard is to be such as to ensure compliance in full with the requirements in [1.6.1] and [1.6.2] and to provide for assistance and inspection of welding personnel, as necessary, by means of a suitable number of competent supervisors.

1.6.4 Non-destructive testing operators

Non-destructive tests are to be carried out by qualified personnel, certified by recognized bodies in compliance with appropriate standards.

The qualifications are to be appropriate to the specific applications.

1.6.5 Technical equipment and facilities

The welding equipment is to be appropriate to the adopted welding procedures, of adequate output power and such as to provide for stability of the arc in the different welding positions.

In particular, the welding equipment for special welding procedures is to be provided with adequate and duly calibrated measuring instruments, enabling easy and accurate reading, and adequate devices for easy regulation and regular feed.

Manual electrodes, wires and fluxes are to be stored in suitable locations so as to ensuring their preservation in proper condition. Especially, where consumables with hydrogen-controlled grade are to be used, proper precautions are to be taken to ensure that manufacturer's instructions are followed to obtain (drying) and maintain (storage, maximum time exposed, re-backing, ...) hydrogen-controlled grade.

2 Type of connections and preparation

2.1 General

2.1.1 The type of connections and the edge preparation are to be appropriate to the welding procedure adopted, the structural elements to be connected and the stresses to which they are subjected.

2.2 Butt welding

2.2.1 General

In general, butt connections of plating are to be full penetration, welded on both sides except where special procedures or specific techniques, considered equivalent by the Society, are adopted.

Connections different from the above may be accepted by the Society on a case-by-case basis; in such cases, the relevant detail and workmanship specifications are to be approved.

2.2.2 Welding of plates with different thicknesses

In the case of welding of plates with a difference in gross thickness equal to, or greater than:

- 3 mm, if the thinner plate has a gross thickness equal to, or less than, 10 mm
- 4 mm, if the thinner plate has a gross thickness greater than 10 mm,

a taper having a length of not less than 4 times the difference in gross thickness is to be adopted for connections of plating perpendicular to the direction of main stresses. For connections of plating parallel to the direction of main stresses, the taper length may be reduced to 3 times the difference in gross thickness.

When the difference in thickness is less than the above values, it may be accommodated in the weld transition between plates.

For large thicknesses (e.g. 25mm), other criteria may be considered on a case-by-case basis, when deemed equivalent.

2.2.3 Edge preparation, root gap

Typical edge preparations and gaps are indicated in Ch 11, App 1.

The acceptable root gap is to be in accordance with the adopted welding procedure and relevant bevel preparation.

2.2.4 Butt welding on permanent backing

Butt welding on permanent backing, i.e. butt welding assembly of two plates backed by the flange or the face plate of a stiffener, may be accepted where back welding is not feasible or in specific cases deemed acceptable by the Society.

The type of bevel and the gap between the members to be assembled are to be such as to ensure a proper penetration of the weld on its backing and an adequate connection to the stiffener as required.

2.2.5 Section, bulbs and flat bars

When lengths of longitudinals of the shell plating and strength deck within 0,6 L amidships, or elements in general subject to high stresses, are to be connected together by butt joints, these are to be full penetration. Other solutions may be adopted if deemed acceptable by the Society on a case-by-case basis.

The work is to be done in accordance with an approved procedure; in particular, this requirement applies to work done on board or in conditions of difficult access to the welded connection. Special measures may be required by the Society.

2.3 Fillet welding

2.3.1 General

In general, ordinary fillet welding (without bevel) may be adopted for T connections of the various simple and composite structural elements.

Where stress level is high or where there is a possibility of local laminations, partial or full T penetration welding according to [2.4] may be requested by the Society.

2.3.2 Fillet welding types

Fillet welding may be of the following types:

- continuous fillet welding, where the weld is constituted by a continuous fillet on each side of the abutting plate (see [2.3.3])
- intermittent fillet welding, which may be subdivided (see [2.3.4]) into:
  - chain welding
  - scallop welding
  - staggered welding.

2.3.3 Continuous fillet welding

Continuous fillet welding is to be adopted:

- for watertight connections
- for connections of brackets, lugs and scallops
- at the ends of connections for a length of at least 75 mm
- where intermittent welding is not allowed, according to [2.3.4].

Continuous fillet welding may also be adopted in lieu of intermittent welding wherever deemed suitable, and it is recommended where the spacing p, calculated according to [2.3.4], is low.

2.3.4 Intermittent welding

The spacing p and the length d, in mm, of an intermittent weld, shown in Tab 2 for chain welding, scallop welding or staggered welding, are to be such that:

$$\frac{p}{d} \leq \varphi$$

where the coefficient φ is defined in Tab 3 and Tab 4 for the different types of intermittent welding, depending on the type and location of the connection.

In general, staggered welding is not allowed for connections subjected to high alternate stresses.

In addition, the limitations defined in Tab 2 are to be complied with.

Table 2 : Intermittent welding

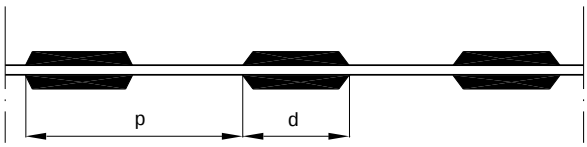
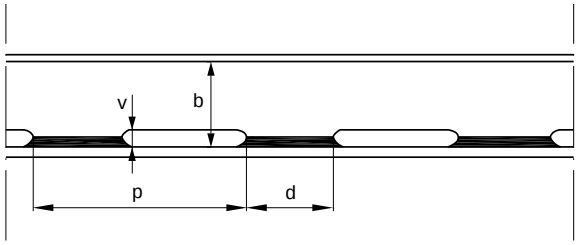
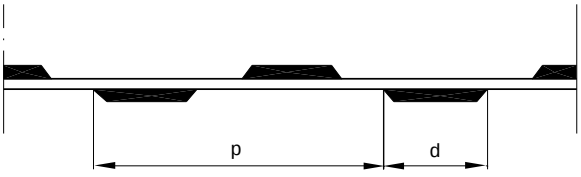
Intermittent chain welding: d ≥ 75 mm p – d ≤ 200 mm	
Intermittent scallop welding: d ≥ 75 mm p – d ≤ 150 mm v ≤ 0,25 b, without being greater than 75 mm	
Intermittent staggered welding: d ≥ 75 mm p – 2d ≤ 300 mm p ≤ 2d for connections subjected to high alternate stresses	

Table 3 : Welding factor w_F and coefficient φ for the various hull structural connections

Hull area	Connection of	Connection to		w_F **(1)**	φ**(2)(3)** CH	SC	ST	p_1, in mm (see [2.3.6])**(3)**
General, unless otherwise specified in the table	watertight plates	boundaries		0,35				
	webs of ordinary stiffeners	plating		0,13	3,5	3,0	4,6	ST 260
		face plate of fabricated stiffeners	at ends**(4)**	0,13				
			elsewhere	0,13	3,5	3,0	4,6	ST 260
Bottom and double bottom	longitudinal ordinary stiffeners	bottom and inner bottom plating		0,13	3,5	3,0	4,6	ST 260
	centre girder	keel		0,25	1,8	1,8		CH/SC 130
		inner bottom plating		0,20	2,2	2,2		CH/SC 160
	side girders	bottom and inner bottom plating		0,13	3,5	3,0	4,6	ST 260
		floors (interrupted girders)		0,20	2,2			CH 160
	floors	bottom and inner bottom plating	in general	0,13	3,5	3,0	4,6	ST 260
			at ends (20% of span) for longitudinally framed double bottom	0,25	1,8			CH 130
		inner bottom plating in way of brackets of primary supporting members		0,25	1,8			CH 130
		girders (interrupted floors)		0,20	2,2			CH 160
		side girders in way of hopper tanks		0,35				
	partial side girders	floors		0,25	1,8			CH 130
	web stiffeners	floor and girder webs		0,13	3,5	3,0	4,6	ST 260
Side and inner side	ordinary stiffeners	side and inner side plating		0,13	3,5	3,0	4,6	ST 260
	girders in double side skin ships	side and inner side plating		0,35				
Deck	strength deck	side plating		Partial penetration welding				
	non-watertight decks	side plating		0,20	2,2			CH 160
	ordinary stiffeners and intercostal girders	deck plating		0,13	3,5	3,0	4,6	ST 260
	hatch coamings	deck plating	in general	0,35				
			at corners of hatchways for 15% of the hatch length	0,45				
	web stiffeners	coaming webs		0,13	3,5	3,0	4,6	ST 260
Bulkheads	tank bulkhead structures	tank bottom	plating and ordinary stiffeners (plane bulkheads)	0,45				
			vertical corrugations (corrugated bulkheads)	Full penetration welding, in general				
		boundaries other than tank bottom		0,35				
	watertight bulkhead structures	boundaries		0,35				
	non-watertight bulkhead structures	boundaries	wash bulkheads	0,20	2,2	2,2		CH/SC 160
			others	0,13	3,5	3,0	4,6	ST 260
	ordinary stiffeners	bulkhead plating	in general **(5)**	0,13	3,5	3,0	4,6	ST 260
			at ends (25% of span), where no end brackets are fitted	0,35				
Structures located forward of 0,75 L from the AE **(6)**	bottom longitudinal ordinary stiffeners	bottom plating		0,20	2,2			CH 160
	floors and girders	bottom and inner bottom plating		0,25	1,8			CH 130
	side frames in panting area	side plating		0,20	2,2			CH 160
	webs of side girders in single side skin structures	side plating and face plate	A < 65 cm^2 **(7)**	0,25	1,8	1,8		CH/SC 130
			A ≥ 65 cm^2 **(7)**	see Tab 4				

Hull area	Connection			w_F **(1)**	φ**(2)(3)**			p_1, in mm (see [2.3.6])**(3)**
	of	to			CH	SC	ST	
After peak **(6)**	internal structures	each other		0,20				
	side ordinary stiffeners	side plating		0,20				
	floors	bottom and inner bottom plating		0,20				
Machinery space **(6)**	centre girder	keel and inner bottom plating	in way of main engine foundations	0,45				
			in way of seating of auxiliary machinery and boilers	0,35				
			elsewhere	0,25	1,8	1,8		CH/SC 130
	side girders	bottom and inner bottom plating	in way of main engine foundations	0,45				
			in way of seating of auxiliary machinery and boilers	0,35				
			elsewhere	0,20	2,2	2,2		CH/SC 160
	floors (except in way of main engine foundations)	bottom and inner bottom plating	in way of seating of auxiliary machinery and boilers	0,35				
			elsewhere	0,20	2,2	2,2		CH/SC 160
	floors in way of main engine foundations	bottom plating		0,35				
		foundation plates		0,45				
	floors	centre girder	single bottom	0,45				
			double bottom	0,25	1,8	1,8		CH/SC 130
Superstructures and deckhouses	external bulkheads	deck	in general	0,35				
			engine and boiler casings at corners of openings (15% of opening length)	0,45				
	internal bulkheads	deck		0,13	3,5	3,0	4,6	ST 260
	ordinary stiffeners	external and internal bulkhead plating		0,13	3,5	3,0	4,6	ST 260
Hatch covers	ordinary stiffener	plating		0,13	3,5	3,0	4,6	ST 260
Pillars	elements composing the pillar section	each other (fabricated pillars)		0,13				
	pillars	deck	pillars in compression	0,35				
			pillars in tension	Full penetration welding				
Ventilators	coamings	deck		0,35				
Rudders	horizontal and vertical webs directly connected to solid parts	each other		0,45				
	other webs	each other		0,20		2,2		SC 160
	webs	plating	in general	0,20		2,2		SC 160
			top and bottom plates of rudder plating	0,35				
		solid parts or rudder stock		according to Ch 9, Sec 1, [7.4] or Ch 9, Sec 1, [7.5]				

(1) In connections for which $w_F \geq 0,35$, continuous fillet welding is to be adopted.

(2) For coefficient φ, see [2.3.4]. In connections for which no φ value is specified for a certain type of intermittent welding, such type is not permitted and continuous welding is to be adopted.

(3) CH = chain welding, SC = scallop welding, ST = staggered welding.

(4) Ends of ordinary stiffeners means the area extended 75 mm from the span ends. Where end brackets are fitted, ends means the area extended in way of brackets and at least 50 mm beyond the bracket toes.

(5) In tanks intended for the carriage of ballast or fresh water, continuous welding with $w_F = 0,35$ is to be adopted.

(6) For connections not mentioned, the requirements for the central part apply.

(7) A is the face plate sectional area of the side girders, in cm^2.

Table 4 : Welding factor w_F and coefficient φ for connections of primary supporting members

Primary supporting member	Connection			w_F**(1)**	φ **(2) (3)**			p_1, in mm (see [2.3.6])**(3)**
	of	to			CH	SC	ST	
General**(4)**	web, where A < 65 cm²	plating and face plate	at ends	0,20				
			elsewhere	0,15	3,0	3,0		CH/SC 210
	web, where A ≥ 65 cm²	plating		0,35				
		face plate	at ends	0,35				
			elsewhere	0,25	1,8	1,8		CH/SC 130
	end brackets	face plate		0,35				
In tanks, where A < 65 cm² **(5)**	web	plating	at ends	0,25				
			elsewhere	0,20	2,2	2,2		CH/SC 160
		face plate	at ends	0,20				
			elsewhere	0,15	3,0	3,0		CH/SC 210
	end brackets	face plate		0,35				
In tanks, where A ≥ 65 cm²	web	plating	at ends	0,45				
			elsewhere	0,35				
		face plate		0,35				
	end brackets	face plate		0,45				

(1) In connections for which $w_F \geq 0,35$, continuous fillet welding is to be adopted.

(2) For coefficient φ, see [2.3.4]. In connections for which no φ value is specified for a certain type of intermittent welding, such type is not permitted.

(3) CH = chain welding, SC = scallop welding, ST = staggered welding.

(4) For cantilever deck beams, continuous welding is to be adopted.

(5) For primary supporting members in tanks intended for the carriage of ballast or fresh water, continuous welding is to be adopted.

Note 1: A is the face plate sectional area of the primary supporting member, in cm².

Note 2: Ends of primary supporting members means the area extended 20% of the span from the span ends. Where end brackets are fitted, ends means the area extended in way of brackets and at least 100 mm beyond the bracket toes.

2.3.5 Throat thickness of fillet weld T connections

The throat thickness of fillet weld T connections is to be obtained, in mm, from the following formula:

$$t_T = w_F t \frac{p}{d}$$

where:

w_F : Welding factor, defined in Tab 3 for the various hull structural connections; for connections of primary supporting members belonging to single skin structures and not mentioned in Tab 3, w_F is defined in Tab 4

t : Actual gross thickness, in mm, of the structural element which constitutes the web of the T connection

p, d : Spacing and length, in mm, of an intermittent weld, defined in [2.3.4].

For continuous fillet welds, p/d is to be taken equal to 1.

In no case may the throat thickness be less than:

- 3,0 mm, where the gross thickness of the thinner plate is less than 6 mm
- 3,5 mm, otherwise.

The throat thickness may be required by the Society to be increased, depending on the results of structural analyses.

The leg length of fillet weld T connections is to be not less than 1,4 times the required throat thickness.

2.3.6 Weld dimensions in a specific case

Where intermittent fillet welding is adopted with:

- length d = 75 mm
- throat thickness t_T specified in Tab 5 depending on the thickness t defined in [2.3.5],

the weld spacing may be taken equal to the value p_1 defined in Tab 1. The values of p_1 in Tab 3 may be used when 8 mm ≤ t ≤ 16 mm.

For thicknesses t less than 8 mm, the values of p_1 may be increased, with respect to those in Tab 3, by:

- 10 mm, for chain or scallop welding
- 20 mm, for staggered welding,

without exceeding the limits given in [2.3.4].

For thicknesses t greater than 16 mm, the values of p_1 are to be reduced, with respect to those in Tab 3, by:

- 10 mm, for chain or scallop welding
- 20 mm, for staggered welding.

Table 5 : Required throat thickness t_T

t, in mm	t_T, in mm	t, in mm	t_T, in mm
6	3,0	17	7,0
8	3,5	18	7,0
9	4,0	19	7,5
10	4,5	20	7,5
11	5,0	21	8,5
12	5,5	22	8,5
13	6,0	23	9,0
14	6,0	24	9,0
15	6,5	25	10,0
16	6,5	26	10,0

2.3.7 Throat thickness of welds between cut-outs

The throat thickness of the welds between the cut-outs in primary supporting member webs for the passage of ordinary stiffeners is to be not less than the value obtained, in mm, from the following formula:

$$t_{TC} = t_T \frac{\varepsilon}{\lambda}$$

where:

t_T : Throat thickness defined in [2.3.5]

ε, λ : Dimensions, in mm, to be taken as shown in:

- Fig 1, for continuous welding
- Fig 2, for intermittent scallop welding.

Figure 1 : Continuous fillet welding between cut-outs

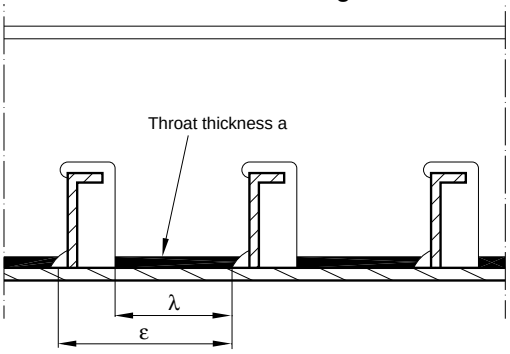
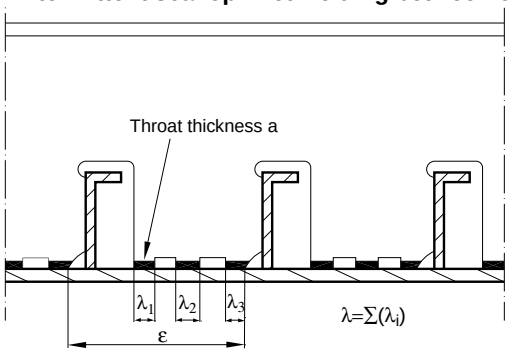


Figure 2 : Intermittent scallop fillet welding between cut-outs



2.3.8 Throat thickness of welds connecting ordinary stiffeners with primary supporting members

The throat thickness of fillet welds connecting ordinary stiffeners and collar plates, if any, to the web of primary supporting members is to be not less than $0,35t_W$, where t_W is the web gross thickness, in mm. Further requirements are specified in Ch 11, Sec 2.

Where primary supporting member web stiffeners are welded to ordinary stiffener face plates, in certain cases the Society may require the above throat thickness to be obtained, in mm, from the following formula:

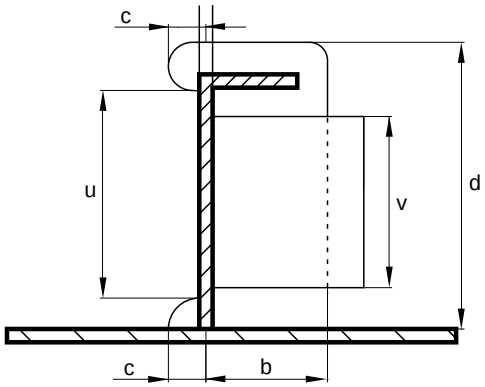
$$t_T = \frac{4(p_S + p_W)s\ell\left(1 - \frac{s}{2\ell}\right)}{u + v\left(\frac{c + 0,2d}{b + 0,2d}\right)}$$

where:

p_S, p_W : Still water and wave pressure, respectively, in kN/m², acting on the ordinary stiffener, defined in Ch 7, Sec 2, [3.3.2]

b,c,d,u,v: Main dimensions, in mm, of the cut-out shown in Fig 3.

Figure 3 : End connection of ordinary stiffener - Dimensions of the cut-out



2.3.9 Throat thickness of deep penetration fillet welding

When fillet welding is carried out with automatic welding procedures, the throat thickness required in [2.3.5] may be reduced up to 15%, depending on the properties of the electrodes and consumables. However, this reduction may not be greater than 1,5 mm.

The same reduction applies also for semi-automatic procedures where the welding is carried out in the downhand position.

2.4 Partial and full T penetration welding

2.4.1 General

Partial or full T penetration welding is to be adopted for connections subjected to high stresses for which fillet welding is considered unacceptable by the Society.

Partial or full T penetration welding is required, depending on the ship type. Further requirements are specified in Ch 11, Sec 2.

Typical edge preparations are indicated in:

- Fig 4 for partial penetration welds, in which f, in mm, is to be taken between 3 mm and t/3, and α between 45° and 60°
- Fig 5 for full penetration welds, in which f, in mm, is to be taken between 0 and 3 mm, and α between 45° and 60°.

  Back gouging is generally required for full penetration welds.

2.4.2 Lamellar tearing

Precautions are to be taken in order to avoid lamellar tears, which may be associated with:

- cold cracking when performing T connections between plates of considerable thickness or high restraint
- large fillet welding and full penetration welding on higher strength steels.

Figure 4 : Partial penetration weld

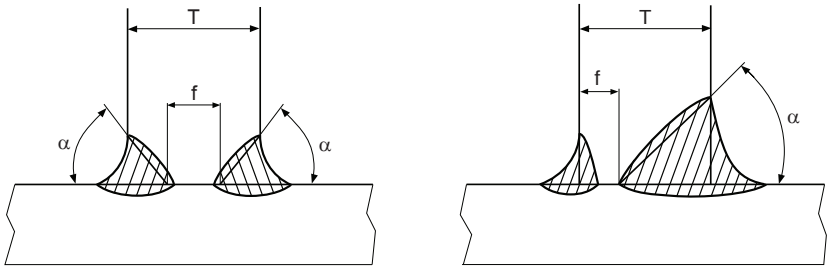
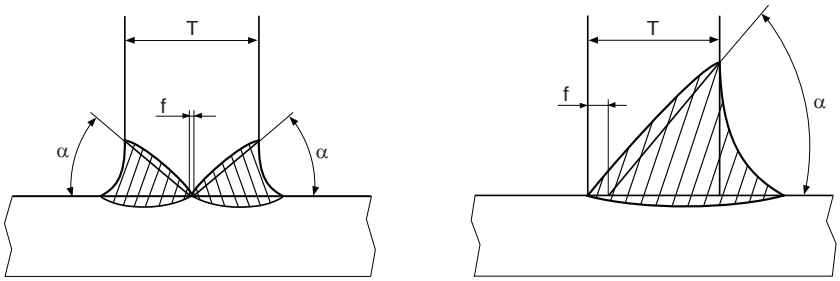


Figure 5 : Full penetration weld



2.5 Lap-joint welding

2.5.1 General

Lap-joint welding may be adopted for:

- peripheral connection of doublers
- internal structural elements subjected to very low stresses.

Elsewhere, lap-joint welding may be allowed by the Society on a case-by-case basis, if deemed necessary under specific conditions.

Continuous welding is generally to be adopted.

2.5.2 Gap

The surfaces of lap-joints are to be in sufficiently close contact.

2.5.3 Dimensions

The dimensions of the lap-joint are to be specified and are considered on a case-by-case basis. Typical details are given in Ch 11, App 1, [1.3].

2.6 Slot welding

2.6.1 General

Slot welding may be adopted in very specific cases subject to the special agreement of the Society, e.g. for doublers according to Ch 4, Sec 3, [2.1].

In general, slot welding of doublers on the outer shell and strength deck is not permitted within 0,6 L amidships. Beyond this zone, slot welding may be accepted by the Society on a case-by-case basis.

Slot welding is, in general, permitted only where stresses act in a predominant direction. Slot welds are, as far as possible, to be aligned in this direction.

2.6.2 Dimensions

Slot welds are to be of appropriate shape (in general oval) and dimensions, depending on the plate thickness, and may not be completely filled by the weld.

Typical dimensions of the slot weld and the throat thickness of the fillet weld are given in Ch 11, App 1.

The distance between two consecutive slot welds is to be not greater than a value which is defined on a case-by-case basis taking into account the:

- transverse spacing between adjacent slot weld lines
- stresses acting in the connected plates
- structural arrangement below the connected plates.

2.7 Plug welding

2.7.1 Plug welding may be adopted only when accepted by the Society on a case-by-case basis, according to specifically defined criteria. Typical details are given in Ch 11, App 1.

3 Specific weld connections

3.1 Corner joint welding

3.1.1 Corner joint welding, as adopted in some cases at the corners of tanks, performed with ordinary fillet welds, is permitted provided the welds are continuous and of the required size for the whole length on both sides of the joint.

3.1.2 Alternative solutions to corner joint welding may be considered by the Society on a case-by-case basis.

3.2 Bilge keel connection

3.2.1 Except where indicated, the following requirements apply to single web bilge keels. Additional requirements for other types of design will be considered on a case-by-case basis.

3.2.2 The ground bar is to be connected to the shell with a continuous fillet weld, and the bilge keel to the ground bar with a continuous fillet weld in accordance with Tab 6. Throat thicknesses differing from these values will be specially considered by the Society, if designed so that joints between the bilge keel and ground bar will fail before the joints between the ground bar and shell.

3.2.3 In the case of box type bilge keels, direct connection of members to the shell (i.e. without doublers) is to be by continuous full tee penetration welding. The type of bevel and the gap between the members to be assembled are to be such as to ensure a proper penetration of the welds.

3.2.4 Butt welds, in the bilge keel and ground bar, are to be well clear of each other and of butts in the shell plating as shown in Fig 6. In general, shell butts are to be flush in way of the ground bar and ground bar butts are to be flush in way of the bilge keel. Direct connection between ground bar butt welds and shell plating is not permitted. This may be obtained by use of removable backing.

In the case of box type bilge keels, the butt welds in longitudinal members of the bilge keel are to be shifted from the shell butts.

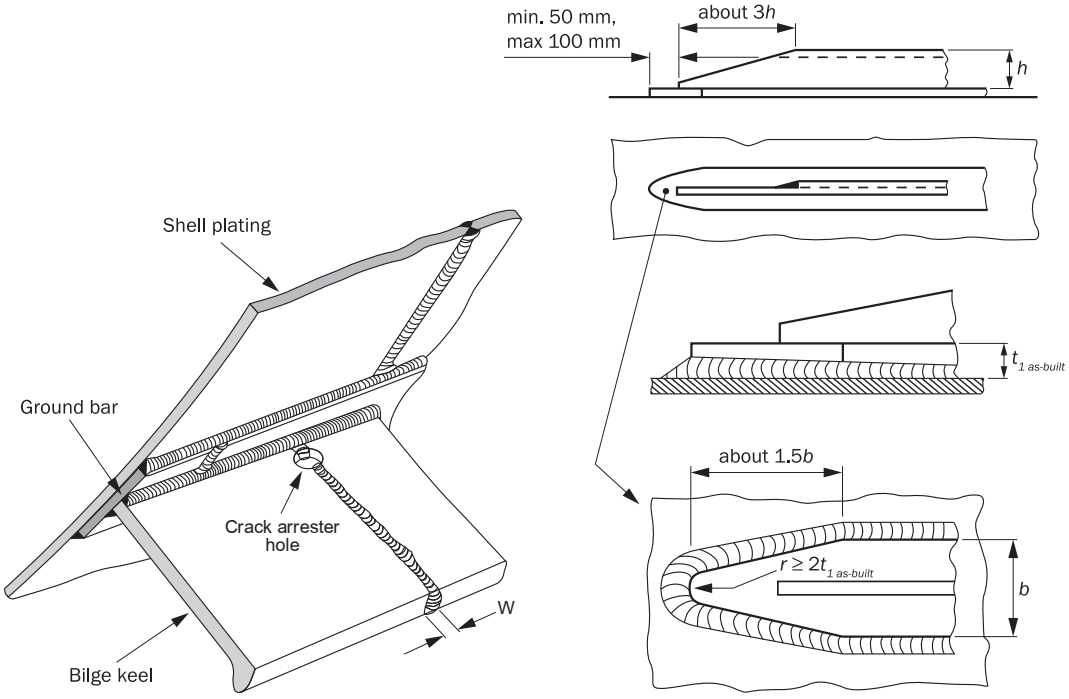
3.2.5 At the ends of the ground bar, the throat thickness is to be increased as given in Tab 6, without exceeding 0,707 times the as-built thickness of the ground bar as shown in Fig 6. The welded transition at the ends of the ground bar to the plating connection should be formed with the weld flank angle of 45° or less.

3.2.6 In general, scallops and cut-outs are not to be used in single web bilge keels. Crack arresting holes are to be drilled in the bilge keel butt welds as close as practicable to the ground bar. The diameter of the hole is to be greater than the width W of the butt weld and is to be a minimum of 25 mm. Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

Table 6 : Connections of single web bilge keels

Structural items being joined	Throat thickness of weld, in mm	
	At ends **(1)**	Elsewhere
Ground bar to the shell	0,44 $t_{1as\text{-}built}$	0,34 $t_{1as\text{-}built}$
Bilge keel web to ground bar	0,34 $t_{2as\text{-}built}$	0,21 $t_{2as\text{-}built}$
$t_{1as\text{-}built}$: As-built thickness of ground bar, in mm $t_{2as\text{-}built}$: As-built thickness of web of bilge keel, in mm. **(1)** Zone "b" in Ch 4, Sec 4, Fig 3 and Ch 4, Sec 4, Fig 4 for definition of "ends"		

Figure 6 : Connections of single web bilge keels



3.3 Connection between propeller post and propeller shaft bossing

3.3.1 Fabricated propeller posts are to be welded with full penetration welding to the propeller shaft bossing.

3.4 Bar stem connection

3.4.1 The bar stem is to be welded to the bar keel generally with butt welding.

The shell plating is also to be welded directly to the bar stem with butt welding.

4 Workmanship

4.1 Welding procedures and consumables

4.1.1 The various welding procedures and consumables are to be used within the limits of their approval and in accordance with the conditions of use specified in the respective approval documents.

4.2 Welding operations

4.2.1 Weather protection

Adequate protection from the weather is to be provided to parts being welded; in any event, such parts are to be dry.

In welding procedures using bare, cored or coated wires with gas shielding, the welding is to be carried out in weather protected conditions, so as to ensure that the gas outflow from the nozzle is not disturbed by winds and draughts.

4.2.2 Butt connection edge preparation

The edge preparation is to be of the required geometry and correctly performed. In particular, if edge preparation is carried out by flame, it is to be free from cracks or other detrimental notches.

4.2.3 Surface condition

The surfaces to be welded are to be free from rust, moisture and other substances, such as mill scale, slag caused by oxygen cutting, grease or paint, which may produce defects in the welds.

Effective means of cleaning are to be adopted particularly in connections with special welding procedures; flame or mechanical cleaning may be required.

The presence of a shop primer may be accepted, provided it has been approved by the Society.

Shop primers are to be approved by the Society for a specific type and thickness according to NR216 Materials and Welding, Ch 5, Sec 3.

4.2.4 Assembling and gap

The setting appliances and system to be used for positioning are to ensure adequate tightening adjustment and an appropriate gap of the parts to be welded, while allowing maximum freedom for shrinkage to prevent cracks or other defects due to excessive restraint.

The gap between the edges is to comply with the required tolerances or, when not specified, it is to be in accordance with normal good practice.

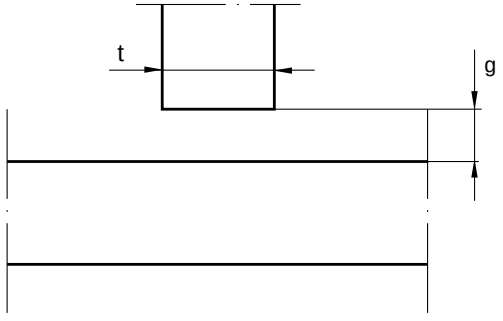
4.2.5 Gap in fillet weld T connections

In fillet weld T connections, a gap g, as shown in Fig 7, not greater than 2 mm may be accepted without increasing the throat thickness calculated according to [2.3.5] to [2.3.9], as applicable.

In the case of a gap greater than 2 mm, the above throat thickness is to be increased accordingly as specified in Ch 11, Sec 2 for some special connections of various ship types.

In any event, the gap g may not exceed 4 mm.

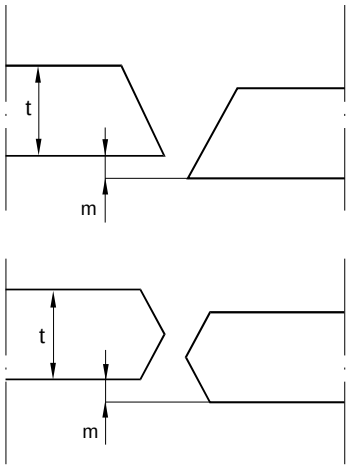
Figure 7 : Gap in fillet weld T connections



4.2.6 Plate misalignment in butt connections

The misalignment m, measured as shown in Fig 8, between plates with the same gross thickness t is to be less than 0,15 t, without being greater than 3 mm.

Figure 8 : Plate misalignment in butt connections



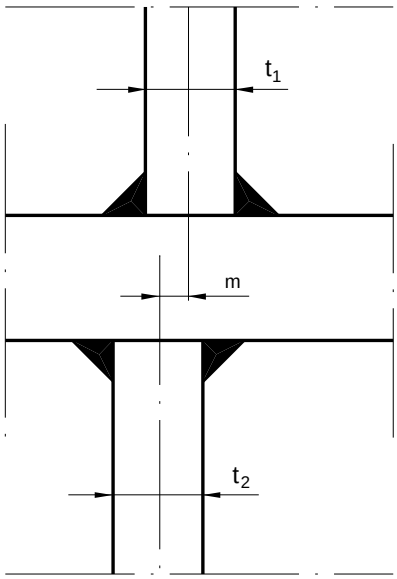
4.2.7 Misalignment in cruciform connections

The misalignment m in cruciform connections, measured on the median lines as shown in Fig 9, is to be less than:

- t/2, in general, where t is the gross thickness of the thinner abutting plate
- the values specified in Ch 11, Sec 2 for some special connections of various ship types.

The Society may require lower misalignment to be adopted for cruciform connections subjected to high stresses.

Figure 9 : Misalignment in cruciform connections



4.2.8 Assembling of aluminium alloy parts

When welding aluminium alloy parts, particular care is to be taken so as to:

- reduce as far as possible restraint from welding shrinkage, by adopting assembling and tack welding procedures suitable for this purpose
- keep possible deformations within the allowable limits.

4.2.9 Preheating and interpass temperatures

Suitable preheating, to be maintained during welding, and slow cooling may be required by the Society on a case-by-case basis.

4.2.10 Welding sequences

Welding sequences and direction of welding are to be determined so as to minimize deformations and prevent defects in the welded connection.

All main connections are generally to be completed before the ship is afloat.

Departures from the above provision may be accepted by the Society on a case-by-case basis, taking into account any detailed information on the size and position of welds and the stresses of the zones concerned, both during ship launching and with the ship afloat.

4.2.11 Interpass cleaning

After each run, the slag is to be removed by means of a chipping hammer and a metal brush; the same precaution is to be taken when an interrupted weld is resumed or two welds are to be connected.

4.2.12 Stress relieving

It is recommended and in some cases it may be required that special structures subject to high stresses, having complex shapes and involving welding of elements of considerable thickness (such as rudder spades and stern frames), are prefabricated in parts of adequate size and stress-relieved in the furnace, before final assembly, at a temperature within the range 550°C ÷ 620°C, as appropriate for the type of steel. Concerned structures are agreed on case-by-case basis.

4.3 Crossing of structural elements

4.3.1 In the case of T crossing of structural elements (one element continuous, the other physically interrupted at the crossing) when it is essential to achieve structural continuity through the continuous element (continuity obtained by means of the welded connections at the crossing), particular care is to be devoted to obtaining the correspondence of the interrupted elements on both sides of the continuous element. Suitable systems for checking such correspondence are to be adopted.

5 Modifications and repairs during construction

5.1 General

5.1.1 Deviations in the joint preparation and other specified requirements, in excess of the permitted tolerances and found during construction, are to be repaired as agreed with the Society on a case-by-case basis.

5.2 Gap and weld deformations

5.2.1 Welding by building up of gaps exceeding the required values and repairs of weld deformations may be accepted by the Society upon special examination.

5.3 Defects

5.3.1 Defects and imperfections on the materials and welded connections found during construction are to be evaluated for possible acceptance on the basis of the applicable requirements of the Society.

Where the limits of acceptance are exceeded, the defective material and welds are to be discarded or repaired, as deemed appropriate by the Surveyor on a case-by-case basis.

When any serious or systematic defect is detected either in the welded connections or in the base material, the manufacturer is required to promptly inform the Surveyor and submit the repair proposal.

The Surveyor may require destructive or non-destructive examinations to be carried out for initial identification of the defects found and, in the event that repairs are undertaken, for verification of their satisfactory completion.

5.4 Repairs on structures already welded

5.4.1 In the case of repairs involving the replacement of material already welded on the hull, the procedures to be adopted are to be agreed with the Society on a case-by-case basis.

6 Inspections and checks

6.1 General

6.1.1 Materials, workmanship, structures and welded connections are to be subjected, at the beginning of the work, during construction and after completion, to inspections by the Shipbuilder suitable to check compliance with the applicable requirements, approved plans and standards.

6.1.2 The Shipbuilder is to make available to the Surveyor a list of the manual welders and welding operators and their respective qualifications.

The Shipbuilder's internal organisation is responsible for ensuring that welders and operators are not employed under improper conditions or beyond the limits of their respective valid qualifications and that welding procedures are adopted within the approved limits and under the appropriate operating conditions.

6.1.3 The Shipbuilder is responsible for ensuring that the operating conditions, welding procedures and work schedule are in accordance with the applicable requirements, approved plans and recognised good welding practice.

6.1.4 The Shipbuilder is responsible for ensuring that non-destructive examination (NDE) procedures and plans are adhered to during the construction and that NDE reports are made available to the Society.

6.2 Non-destructive examination (NDE)

6.2.1 Non-destructive examination techniques refer to the testing methods applicable to the detection of surface imperfections (Visual Testing, Magnetic particle Testing, Liquid penetrant Testing) or sub-surface imperfections (Ultrasonic Testing, Radiographic Testing).

6.2.2 NDE of hull welds are to be performed in accordance with written procedures accepted by the Society. Such procedures are to contain appropriate details about the applied codes or standards, testing method, equipment, calibration, testing conditions and personnel qualification. For each NDE technique, appropriate details means typically the details described in IACS Recommendation 20.

6.2.3 The NDE acceptance criteria defined by the Shipbuilder are to be submitted to the Society and should comply with the IACS Recommendation 20 or with a recognized standard accepted by the Society.

Where applicable, specific criteria defined in Ch 11, Sec 2, for special structural details are to be referred to.

6.2.4 All finished welds are to be subjected to visual testing by the Shipbuilder's qualified personnel.

6.2.5 After completion of the welding operation and workshop inspection, the structure is to be presented to the Surveyor for general visual examination at a suitable stage of fabrication.

As far as possible, the results on non-destructive examinations are to be submitted.

6.2.6 Radiographic testing is to be carried out on the welded connections of the hull in accordance with [6.3]. The results are to be made available to the Society. The Surveyor may require to witness some testing preparations.

6.2.7 The Society may accept radiographic testing to be replaced by ultrasonic testing.

6.2.8 The Shipbuilder's NDE plan describing the extent, type and location of NDE is to be submitted to the Society for acceptance.

6.2.9 When the non-destructive examinations reveal the presence of unacceptable indications, the relevant connection is to be repaired to an extent and according to a procedure agreed with the Surveyor.

The repaired zone is then to be submitted to non-destructive examination, using a method deemed suitable by the Surveyor to verify that the repair is satisfactory.

Additional examinations may be required by the Surveyor on a case-by-case basis.

6.2.10 Ultrasonic and magnetic particle testing may also be required by the Surveyor in specific cases to check the base material.

6.3 Radiographic testing

6.3.1 Radiographic testing is to be carried out on the welded butts of shell plating, strength deck plating as well as of members contributing to the longitudinal strength.

Radiographic Testing may also be required for the joints of members subject to heavy stresses.

The requirements [6.3.2] to [6.3.5] constitute general rules: the number of radiographs may be increased where requested by the Surveyor, mainly where visual inspection or radiographic soundings have revealed major defects, specially for butts of sheerstrake, stringer plate, bilge strake or keel plate.

Provisions alteration to these rules may be accepted by the Society when justified by the organisation of the Shipbuilder or of the inspection department. The inspection is then to be equivalent to that deduced from [6.3.2] to [6.3.5].

6.3.2 As far as automatic welding of the panels butt welds during the premanufacturing stage is concerned, the Shipbuilder is to carry out random non-destructive testing of the welds (radiographic or ultrasonic testing) in order to ascertain the regularity and the constancy of the welding inspection.

6.3.3 In the midship area, radiographies are to be taken at the joinings of panels.

Each radiography is situated in a butt joint at a cross-shaped welding.

In a given ship cross-section bounded by the panels, a radiography is to be made of each butt of sheerstrake, stringer, bilge and keel plate; in addition, the following radiographies are to be taken:

- bottom plating: two
- deck plating: two
- side shell plating: two on each side.

For ships where B + D ≤ 15 m, only one radiography for each of the above items is required.

This requirement remains applicable where panel butts are shifted or where some strakes are built independently from the panels. It is recommended to take most of these radiographies at the intersections of butt and panel seams.

Still in the midship area, radiographic testing is to be carried out, at random, of the following main members of the structure:

- butts of continuous longitudinal bulkheads
- butts of longitudinal stiffeners, deck and bottom girders contributing to the overall strength
- assembly joints of insert plates at the corners of the openings.

Moreover, radiographic testing is to be carried out, at random, of the weldings of the bilge keel and of intermediate flat.

6.3.4 Outwards the midship area, a programme of radiographic testing at random is to be set up by the Shipbuilder in agreement with the Surveyor for the major points. It is further recommended to take:

- a number of radiographies of the very thick parts and those comprising restrained joint, such as sternframes, shaft brackets, stabiliser recesses, masts
- a complete set of radiographies or to increase the number of radiographies for the first joint of a series of identical joints. This recommendation is applicable not only to the assembly joints of prefabricated members completed on the slip, but also to joints completed in the workshop to prepare such prefabricated members.

6.3.5 Where a radiography is rejected and where it is decided to carry out a repair, the Shipbuilder is to determine the length of the defective part, then a set of radiographies of the repaired joint and of adjacent parts is to be taken. Where the repair has been decided by the inspection office of the Shipbuilder, the film showing the initial defect is to be submitted to the Surveyor together with the film taken after repair of the joint.

Section 2 Special Structural Details

Symbols

T_B : Ship draught in light ballast condition, see Ch 5, Sec 1, [2.4.3].

1 General

1.1 Application

1.1.1 Special structural details are those characterized by complex geometry, possibly associated with high or alternate stresses.

1.1.2 For special structural details, specific requirements are to be fulfilled during:

- design
- construction
- selection of materials
- welding
- survey.

The purpose of these requirements is specified in [1.2] to [1.6].

1.1.3 Special structural details are those listed in Article [2] together with the specific requirements which are to be fulfilled.

Other structural details may be considered by the Society as special details, when deemed necessary on the basis of the criteria in [1.1.1]. The criteria to be fulfilled in such cases are defined by the Society on a case-by-case basis.

1.1.4 As regards matters not explicitly specified in Article [2], the rule requirements are to be complied with in any event, in particular:

- Part B, Chapter 4 for design principles and structural arrangements
- Part B, Chapter 7 for structural scantling
- Part B, Chapter 11 for construction and welding requirements
- the applicable requirements in Part D and Part E.

1.2 Design requirements

1.2.1 General requirements

Design requirements specify:

- the local geometry, dimensions and scantlings of the structural elements which constitute the detail
- any local strengthening
- the cases where a fatigue check is to be carried out according to Ch 7, Sec 4.

1.2.2 Fatigue check requirements

Where a fatigue check is to be carried out, the design requirements specify (see Ch 7, Sec 4, [1.1]):

- the locations (hot spots) where the stresses are to be calculated and the fatigue check performed
- the direction in which the normal stresses are to be calculated
- the stress concentration factors K_h and $K\ell$ to be used for calculating the hot spot stress range.

1.3 Constructional requirements

1.3.1 Constructional requirements specify the allowable misalignment and tolerances, depending on the detail arrangement and any local strengthening.

1.4 Material requirements

1.4.1 Material requirements specify the material quality to be used for specific elements which constitute the detail, depending on their manufacturing procedure, the type of stresses they are subjected to, and the importance of the detail with respect to the ship operation and overall safety.

In addition, these requirements specify where material inspections are to be carried out.

1.5 Welding requirements

1.5.1 Welding requirements specify where partial or full T penetration welding (see Ch 11, Sec 1, [2.4]) or any particular welding type or sequence is to be adopted. In addition, these requirements specify when welding procedures are to be approved.

Since weld shape and undercuts are influencing factors on fatigue behaviour, fillet welds are to be elongated in the direction of the highest stresses and care is to be taken to avoid undercuts, in particular at the hot spots.

1.6 Survey requirements

1.6.1 Survey requirements specify where non-destructive examinations of welds are to be carried out and, where this is the case, which type is to be adopted.

2 List and characteristics of special structural details

2.1 General

2.1.1 This Article lists and describes, depending on the ship type, the special structural details and specifies the specific requirements which are to be fulfilled according to [1.2] to [1.6]. This is obtained through:

- a description of the hull areas where the details are located
- the detail description
- the requirements for the fatigue check
- a reference to a sheet in the Appendixes where a picture of the detail is shown together with the specific requirements which are to be fulfilled.

2.1.2 The special structural details relevant to all types of longitudinally framed ships are listed and described in Tab 1.

Table 1 : Special structural details

Area reference number	Area description	Detail description	Fatigue check	Reference tables in Ch 11, App 2
1	Part of side extended: • longitudinally, between the after peak bulkhead and the collision bulkhead • vertically, between 0,7 T_B and 1,15 T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members	No	Ch 11, App 2, Tab 1 to Ch 11, App 2, Tab 6
		Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members, or transverse bulkheads	for L ≥ 90 m	Ch 11, App 2, Tab 7 to Ch 11, App 2, Tab 13
2	Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors	for L ≥ 90 m	Ch 11, App 2, Tab 14 to Ch 11, App 2, Tab 17
3	Hatch corners	Deck plating in way of hatch corners	No	Ch 11, App 2, Tab 18
		Ends of longitudinal hatch coamings	No	Ch 11, App 2, Tab 19 and Ch 11, App 2, Tab 20

Section 3 Testing

1 General

1.1 Introduction

1.1.1 All gravity tanks and other boundaries required to be watertight or weathertight are to be tested in accordance with the procedures defined in this Section and proven to be tight and structurally adequate as follows:

a) gravity tanks for their tightness and structural adequacy

b) watertight boundaries other than tank boundaries for their watertightness

c) weathertight boundaries for their weathertightness.

1.1.2 The tightness of all tanks and watertight boundaries of ships during new construction and those relevant to major conversions or major repairs is to be confirmed by these test procedures prior to the delivery of the ship.

1.2 Application

1.2.1 The requirements in this Section apply to the structures listed in Tab 2.

1.2.2 The testing of structures not listed in Tab 2 will be specially considered.

1.2.3 Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion so that any subsequent work would not impair the strength and tightness of the structure.

In particular, tests are to be carried out after air vents and sounding pipes are fitted.

When tests are performed before final air vents and sounding pipes are fitted, temporary air vents and sounding pipes may be accepted, provided they are deemed equivalent by the Surveyor.

For the timing of the application of coatings and the provision of safe access to joints, see [2.3.5] to [2.3.7] and Tab 3.

1.2.4 Where the structural adequacy of the tanks and spaces of a vessel were verified by the structural testing required in Tab 2, subsequent vessels in the series (i.e. sister ships built from the same plans at the same shipyard) may be exempted from structural testing of tanks, provided that:

a) water-tightness of boundaries of all tanks and spaces are verified by leak tests and thorough inspections are carried out

b) structural testing is carried out for at least one tank or space of each type among all tanks/spaces of each sister vessel

c) additional tanks and spaces may require structural testing if found necessary after the structural testing of the first tank or if deemed necessary by the attending Surveyor.

1.2.5 Sister ships built (i.e. keel laid) two years or more after the delivery of the previous ship of the series, may be tested in accordance with [1.2.4] at the discretion of the Society, provided that:

a) general workmanship has been maintained (i.e. there has been no discontinuity of shipbuilding or significant changes in the construction methodology or technology at the yard, shipyard personnel are appropriately qualified and demonstrate an adequate level of workmanship as determined by the Society)

b) an NDT plan is implemented and evaluated by the Society for the tanks not subject to structural tests. Shipbuilding quality standards for the hull structure during new construction are to be reviewed and agreed during the kick-off meeting. The work is to be carried out in accordance with the Rules and under survey of the Society.

1.3 Definitions

1.3.1 Shop primer

Shop primer is a thin coating applied after surface preparation and prior to fabrication as a protection against corrosion during fabrication.

1.3.2 Protective coating

Protective coating is a final coating protecting the structure from corrosion.

1.3.3 Structural test

A test to verify structural adequacy of a boundary. This may be a hydrostatic test or, where the situation warrants, a hydropneumatic test.

1.3.4 Leak test

A test to verify the tightness of a boundary. Unless a specific test is indicated, this may be a hydrostatic/hydropneumatic test or an air test. A hose test may be considered an acceptable form of leak test for certain boundaries, as indicated by footnote (3) of Tab 2.

1.3.5 Sister ship

A sister ship is a ship having the same main dimensions, general arrangement, capacity plan and structural design as those of the first ship in a series.

1.3.6 Gravity tank

Gravity tank means a tank that is subject to vapour pressure not greater than 70 kPa.

1.3.7 Major repair

Major repair means a repair affecting structural integrity.

2 Test conditions and selection of test procedures

2.1 General

2.1.1 Structures are to be tested for tightness and structural strength as indicated in Tab 2.

2.1.2 General requirements for structural and leak testing are given in [2.2] and [2.3].

2.1.3 Procedures for specific structural and leak test methods are described in Article [3].

2.2 Structural test

2.2.1 Where a structural test is specified in Tab 2, a hydrostatic test in accordance with [3.2.1] will be acceptable. Where practical limitations (strength of building berth, light density of liquid, etc.) prevent the performance of a hydrostatic test, a hydropneumatic test in accordance with [3.2.2] may be accepted instead.

2.2.2 A hydrostatic or hydropneumatic test for the confirmation of structural adequacy may be carried out while the ship is afloat, provided the results of a leak test are confirmed to be satisfactory before the ship is afloat.

2.2.3 Alternative equivalent tank testing procedures may be considered for tanks which are constructed from composite materials such as glass reinforced plastic (GRP) and fibre reinforced plastic (FRP) based on the recommendations of the composite manufacturer.

2.2.4 Structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test.

Additional tanks may require structural testing if found necessary after the structural testing of the first tank.

2.2.5 The tank boundaries are to be tested from at least one side. The tanks for structural test are to be selected so that all representative structural members are tested for the expected tension and compression.

2.2.6 Watertight boundaries of spaces other than tanks may be exempted from the structural test, provided that the boundary watertightness of the exempted spaces is verified by leak tests and inspections. In the case of chain lockers, the possibility to exempt these spaces from structural test will be considered by the Society on a case-by-case basis.

2.2.7 The 'top of the overflow' is defined as being the top of any overflow system which is used to prevent overfilling of a tank. Such system can be an overflow pipe, airpipe, intermediate tank. For gravity tanks (i.e. sewage, grey water and similar tanks, not filled with pumps) the top of the overflow is to be taken as the highest point of the filling line.

Gauging devices are not considered equivalent to an overflow system with the exception of fuel oil overflow tanks not intended to hold fuel which have been fitted with a level alarm.

Where a tank is fitted with multiple means of preventing overfilling, the decision on which overflow system is to be used to determine the test head is to be based on the highest point to which the liquid may rise in service.

2.3 Leak test

2.3.1 For the leak tests specified in Tab 2, tank air tests, compressed air fillet weld tests and vacuum box tests, in accordance respectively with [3.3.2] to [3.3.4], or their combinations, are acceptable.

Hydrostatic or hydropneumatic tests may be also accepted as leak tests, provided [2.3.5] to [2.3.7] are complied with.

Hose tests, in accordance with [3.3.1], are also acceptable for those items in Tab 2 indicated with footnote (3).

2.3.2 In cases where hydrostatic or hydropneumatic tests are applied instead of a specific leak test, the examined boundaries are to be dew-free, otherwise small leaks will not be visible.

2.3.3 Air tests of joints may be carried out at the block stage, provided that all work on the block that may affect the tightness of a joint is completed before the test.

2.3.4 The application of the leak test for each type of welded joint is specified in Tab 3.

2.3.5 For butt joints welded by an automatic process, the final coating may be applied any time before the completion of a leak test of spaces bounded by the joints, provided that the welds have been carefully inspected visually to the satisfaction of the Surveyor.

Surveyors reserve the right to require a leak test prior to the application of final coating over automatic erection butt welds.

For all other joints, the final coating is to be applied after the completion of the leak test of the joint. See also Tab 3.

2.3.6 Any temporary coating which may conceal defects or leaks is to be applied at the time as specified for the final coating (see [2.3.5]). This requirement does not apply to shop primer.

2.3.7 For leak tests, a safe access to all joints under examination is to be provided. See also Tab 3.

3 Test procedures

3.1 General

3.1.1 An overview of test procedures for leak and structural tests are given in Tab 1. Detailed requirements are given in the following sub-Articles.

Table 1 : Test procedures

Test	Type	Procedure
Hydrostatic test	Leak and structural	The space to be tested is filled with a liquid to a specified head
Hydropneumatic test	Leak and structural	Combination of a hydrostatic test and an air test, the space to be tested being partially filled with liquid and pressurized with air
Hose test	Leak	Tightness check of the joint to be tested by means of a jet of water, the joint being visible from the opposite side
Air test	Leak	Tightness check by means of an air pressure differential and a leak-indicating solution. It includes tank air tests and joint air tests, such as compressed air fillet weld tests and vacuum box tests
Compressed air fillet weld test	Leak	Air test of fillet welded tee joints, by means of a leak indicating solution applied on fillet welds
Vacuum box test	Leak	A box over a joint with a leak indicating solution applied on the welds. A vacuum is created inside the box to detect any leaks
Ultrasonic test	Leak	Tightness check of the sealing of closing devices such as hatch covers, by means of ultrasonic detection techniques
Penetration test	Leak	Check, by means of low surface tension liquids (i.e. dye penetrant test), that no visual dye penetrant indications of potential continuous leakages exist in the boundaries of a compartment
Compartment air test	Leak	Compartment pressurisation and verification of pressure loss across boundaries over a defined time period

3.2 Structural test

3.2.1 Hydrostatic test

Unless another liquid is approved, hydrostatic tests are to consist of filling the space with fresh water or sea water, whichever is appropriate for testing, to the level specified in Tab 2.

In cases where a space is designed for liquid densities greater than sea water and testing is with fresh water or sea water, the testing pressure height is to simulate the actual loading for those greater cargo densities as far as practicable, but the test pressure is not to exceed the maximum design internal pressure at the top of space.

All external surfaces of the tested space are to be examined for structural distortion, bulging and buckling, other related damage and leaks.

3.2.2 Hydropneumatic test

Hydropneumatic tests, where approved, are to be such that the test condition, in conjunction with the approved liquid level and supplemental air pressure, will simulate the actual loading as far as practicable. The requirements for tank air tests in [3.3.2] will also apply to hydropneumatic tests.

The value of the additional air pressure is at the discretion of the Society, but is to be at least as defined in [3.3.2] for tank air test.

All external surfaces of the tested space are to be examined for structural distortion, bulging and buckling, other related damage and leaks.

3.3 Leak test

3.3.1 Hose testing

Hose tests are to be carried out with the pressure in the hose nozzle maintained at least at $2 \cdot 10^5$ Pa during the test. The nozzle is to have a minimum inside diameter of 12 mm and be at a perpendicular distance from the joint not exceeding 1,5 m. The water jet is to impinge directly upon the weld.

Where a hose test is not practical because of possible damage to machinery, electrical equipment insulation or outfitting items, it may be replaced by a careful visual examination of welded connections, supported where necessary by means such as a dye penetrant test or ultrasonic leak test or the equivalent. Alternatively, a compartment air test may be conducted as per [3.3.7].

3.3.2 Tank air test

All boundary welds, erection joints and penetrations, including pipe connections, are to be examined in accordance with approved procedure and under a stabilized pressure differential above atmospheric pressure not less than $0.15 \cdot 10^5$ Pa, with a leak indicating solution such as soapy water/detergent or a proprietary brand applied.

A U-tube with a height sufficient to hold a head of water corresponding to the required test pressure is to be arranged. The cross sectional area of the U-tube is not to be less than that of the pipe supplying air to the tank.

Note 1: Acceptability of alternative arrangements, including those involving the use of two calibrated pressure gauges to verify the required test pressure, will depend on an evaluation of the risks after taking into account necessary precautions and whether the design of the mechanism is similar to the U-tube principle (i.e. suitable to be lifted by the predetermined excessive pressure, and not subject to any kind of spring or restricting device). The following points are also to be considered:

- If an arrangement depending upon a safety valve is selected, in some cases, this approach has resulted in catastrophic failure of the space being tested
- Releasing mechanisms or safety valves are to be of adequate size/rating
- Test pressure gauges (a minimum of two are to be provided) are to be calibrated and of suitable range as per test pressure
- Inlet, outlet and release arrangement for the test medium to or from the item being tested are to be properly fabricated and supported, including their appropriate dimensions (e.g. smaller diameter for inlets and bigger diameter for outlets, as well as releasing means).

A double inspection is to be made of tested welds. The first is to be immediately upon applying the leak indication solution; the second is to be after approximately four or five minutes in order to detect those smaller leaks which may take time to appear.

3.3.3 Compressed air fillet weld test

In this air test, compressed air is injected from one end of a fillet welded joint and the pressure verified at the other end of the joint by a pressure gauge. Pressure gauges are to be arranged so that an air pressure of at least $0.15 \cdot 10^5$ Pa can be verified at each end of all passages within the portion being tested.

Note 1: Where a leak test is required for fabrication involving partial penetration welds, a compressed air test is also to be applied in the same manner as to fillet weld where the root face is large, i.e., 6-8 mm.

3.3.4 Vacuum box test

A box (vacuum testing box) with air connections, gauges and an inspection window is placed over the joint with a leak indicating solution applied to the weld cap vicinity. The air within the box is removed by an ejector to create a vacuum of $0{,}20 \cdot 10^5$ - $0{,}26 \cdot 10^5$ Pa inside the box.

3.3.5 Ultrasonic test

An ultrasonic echo transmitter is to be arranged inside of a compartment and a receiver is to be arranged on the outside. The watertight/weathertight boundaries of the compartment are scanned with the receiver in order to detect an ultrasonic leak indication. A location where sound is detectable by the receiver indicates a leakage in the sealing of the compartment.

3.3.6 Penetration test

A test of butt welds or other weld joints uses the application of a low surface tension liquid at one side of a compartment boundary or structural arrangement. If no liquid is detected on the opposite sides of the boundaries after the expiration of a defined period of time, this indicates tightness of the boundaries. In certain cases, a developer solution may be painted or sprayed on the other side of the weld to aid leak detection.

3.3.7 Compartment air test

A compartment is pressurised to create a pressure differential across the boundaries to be tested. It is verified that the pressure loss from the compartment over a defined period of time satisfies a maximum allowable value. Leaks are identified using an approved methodology and rectified to the satisfaction of the Society.

Application of this test method is subject to the conditions of assignment of the additional class notation **AIRTEST** as per Pt E, Ch 11, Sec 5. This test may be used as an alternative method of leak test only for those boundaries where hose test is permitted in Tab 2 but is not practicable as described in [3.3.1]. For boundaries that have been leak tested by other methods, this test may be used as a complementary verification.

Compartment air test cannot be used to forgo hose testing from the exterior side of watertight and weathertight elements fitted in the shell plating and other external boundaries but may replace hose testing from the interior side if it is not practicable.

3.3.8 Other test

Other methods of testing may be considered by the Society upon submission of full particulars prior to the commencement of the tests.

Table 2 : Test requirements

No.	Structure or boundaries to be tested	Test type	Test head or pressure
1	Double bottom tanks	Leak and structural	The greater of: • top of overflow • to 2,4 m above top of tank **(1)** • to the margin line **(2)**
2	Double bottom voids, duct keels and dry compartments on the ship's bottom	Leak	See [3.3.2] to [3.3.4], as applicable
3	Double side tanks	Leak and structural	The greater of: • top of overflow • to 2,4 m above top of tank **(1)** • to the margin line **(2)**
4	Double side voids	Leak	See [3.3.2] to [3.3.4], as applicable
5	Tanks and tank bulkheads other than those listed elsewhere in this table	Leak and structural	The greater of: • top of overflow • to 2,4 m above top of tank **(1)**
6	Fuel oil tanks	Leak and structural	The greater of: • top of the overflow • to 2.4m above top of tank **(1)** • to top of tank plus the design vapour pressure **(1)** • to the margin line **(2)**
7	Fuel oil overflow tanks not intended to hold fuel	Leak and structural	The greater of: • top of the overflow • to 2,4m above top of tank **(1)** • to the margin line **(2)**
8	Peak tanks **(3)**	Leak and structural	The greater of: • top of overflow • to 2,4 m above top of tank **(1)**
9a	Fore peak spaces with equipment	Leak **(4)**	See [3.3.1] to [3.3.4], as applicable
9b	Fore peak voids	Leak	See [3.3.2] to [3.3.4], as applicable
9c	After peak spaces with equipment	Leak **(4)**	See [3.3.1] to [3.3.4], as applicable
9d	Aft peak voids **(3)**	Leak	See [3.3.2] to [3.3.4], as applicable
10	Cofferdams **(5)**	Leak	See [3.3.2] to [3.3.4], as applicable
11a	Watertight bulkheads	Leak **(4)**	See [3.3.1] to [3.3.4], as applicable
11b	Superstructure end bulkheads		
11c	Watertight decks		
12	Watertight doors, hatches and closing appliances	Leak **(4)(6)(7)(8)**	See [3.3.1] to [3.3.4], as applicable

No.	Structure or boundaries to be tested	Test type	Test head or pressure
13	Double plate rudders blades, box-type bilge keels, steering nozzles and other hull appendages **(9)**	Leak	See [3.3.2] to [3.3.4], as applicable
14	Shaft tunnel clear of deep tanks	Leak **(4)**	See [3.3.1] to [3.3.4], as applicable
15	Shell doors	Leak **(4)(10)**	See [3.3.1] to [3.3.4], as applicable
16	Weathertight doors, hatch covers and closing appliances	Leak **(4)(8)**	See [3.3.1] to [3.3.4], as applicable
17	Chain locker	Leak and structural **(11)**	Top of chain pipe
18	Independent tanks	Leak **(12)**	See [3.3.2] to [3.3.4], as applicable
19	Ballast ducts	Leak and structural	The greater of: • ballast pump maximum pressure • setting of any pressure relief valve
20	Ammunition storage subject to fire extinguishing by flooding	Leak **(4)**	See [3.3.1] to [3.3.4], as applicable
21	Voids other than those listed elsewhere in this table	Leak **(13)**	See [3.3.2] to [3.3.4], as applicable

(1) The top of a tank is the deck forming the top of the tank, excluding any hatchways

(2) When detailed information on the head of water after damage is available and justified, such information can be considered instead

(3) After peak to be tested after installation of stern tube

(4) Hose test may be considered as a means of test

(5) Applies to cofferdams serving to avoid a common boundary between a particular liquid capacity and other capacities or spaces as required by Ch 2, Sec 2, [2.2]

(6) As an alternative to the hose testing, other testing methods listed in [3.3.5] through [3.3.7] may be applicable, subject to adequacy of such testing methods being verified. Alternatives to hose testing may only be used where a hose test is not practicable

(7) A prototype test (structural test) is to be conducted before the ship is put into service. A prototype test of each type and size of closing appliance may be carried out instead of individual tests. Refer to Ch 8, Sec 7 for watertight doors and to Ch 8, Sec 8 for watertight hatch covers

(8) Includes closing appliances of ventilators

(9) The hull appendages requiring leak testing are to be agreed with the Society

(10) Watertight shell doors are to be subject to prototype test (structural test with test pressure to be agreed with the Society) before the ship is put into service. Refer to Ch 8, Sec 7

(11) The possibility of exempting chain lockers from structural test will be considered on a case-by-case basis as per [2.2.6]

(12) Independent tanks not confirmed to be structurally adequate by a prototype test are to be subject to a structural test with a head of water to be agreed with the Society

(13) The voids requiring leak testing are to be agreed with the Society

Table 3 : Application of leak test, coating, and provision of safe access for the different types of welded joints

Type of welded joints		Leak test	Coating **(1)**		Safe access **(2)**	
			Before leak test	After leak test but before structural test	Leak test	Structural test
Butt	Automatic	not required	allowed **(3)**	not applicable	not required	not required
	Manual or semi-automatic **(4)**	required	not allowed	allowed	required	not required
Fillet	Boundary including penetrations	required	not allowed	allowed	required	not required

(1) Coating refers to internal (tank/hold) coating, where applied, and external (shell/deck) painting. It does not refer to shop primer

(2) Temporary means of access for verification of the leak test

(3) The condition applies provided that the welds have been visually inspected with care, to the satisfaction of the Surveyor

(4) Flux Core Arc Welding (FCAW) semi-automatic butt welds need not be tested, provided careful visual inspections show continuous and uniform weld profile shape, free from repairs, and the results of NDT show no significant defects

Appendix 1 Welding Details

1 Contents

1.1 General

1.1.1 Types and edge plate preparation of the manual welds carried out on the various parts of the hull are dealt with in this Appendix.

Other types and tolerances may be used after special examination of the Society.

1.1.2 The method used to prepare the parts to be welded is left to the discretion of each shipyard, according to its own technology and experience. It is approved at the same time as the approval of the welding procedures referred to in Ch 11, Sec 1, [1.5.1].

1.2 Butt welding edge preparation

1.2.1 Typical butt weld plate edge preparation for manual welding is specified in Tab 1.

1.3 Lap-joint, slot and plug welding

1.3.1 Welding details of lap-joint, slot and plug welds are specified in Tab 2.

Table 1 : Typical butt weld plate edge preparation (manual welding)

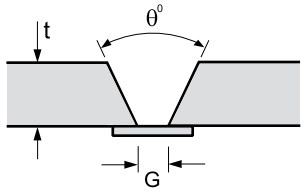
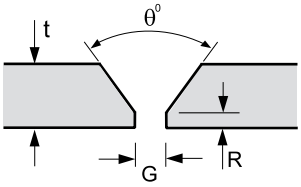
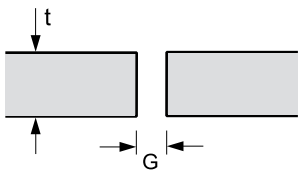
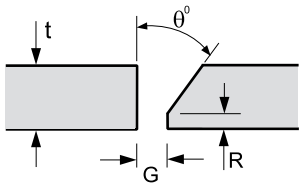
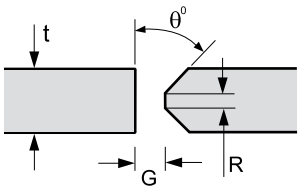
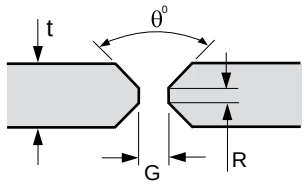
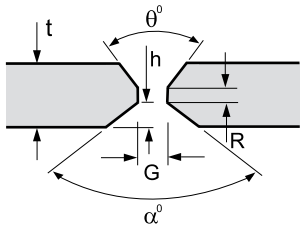
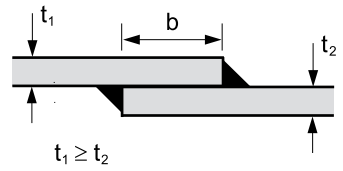
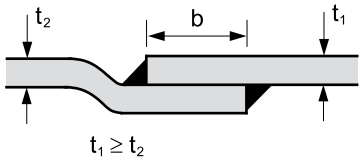
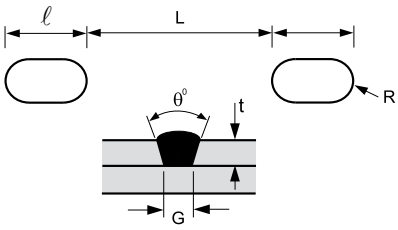
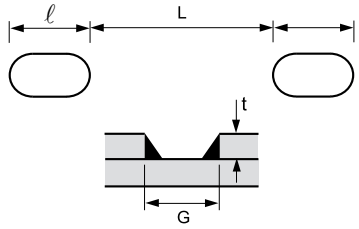
Single vee butt, one side welding with backing strip (temporary or permanent)  3 ≤ G ≤ 9 mm 30° ≤ θ ≤ 45°	**Single vee butt**  G ≤ 3 mm 50° ≤ θ ≤ 70° R ≤ 3 mm
Square butt  t ≤ 5 mm G = 3 mm	
Single bevel butt  t > 5 mm G ≤ 3 mm R ≤ 3 mm 50° ≤ θ ≤ 70°	**Double bevel butt**  t > 19 mm G ≤ 3 mm R ≤ 3 mm 50° ≤ θ ≤ 70°
Double vee butt, uniform bevels  G ≤ 3 mm R ≤ 3 mm 50° ≤ θ ≤ 70°	**Double vee butt, non-uniform bevels**  G ≤ 3 mm R ≤ 3 mm 6 ≤ h ≤ t/3 mm θ = 50° α = 90°
Note 1: Different plate edge preparation may be accepted or approved by the Society on the basis of an appropriate welding procedure specification.	

Table 2 : Typical lap joint, plug and slot welding (manual welding)

Detail	Standard	Remark
Fillet weld in lap joint  	b = 2 t_2 + 25 mm	location of lap joint to be approved by the Society
Fillet weld in joggled lap joint  	b ≥ 2 t_2 + 25 mm	
Plug welding  	• t ≤ 12 mm ℓ = 60 mm R = 6 mm 40° ≤ θ ≤ 50° G = 12 mm L > 2 ℓ • 12 mm < t ≤ 25 mm ℓ = 80 mm R = 0,5 t mm θ = 30° G = t mm L > 2 ℓ	
Slot welding  	• t ≤ 12 mm G = 20 mm ℓ = 80 mm 2 ℓ ≤ L ≤ 3 ℓ, max 250 mm • t > 12 mm G = 2 t ℓ = 100 mm 2 ℓ ≤ L ≤ 3 ℓ, max 250 mm	

Appendix 2 Reference Sheets for Special Structural Details

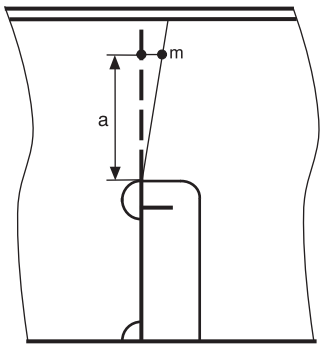
1 Contents

1.1 General

1.1.1 This Appendix includes the reference sheets for special structural details, as referred to in Ch 11, Sec 2.

Table 1 :

AREA 1: Side between 0,7T_B and 1,15T from the baseline	**Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - No collar plate**	**Sheet 1.1**

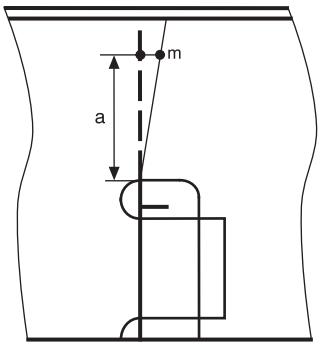


t_W = web thickness of transverse primary supporting member

SCANTLINGS:	**FATIGUE:**
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Cut-outs in the web free of sharp notches. • Gap between web and side longitudinal to be not greater than 4 mm.	Visual examination 100%.
WELDING AND MATERIALS:	
Welding requirements: - continuous fillet welding along the connection of web with side longitudinal, - throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by 0,7 (g – 2) mm, - weld around the cuts in the web at the connection with the longitudinal and the side shell, - avoid burned notches on web.	

Table 2 :

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - One collar plate	Sheet 1.2



t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness

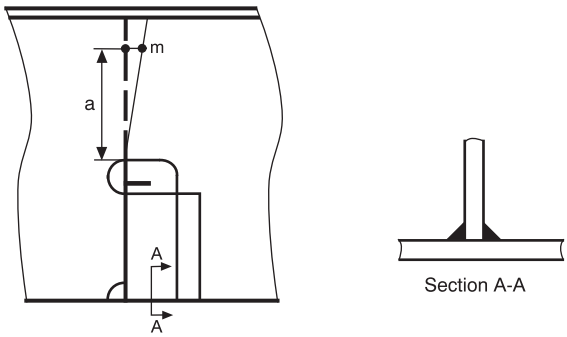
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between web and collar plate ≤ t_{CP}. • Cut-outs in the web free of sharp notches. • Gap between web and side longitudinal and between collar plate and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of web and collar plate with side longitudinal and at the lap joint between web and collar plate,
  - throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by 0,7 (g – 2) mm,
  - weld around the cuts in the web at the connection with the longitudinal and the side shell,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 3 :

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - One large collar plate	Sheet 1.3



t_W = web thickness of transverse primary supporting member

t_{CP} = collar plate thickness

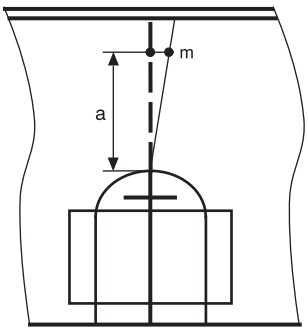
SCANTLINGS:	**FATIGUE:**
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between web and collar plate ≤ t_{CP}. • Cut-outs in the web free of sharp notches. • Gap between web and side longitudinal and between collar plate and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of web and collar plate with side longitudinal and at the lap joint between web and collar plate,
  - throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by 0,7 (g – 2) mm,
  - T joint connection of collar plate with side shell: see section A-A,
  - weld around the cuts in the web at the connection with the longitudinal and the side shell,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 4 :

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - Two collar plates	Sheet 1.4



t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness

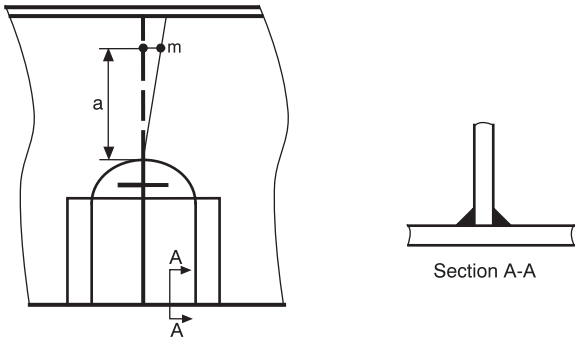
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between collar plates across the side longitudinal ≤ t_{CP} / 2. • Cut-outs in the web free of sharp notches. • Gap between collar plates and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of collar plates with side longitudinal and at the lap joint between web and collar plates,
  - throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by 0,7 (g – 2) mm,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 5 :

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - Two large collar plates	Sheet 1.5



t_W = web thickness of transverse primary supporting member

t_{CP} = collar plate thickness

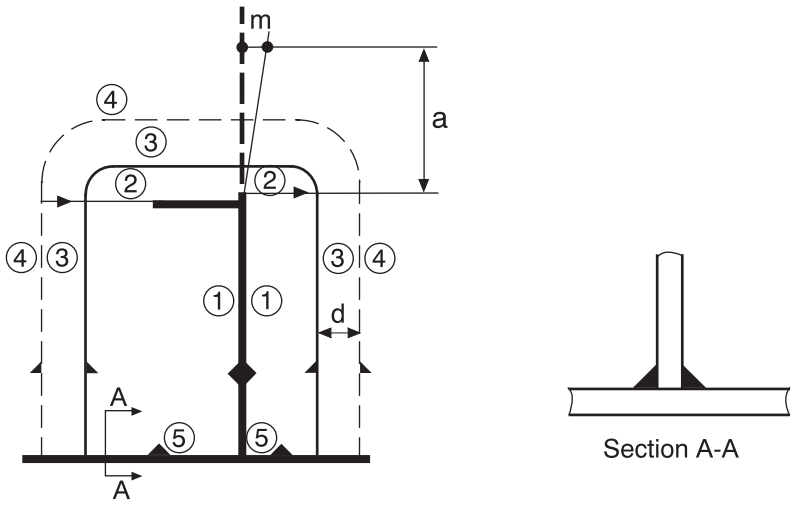
SCANTLINGS:	**FATIGUE:**
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between collar plates across the side longitudinal ≤ t_{CP} / 2. • Cut-outs in the web free of sharp notches. • Gap between collar plates and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of collar plates with side longitudinal and at the lap joint between web and collar plates,
  - throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by 0,7 (g – 2) mm,
  - T joint connection of collar plates with side shell: see section A-A,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 6 :

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Watertight connection of side longitudinal ordinary stiffeners with watertight side diaphragms or transverse bulkheads – Example of connection with lugs	Sheet 1.6



t_W = transverse bulkhead web thickness

t_L = lug thickness

SCANTLINGS:	FATIGUE:
• d = 30 ÷ 60 mm. • $t_L \geq t_W$.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between lugs across the side longitudinal ≤ t_L / 2. • Misalignment at the butts within lug parts ≤ t_L / 5. • Gap between bulkhead plating and lugs to be not greater than 4 mm.	• Visual examination 100%. • Magnetic particle or dye penetrant examination: when deemed necessary depending on the quality of the lap joint weld.

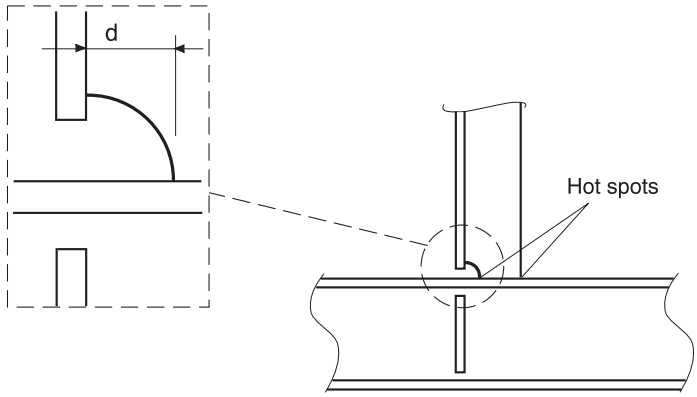
WELDING AND MATERIALS:

Welding requirements:

- continuous fillet welding along the connection of lugs with the side longitudinal and at the lap joints between web and lugs,
- throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by 0,7 (g – 2) mm,
- T joint connection of collar plates with side shell: see section A-A,
- welding sequence: 1 to 5 (see sketch).

Table 7 :

AREA 1: Side between 0,7T_B and 1,15T from the baseline	**Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - No bracket**	**Sheet 1.7**



t = minimum thickness between those of:
- web of side longitudinal,
- stiffener of transverse primary supporting member.

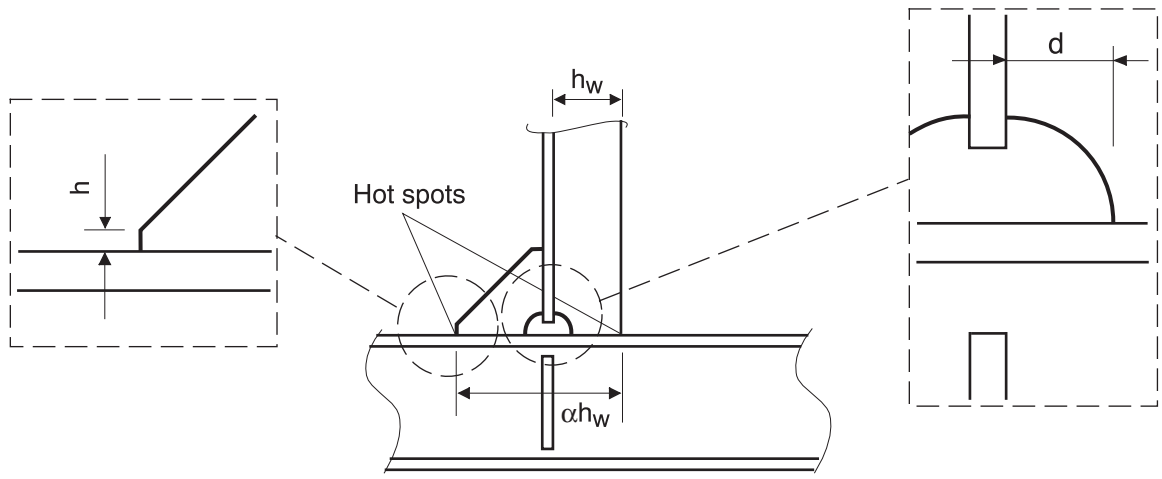
SCANTLINGS:	**FATIGUE:**
d to be as small as possible, maximum 35 mm recommended.	Fatigue check to be carried out for L ≥ 90 m: • with non-watertight collar plate: K_h = 1,30 $K\ell$ = 1,65 • with full collar plate (watertight): K_h = 1,25 $K\ell$ = 1,50
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal and web stiffener ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 8 :

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket	Sheet 1.8



t = minimum thickness among those of the connected elements

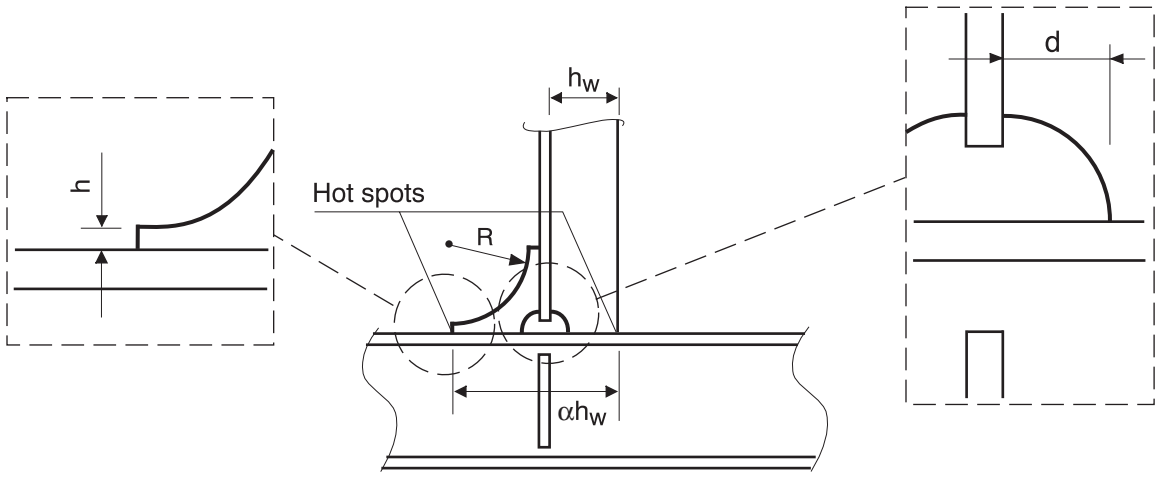
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 90 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ $K_h = 1,20$ $K\ell = 1,40$ - for $\alpha \geq 2,5$ $K_h = 1,15$ $K\ell = 1,40$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ $K_h = 1,15$ $K\ell = 1,32$ - for $\alpha \geq 2,5$ $K_h = 1,10$ $K\ell = 1,32$
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 9 :

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 1.9



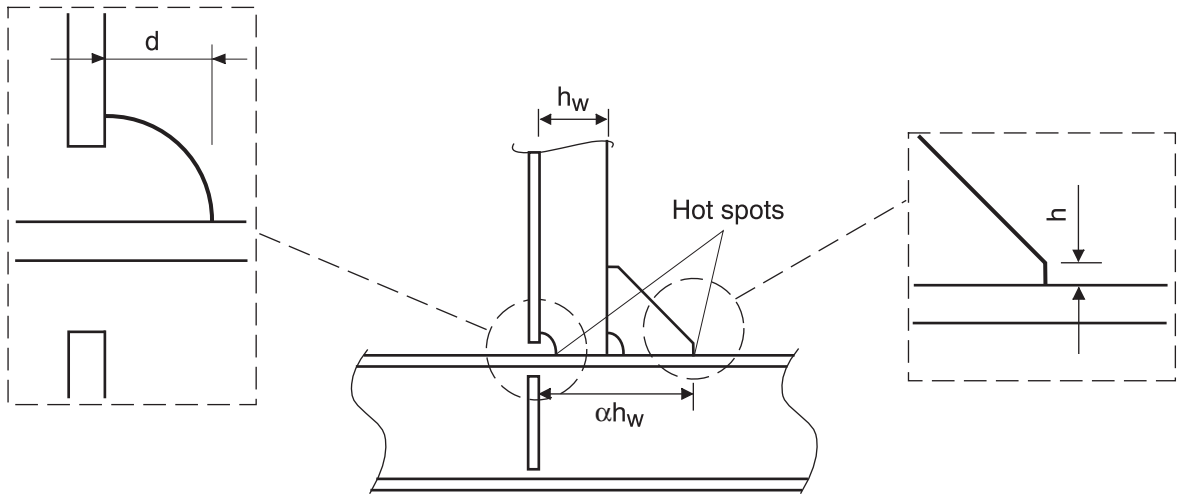
t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5\ (\alpha - 1)\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 90 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ $K_h = 1,15$ $K\ell = 1,35$ - for $\alpha \geq 2,5$ $K_h = 1,10$ $K\ell = 1,35$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ $K_h = 1,13$ $K\ell = 1,30$ - for $\alpha \geq 2,5$ $K_h = 1,08$ $K\ell = 1,30$
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction.

Table 10 :

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket	Sheet 1.10

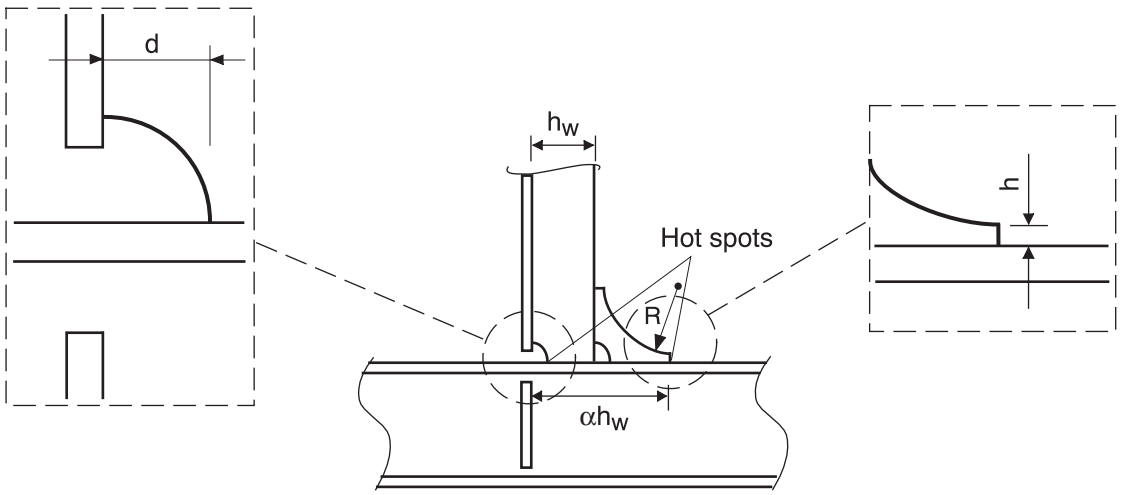


t = minimum thickness among those of the connected elements

SCANTLINGS:	**FATIGUE:**
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 90 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ $K_h = 1,30$ $K\ell = 1,55$ - for $\alpha \geq 2,5$ $K_h = 1,25$ $K\ell = 1,50$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ $K_h = 1,25$ $K\ell = 1,46$ - for $\alpha \geq 2,5$ $K_h = 1,20$ $K\ell = 1,41$
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.
WELDING AND MATERIALS:	
Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction.	

Table 11 :

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 1.11



t = minimum thickness among those of the connected elements

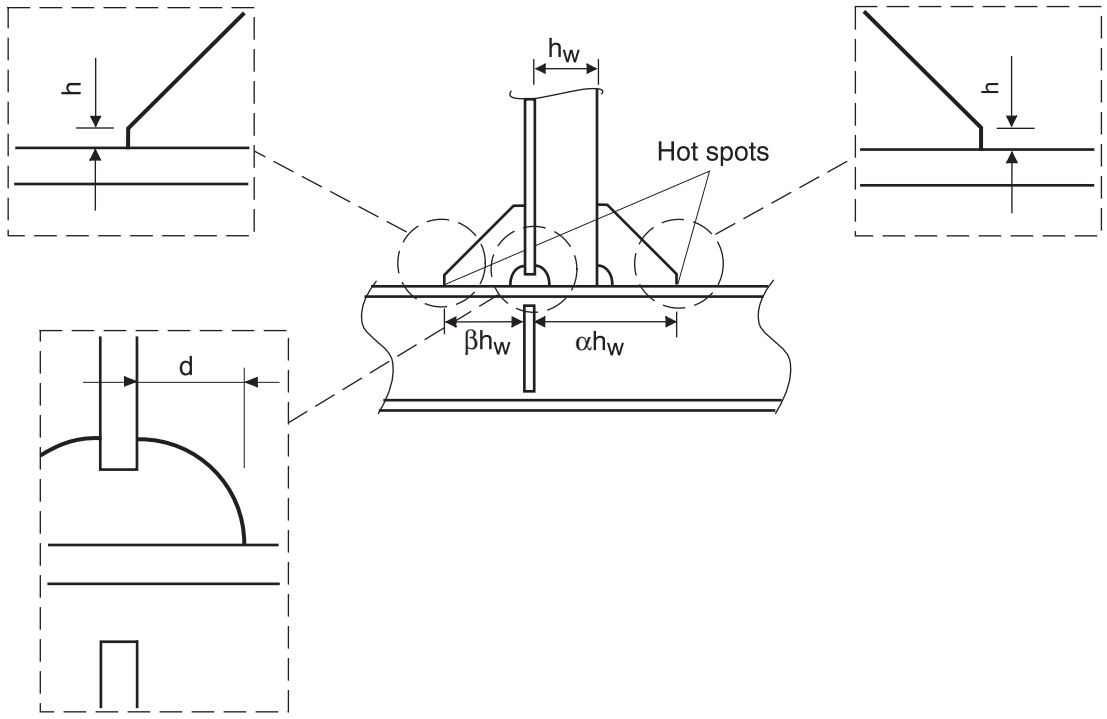
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5\ (\alpha - 1)\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 90 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ $K_h = 1,25$ $K\ell = 1,50$ - for $\alpha \geq 2,5$ $K_h = 1,20$ $K\ell = 1,45$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ $K_h = 1,22$ $K\ell = 1,44$ - for $\alpha \geq 2,5$ $K_h = 1,18$ $K\ell = 1,39$
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 12 :

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two brackets	Sheet 1.12



t = minimum thickness among those of the connected elements

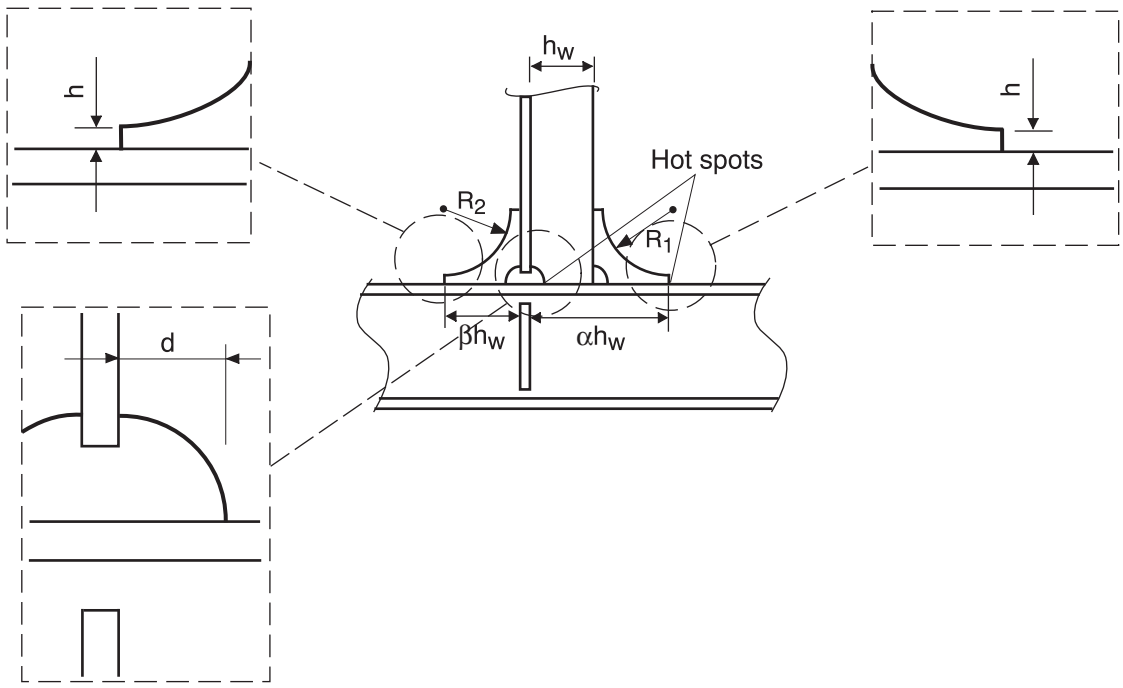
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 90 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ and $1 \leq \beta < 1,5$ $K_h = K\ell = 1,15$ - for $\alpha \geq 2,5$ and $\beta \geq 1,5$ $K_h = K\ell = 1,10$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ and $1 \leq \beta < 1,5$ $K_h = K\ell = 1,10$ - for $\alpha \geq 2,5$ and $\beta \geq 1,5$ $K_h = K\ell = 1,05$
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and brackets ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding,
  - weld around the stiffener's toes,
  - fair shape of fillet at toes in longitudinal direction.
- Material requirements:
  - material of brackets to be the same of longitudinals.

Table 13 :

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two radiused brackets	Sheet 1.13



t = minimum thickness among those of the connected elements

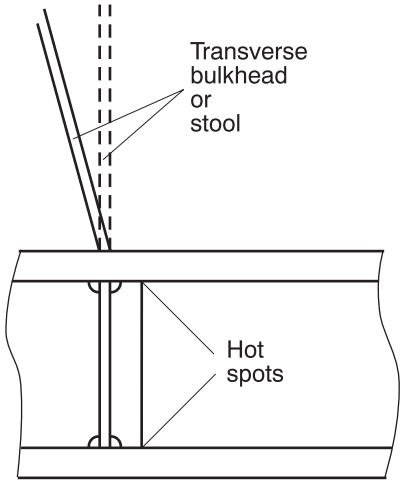
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • $R_1 \geq 1,5\ (\alpha - 1)\ h_W$ • $R_2 \geq 1,5\ \beta\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 90 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ and $1 \leq \beta < 1,5$ $K_h = K\ell = 1,10$ - for $\alpha \geq 2,5$ and $\beta \geq 1,5$ $K_h = K\ell = 1,05$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ and $1 \leq \beta < 1,5$ $K_h = K\ell = 1,10$ - for $\alpha \geq 2,5$ and $\beta \geq 1,5$ $K_h = K\ell = 1,05$
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and brackets ≤ t /3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding,
  - weld around the stiffener's toes,
  - fair shape of fillet at toes in longitudinal direction.
- Material requirements:
  - material of brackets to be the same of longitudinals.

Table 14 :

AREA 2: Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - No bracket	Sheet 2.1



t = minimum thickness between those of:
- web of bottom or inner bottom longitudinal,
- floor stiffener.

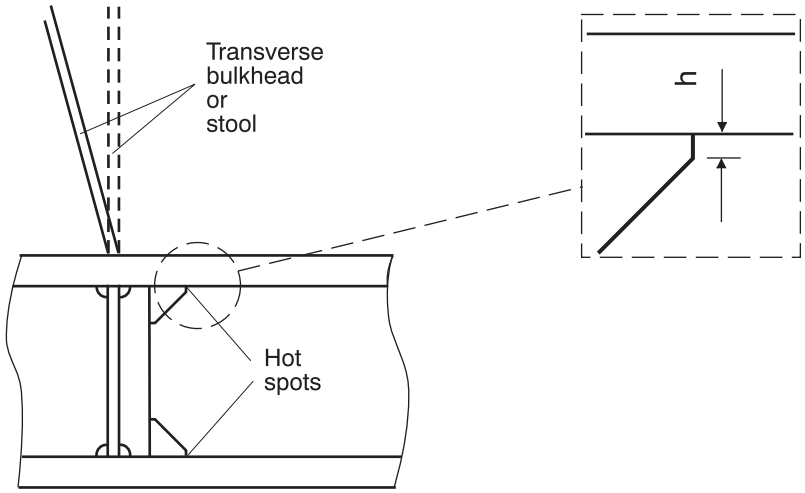
SCANTLINGS:	FATIGUE:
	Fatigue check to be carried out for L ≥ 90 m: K_h = 1,30 $K\ell$ = 1,65
CONSTRUCTION:	**NDE:**
• Misalignment between webs of bottom and inner bottom longitudinal with floor stiffener ≤ t / 3. • In case of fillet weld, misalignment may be as necessary to allow the required fillet leg size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- floor stiffeners to be connected with continuous fillet welding to bottom and inner bottom longitudinals,
- weld all around the stiffeners,
- fair shape of fillet at toes in longitudinal direction.

Table 15 :

AREA 2: Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - Brackets	Sheet 2.2



t = minimum thickness among those of the connected elements

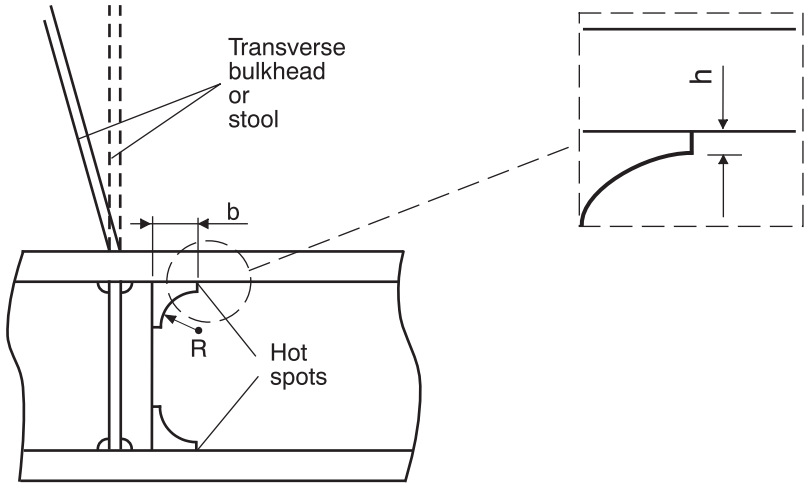
SCANTLINGS:	FATIGUE:
h as necessary to allow the required fillet throat size, but ≤ 15 mm.	Fatigue check to be carried out for L ≥ 90 m: K_h = 1,30 $K\ell$ = 1,55
CONSTRUCTION:	**NDE:**
• Misalignment between webs of bottom and inner bottom longitudinal with floor stiffener ≤ t / 3. • In case of fillet weld, misalignment may be as necessary to allow the required fillet leg size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- floor stiffeners and brackets to be connected with continuous fillet welding to bottom and inner bottom longitudinals,
- partial penetration welding between stiffeners and brackets,
- weld all around the stiffeners and brackets,
- fair shape of fillet at toes in longitudinal direction.

Table 16 :

AREA 2: Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - Radiused brackets	Sheet 2.3



t = minimum thickness among those of the connected elements

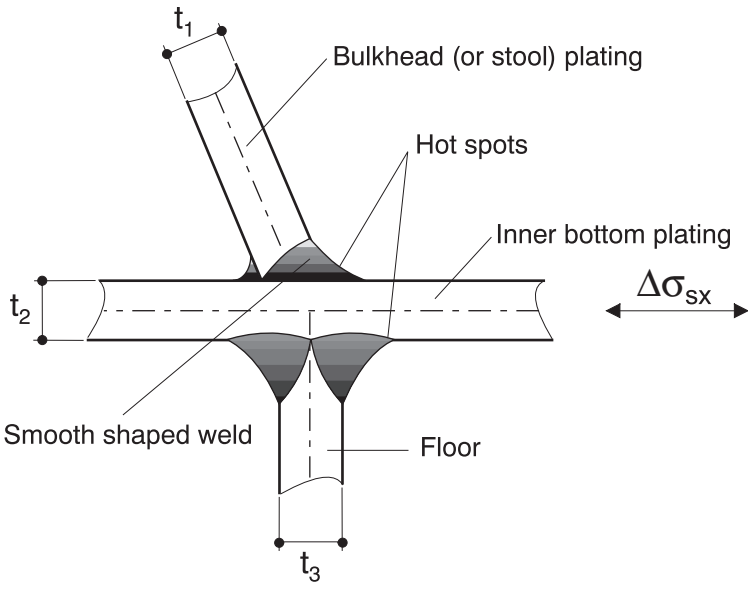
SCANTLINGS:	FATIGUE:
• Brackets to be symmetric. • $R \geq 1,5\ b$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm.	Fatigue check to be carried out for L ≥ 90 m: $K_h = 1,25$ $K\ell = 1,50$
CONSTRUCTION:	**NDE:**
• Misalignment between webs of bottom and inner bottom longitudinal with floor stiffener ≤ t / 3. • In case of fillet weld, misalignment may be as necessary to allow the required fillet leg size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- floor stiffeners and brackets to be connected with continuous fillet welding to bottom and inner bottom longitudinals,
- partial penetration welding between stiffeners and brackets,
- weld all around the stiffeners and brackets,
- fair shape of fillet at toes in longitudinal direction.

Table 17 :

AREA 2: Double bottom in way of transverse bulkheads	Connection of inner bottom with transverse bulkheads or lower stools	Sheet 2.4



Hot spot stresses:
$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{sX}$

$t = \min (t_1 , t_2 , t_3)$

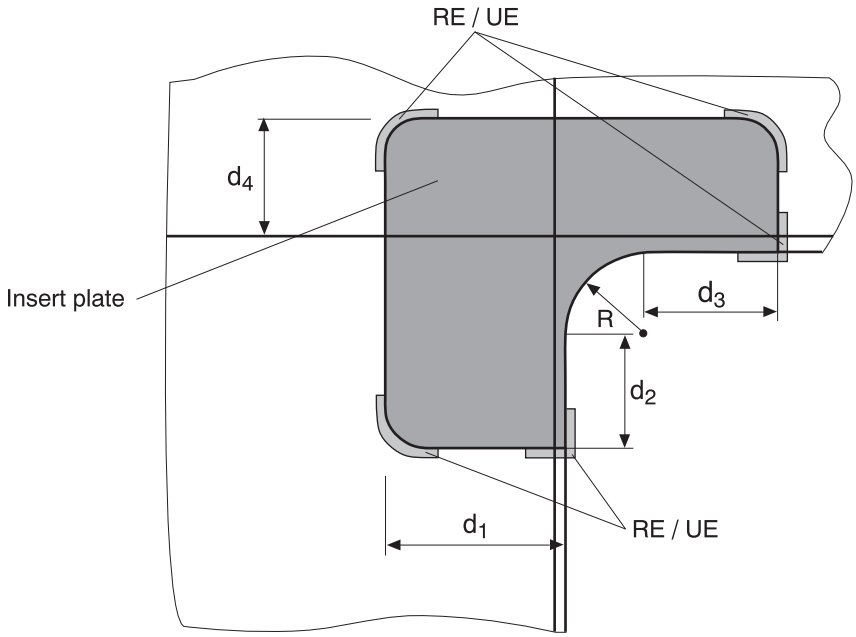
SCANTLINGS:	FATIGUE:
	Fatigue check to be carried out for L ≥ 90 m: $K_{SX} = 3,85$
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between floor and bulkhead (or stool) plating ≤ t / 3. • Cut-outs for connections of the inner bottom longitudinals to double bottom floors to be closed by collar plates welded to the inner bottom.	The following NDE are required: • VE 100%, • UE 35% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

- Welding requirements:
  - bulkhead (or stool) plating and supporting floors generally to be connected with full penetration welding to inner bottom plating (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - special approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating.
- Material requirements:
  - the strake of inner bottom plating in way of the connection is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding.
- Partial fillet welding may also be accepted in place of full penetration welding between floor and inner bottom plating. In such a case, the preparation is to be specified on drawing.

Table 18 :

AREA 3: Hatch corners	Deck plating in way of hatch corners	Sheet 3.1



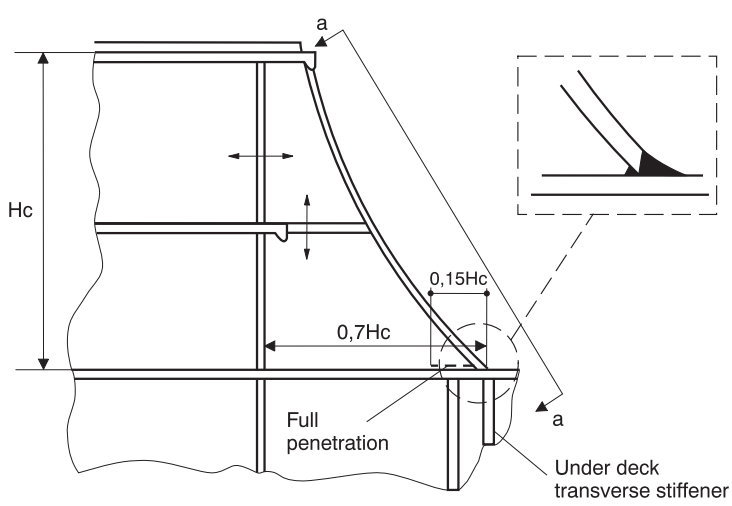
SCANTLINGS:	FATIGUE:
• Insert plates with circular profiles in general to be fitted in way of corners of hatchways located within the cargo area. The radius of circular corners to be in accordance with Ch 4, Sec 6, [6.2.1]. • Insert plates not required in way of corners of hatchways located in the above positions, where corners have an elliptical or parabolic profile according to Ch 4, Sec 6, [6.2.2]. • Where insert plates are required, their thickness to be defined according to Ch 4, Sec 6, [6.2.3] and their extension to be such that d_1 , d_2 , d_3 and $d_4 \geq s$, s being the ordinary frame spacing.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Corners of insert plates to be rounded, unless corresponding to joints of deck strakes. • Insert cut edges to be carefully executed.	The following NDE are required: • VE 100%, • RE / UE in areas indicated in the sketch.

WELDING AND MATERIALS:

- Welding requirements:
  - welds recommended to be continued on auxiliary pieces temporarily fitted at the free end of each joint, to be cut away; the joint ends are to be carefully ground.
- Materials requirements:
  - insert plate material of same or higher quality than the adjacent deck plating, depending on the insert thickness according to Ch 4, Sec 1, [2].

Table 19 :

AREA 3: Hatch corners	Ends of longitudinal hatch coamings - Bracket welded to deck plating	Sheet 3.2



t_A = minimum among:
- thickness of bracket flange at lower end,
- deck plating thickness,
- under deck transverse stiffener web thickness,

t_B = minimum among:
- bracket web thickness,
- deck plating thickness,
- thickness of the under deck longitudinal member.

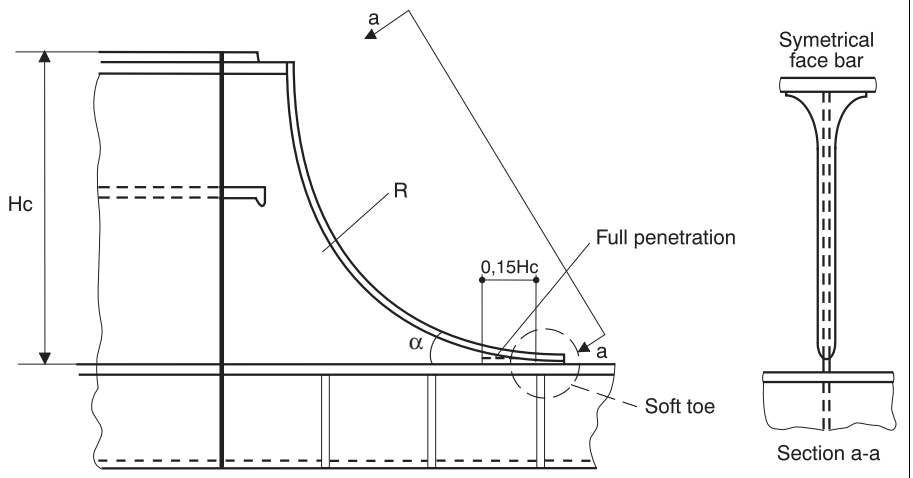
SCANTLINGS:	FATIGUE:
An additional under deck transverse stiffener is to be fitted in way of termination bracket toe, where the toe is clear of normal stiffener.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Misalignment between bracket flange and under deck transverse stiffener ≤ t_A / 3. • Misalignment between bracket and under deck longitudinal ≤ t_B / 3.	The following NDE are required: • VE 100%, with particular care for the weld shape and undercuts on deck plating at the bracket flange connection, • UE 100% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

Welding requirements:
- bracket flange to be connected with full penetration welding to deck plating, with half V bevel and weld shape elongated on deck plating (see sketch),
- ends of bracket webs to be connected with full penetration welding to deck plating for the extension shown in the sketch, with half X bevel,
- under deck transverse stiffener to be connected with full penetration welding to deck plating in way of the bracket flange,
- care is to be taken to ensure soundness of the crossing welds at the bracket toe, if the case, adopting small scallop to be closed by welding.

Table 20 :

AREA 3: Hatch corners	Ends of longitudinal hatch coamings - Bracket sniped at deck plating	Sheet 3.3



t = minimum among:
- bracket web thickness,
- deck plating thickness,
- thickness of the under deck longitudinal member.

SCANTLINGS:	FATIGUE:
R ≥ 500 mm. α ≤ 30°.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Misalignment between bracket and under deck longitudinal ≤ t_B / 3. • Soft toe: tapering of bracket flange at ends: thickness 1:3, width 1:5.	The following NDE are required: • VE 100%, with particular care for the weld shape and undercuts on deck plating, • UE 100% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

Welding requirements:
- ends of bracket webs to be connected with full penetration welding to deck plating for the extension shown in the sketch, with half X bevel.



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