Rules for the Classification of Naval Submarines

PART A - Classification and Surveys
PART B - Main Design Principles and Stability
PART C - Pressure Hull and Structures
PART D - Systems
PART E - Fire Safety and Human Occupancy
PART F - Additional Class Notations

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BUREAU VERITAS

MARINE & OFFSHORE DIVISION

GENERAL CONDITIONS

ARTICLE 1

1.1. - BUREAU VERITAS is a Society the purpose of whose Marine & Offshore Division (the "Society") is the classification (" Classification ") of any ship or vessel or offshore unit or structure of any type or part of it or system therein collectively hereinafter referred to as a "Unit" whether linked to shore, river bed or sea bed or not, whether operated or located at sea or in inland waters or partly on land, including submarines, hovercrafts, drilling rigs, offshore installations of any type and of any purpose, their related and ancillary equipment, subsea or not, such as well head and pipelines, mooring legs and mooring points or otherwise as decided by the Society.

The Society:

- "prepares and publishes Rules for classification, Guidance Notes and other documents (" Rules ");
- "issues Certificates, Attestations and Reports following its interventions (" Certificates ");
- "publishes Registers.

1.2. - The Society also participates in the application of National and International Regulations or Standards, in particular by delegation from different Governments. Those activities are hereafter collectively referred to as " Certification ".

1.3. - The Society can also provide services related to Classification and Certification such as ship and company safety management certification; ship and port security certification, training activities; all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board.

1.4. - The interventions mentioned in 1.1., 1.2. and 1.3. are referred to as " Services ". The party and/or its representative requesting the services is hereinafter referred to as the " Client ". **The Services are prepared and carried out on the assumption that the Clients are aware of the International Maritime and/or Offshore Industry (the "Industry") practices.**

1.5. - The Society is neither and may not be considered as an Underwriter, Broker in ship's sale or chartering, Expert in Unit's valuation, Consulting Engineer, Controller, Naval Architect, Manufacturer, Shipbuilder, Repair yard, Charterer or Shipowner who are not relieved of any of their expressed or implied obligations by the interventions of the Society.

ARTICLE 2

2.1. - Classification is the appraisement given by the Society for its Client, at a certain date, following surveys by its Surveyors along the lines specified in Articles 3 and 4 hereafter on the level of compliance of a Unit to its Rules or part of them. This appraisement is represented by a class entered on the Certificates and periodically transcribed in the Society's Register.

2.2. - Certification is carried out by the Society along the same lines as set out in Articles 3 and 4 hereafter and with reference to the applicable National and International Regulations or Standards.

2.3. - **It is incumbent upon the Client to maintain the condition of the Unit after surveys, to present the Unit for surveys and to inform the Society without delay of circumstances which may affect the given appraisement or cause to modify its scope.**

2.4. - The Client is to give to the Society all access and information necessary for the safe and efficient performance of the requested Services. The Client is the sole responsible for the conditions of presentation of the Unit for tests, trials and surveys and the conditions under which tests and trials are carried out.

ARTICLE 3

3.1. - **The Rules, procedures and instructions of the Society take into account at the date of their preparation the state of currently available and proven technical knowledge of the Industry. They are a collection of minimum requirements but not a standard or a code of construction neither a guide for maintenance, a safety handbook or a guide of professional practices, all of which are assumed to be known in detail and carefully followed at all times by the Client.**

Committees consisting of personalities from the Industry contribute to the development of those documents.

3.2. - **The Society only is qualified to apply its Rules and to interpret them. Any reference to them has no effect unless it involves the Society's intervention.**

3.3. - The Services of the Society are carried out by professional Surveyors according to the applicable Rules and to the Code of Ethics of the Society. Surveyors have authority to decide locally on matters related to classification and certification of the Units, unless the Rules provide otherwise.

3.4. - **The operations of the Society in providing its Services are exclusively conducted by way of random inspections and do not in any circumstances involve monitoring or exhaustive verification.**

ARTICLE 4

4.1. - The Society, acting by reference to its Rules:

- "reviews the construction arrangements of the Units as shown on the documents presented by the Client;
- "conducts surveys at the place of their construction;
- "classes Units and enters their class in its Register;
- "surveys periodically the Units in service to note that the requirements for the maintenance of class are met.

The Client is to inform the Society without delay of circumstances which may cause the date or the extent of the surveys to be changed.

ARTICLE 5

5.1. - **The Society acts as a provider of services. This cannot be construed as an obligation bearing on the Society to obtain a result or as a warranty.**

5.2. - **The certificates issued by the Society pursuant to 5.1. here above are a statement on the level of compliance of the Unit to its Rules or to the documents of reference for the Services provided for.**

In particular, the Society does not engage in any work relating to the design, building, production or repair checks, neither in the operation of the Units or in their trade, neither in any advisory services, and cannot be held liable on those accounts. Its certificates cannot be construed as an implied or express warranty of safety, fitness for the purpose, seaworthiness of the Unit or of its value for sale, insurance or chartering.

5.3. - **The Society does not declare the acceptance or commissioning of a Unit, nor of its construction in conformity with its design, that being the exclusive responsibility of its owner or builder.**

5.4. - The Services of the Society cannot create any obligation bearing on the Society or constitute any warranty of proper operation, beyond any representation set forth in the Rules, of any Unit, equipment or machinery, computer software of any sort or other comparable concepts that has been subject to any survey by the Society.

ARTICLE 6

6.1. - The Society accepts no responsibility for the use of information related to its Services which was not provided for the purpose by the Society or with its assistance.

6.2. - **If the Services of the Society or their omission cause to the Client a damage which is proved to be the direct and reasonably foreseeable consequence of an error or omission of the Society, its liability towards the Client is limited to ten times the amount of fee paid for the Service having caused the damage, provided however that this limit shall be subject to a minimum of eight thousand (8,000) Euro, and to a maximum which is the greater of eight hundred thousand (800,000) Euro and one and a half times the above mentioned fee. These limits apply regardless of fault including breach of contract, breach of warranty, tort, strict liability, breach of statute, etc.**

The Society bears no liability for indirect or consequential loss whether arising naturally or not as a consequence of the Services or their omission such as loss of revenue, loss of profit, loss of production, loss relative to other contracts and indemnities for termination of other agreements.

6.3. - All claims are to be presented to the Society in writing within three months of the date when the Services were supplied or (if later) the date when the events which are relied on of were first known to the Client, and any claim which is not so presented shall be deemed waived and absolutely barred. Time is to be interrupted thereafter with the same periodicity.

ARTICLE 7

7.1. - Requests for Services are to be in writing.

7.2. - **Either the Client or the Society can terminate as of right the requested Services after giving the other party thirty days' written notice, for convenience, and without prejudice to the provisions in Article 8 hereunder.**

7.3. - The class granted to the concerned Units and the previously issued certificates remain valid until the date of effect of the notice issued according to 7.2. here above subject to compliance with 2.3. here above and Article 8 hereunder.

7.4. - The contract for classification and/or certification of a Unit cannot be transferred neither assigned.

ARTICLE 8

8.1. - The Services of the Society, whether completed or not, involve, for the part carried out, the payment of fee upon receipt of the invoice and the reimbursement of the expenses incurred.

8.2. - **Overdue amounts are increased as of right by interest in accordance with the applicable legislation.**

8.3. - **The class of a Unit may be suspended in the event of non-payment of fee after a first unfruitful notification to pay.**

ARTICLE 9

9.1. - The documents and data provided to or prepared by the Society for its Services, and the information available to the Society, are treated as confidential. However:

- "Clients have access to the data they have provided to the Society and, during the period of classification of the Unit for them, to the **classification file** consisting of survey reports and certificates which have been prepared at any time by the Society for the classification of the Unit ;
- "copy of the documents made available for the classification of the Unit and of available survey reports can be handed over to another Classification Society, where appropriate, in case of the Unit's transfer of class;
- "the data relative to the evolution of the Register, to the class suspension and to the survey status of the Units, as well as general technical information related to hull and equipment damages, may be passed on to IACS (International Association of Classification Societies) according to the association working rules;
- "the certificates, documents and information relative to the Units classed with the Society may be reviewed during certificating bodies audits and are disclosed upon order of the concerned governmental or inter-governmental authorities or of a Court having jurisdiction.

The documents and data are subject to a file management plan.

ARTICLE 10

10.1. - Any delay or shortcoming in the performance of its Services by the Society arising from an event not reasonably foreseeable by or beyond the control of the Society shall be deemed not to be a breach of contract.

ARTICLE 11

11.1. - In case of diverging opinions during surveys between the Client and the Society's surveyor, the Society may designate another of its surveyors at the request of the Client.

11.2. - Disagreements of a technical nature between the Client and the Society can be submitted by the Society to the advice of its Marine Advisory Committee.

ARTICLE 12

12.1. - Disputes over the Services carried out by delegation of Governments are assessed within the framework of the applicable agreements with the States, international Conventions and national rules.

12.2. - Disputes arising out of the payment of the Society's invoices by the Client are submitted to the Court of Nanterre, France, or to another Court as deemed fit by the Society.

12.3. - **Other disputes over the present General Conditions or over the Services of the Society are exclusively submitted to arbitration, by three arbitrators, in London according to the Arbitration Act 1996 or any statutory modification or re-enactment thereof. The contract between the Society and the Client shall be governed by English law.**

ARTICLE 13

13.1. - **These General Conditions constitute the sole contractual obligations binding together the Society and the Client, to the exclusion of all other representation, statements, terms, conditions whether express or implied. They may be varied in writing by mutual agreement. They are not varied by any purchase order or other document of the Client serving similar purpose.**

13.2. - The invalidity of one or more stipulations of the present General Conditions does not affect the validity of the remaining provisions.

13.3. - The definitions herein take precedence over any definitions serving the same purpose which may appear in other documents issued by the Society.

BV Mod. Ad. ME 545 L - 7 January 2013

RULES FOR THE CLASSIFICATION OF NAVAL SUBMARINES

Part A **Classification and Surveys**

Part B **Main Design Principles and Stability**

Part C **Pressure Hull and Structures**

Part D **Systems**

Part E **Fire Safety and Human Occupancy**

Part F **Additional Class Notations**

September 2016

Unless otherwise specified, Part A of these rules apply on September 1st, 2016. The Society may refer to the contents hereof before September 1st, 2016, as and when deemed necessary or appropriate.
Unless otherwise specified, Parts B to F of these rules apply to naval submarines for which contracts are signed after September 1st, 2016. The Society may refer to the contents hereof before September 1st, 2016, as and when deemed necessary or appropriate.

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RULES FOR THE CLASSIFICATION OF NAVAL SUBMARINES

Part A
Classification and Surveys

Chapters **1 2 3 4**

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CHAPTER 2 ASSIGNMENT, MAINTENANCE AND WITHDRAWAL OF CLASS

CHAPTER 3 SCOPE OF SURVEYS

CHAPTER 4 SCOPE OF SURVEYS RELATED TO ADDITIONAL CLASS NOTATIONS

September 2016

Part A
Classification and Surveys

Chapter 1

PRINCIPLES OF CLASSIFICATION AND CLASS NOTATIONS

SECTION 1 **GENERAL PRINCIPLES OF CLASSIFICATION**

SECTION 2 **CLASSIFICATION NOTATIONS**

APPENDIX 1 **QUAY AND SEA TRIALS**

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SECTION 1 GENERAL PRINCIPLES OF CLASSIFICATION

1 Principles of classification

1.1 Purpose of the Rules

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

Class assigned to a submarine reflects the discretionary opinion of the Society that the submarine, for declared conditions of use and within the relevant time frame, complies with the Rules applicable at the time the service is rendered. Class requirements can be temporarily suspended under emergency conditions (war, terrorist attack,...) declared by the Naval Authority.

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

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

- Part A - Classification and Surveys: applies to all naval conventional submarines.
- Part B - Main Design Principles and Stability, Part C - Pressure Hull and Structures, Part D - Systems and Part E - Provisions related to Human Occupancy and Fire Safety: apply to seagoing naval conventional submarines whose hull is of welded steel construction. Where necessary, the extent of application is more precisely defined in each chapter of these parts of the Rules.
- Part F - Additional Class Notations: applies, at the request of the Interested Party, to seagoing naval conventional submarines.

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

1.2 General definitions

1.2.1 The following general definitions are used in these Rules :

- Society means the Classification Society with which the submarine is classed
- Rules means the present Rules for the Classification of Naval Submarines (NR535) and documents issued by the Society serving the same purpose
- Surveyor means technical staff acting on behalf of the Society to perform tasks in relation to classification and survey duties
- Survey means an intervention by the Surveyor for assignment or maintenance of class as defined in Part A, Chapter 2, or interventions by the Surveyor within the limits of the tasks delegated by the Naval Authority
- Navy means the Governmental Body to whom the State or the Defence Department of the State has delegated responsibility for ownership of naval submarines. The Navy is responsible for the requirement, procurement and through life support and maintenance of the naval submarine
- Naval Authority means the authority nominated by the Navy responsible for providing regulation associated with procurement and support of the submarine. The Naval Authority may also be responsible for identifying appropriate standards, auditing and classification. The Naval Authority could be a Navy department, Statutory Authority or an independent organization with appropriate standing
- Owner means the party having the responsibility to keep the submarine seaworthy, having particular regard to the provisions relating to the maintenance of class laid down in Part A, Chapter 2
- Design Authority means the party having the responsibility of the technical consistency and the submarine design and of having the design approved by the classification society
- Shipbuilder means the party having the responsibility of the construction of the submarine and of her classification at the assignment phase
- Interested Party means a party, other than the Society, having responsibility for the classification of the submarine, such as the Owners of a submarine and his representatives, or the Shipbuilder, or the Design Authority or the Engine Builder, or the Supplier of parts to be tested
- Approval means the review by the Society of documents, procedures or other items related to classification, verifying solely their compliance with the relevant Rules requirements, or other referentials where requested
- Type approval means an approval process for verifying compliance with the Rules of a product, a group of products or a system, and considered by the Society as representative of continuous production
- Essential service is intended to mean a service having an impact on the safety of the submarine as defined in [1.3.1]. Their determination may also result from a specific analysis as defined in Ch 1, App 2
- Essential safety services are those intended to the detect or fight damages
- Submarine is intended to mean seagoing naval conventional submarines.

1.2.2 Definition of date of "contract for construction":

The date of "contract for construction" of a submarine is the date on which the contract to build the submarine is signed between the Owner and the Shipbuilder. This date is normally to be declared to the Society by the Interested Party applying for the assignment of class to a new submarine.

1.3 Meaning of classification, scope and limits

1.3.1 Levels of classification

Two levels of classification are considered:

a) Safety of the submarine intended to the prevention of sinking and of human being casualties, to maintaining the capacity of the submarine to return and keep to sur face safely and, if not possible, at least to evacuate the crew in safe conditions, covering the following items:

- pressure hull and related equipment
- main propulsion engine
- main batteries
- systems resisting to sea water pressure
- main ballasts including venting and blowing out systems
- electrical equipment and installations
- steering and trimming
- communication and navigation
- fire protection, detection and extinction
- human occupancy
- stability
- emergency and rescue installations
- other systems the list of which is established on case-by-case basis for each type of submarine.

b) Safety and operability of the submarine intended to cover the safety goals and the capability of surface or low depth diving in safe navigation, including all the items of safety plus the following items:

- auxiliary engines and related systems
- systems related to surface navigation other systems the list of which is established on case-by-case basis for each type of submarine.

Specific requirements for different types of submarines may be added on case-by-case basis with the agreement of the Society according to the real conditions of utilization of the submarine and to the return of experience on the actual behaviour of the different components and systems.

1.3.2 Classification process

The classification process consists of:

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

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

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

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

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

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

1.3.4 The class assigned to a submarine by the Society following its interventions is embodied in a Certificate of Classification and noted in the Register.

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

1.4 Request for services

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

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

1.5 Register

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

Referring to the additional notations, only these which publication is authorized by the Owner are mentioned in the Register.

2 Rules

2.1 Effective date

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

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

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

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

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

2.1.5 The rule requirements related to assignment, maintenance and withdrawal of the class of submarines already in operation, as detailed in Part A, Chapter 2 to Part A, Chapter 4, are applicable from the date of their entry into force.

2.2 Equivalence

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

2.3 Novel features

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

2.4 Disagreement and appeal

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

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

3 Duties of the Interested Parties

3.1 International and national regulations

3.1.1 The classification of a submarine does not relieve the Interested Party from compliance with any requirements issued by the Naval Authority.

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

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

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

3.2 Surveyor's intervention

3.2.1 Except for secrecy or operational restrictions, Surveyors are to be given free access at all times to submarines which are classed or being classed, shipyards and works, to carry out their interventions within the scope of assignment or maintenance of class, or within the scope of interventions carried out on behalf of Naval Authority, when so delegated.

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

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

Refer also to Ch 2, Sec 2, [2.4] to Ch 2, Sec 2, [2.6].

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

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

3.3 Operation and maintenance of submarines

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

In particular, it will be assumed that the submarine is operated in the allowable operational and environmental limits for which it has been designed.

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

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

3.4 Use of measuring equipment and of service suppliers

3.4.1 General

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

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

3.4.2 Simple measuring equipment

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

3.4.3 Shipboard measuring equipment

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

3.5 Spare parts

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

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

However, in the case of repairs or replacement, the spare parts used are to meet the requirements of the Rules as far as practicable. Refer to Ch 2, Sec 2, [6.3.2].

SECTION 2 CLASSIFICATION NOTATIONS

1 General

1.1 Purpose of the classification notations

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

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

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

1.1.2 The classification notations assigned to a submarine are indicated on the Certificate of Classification.

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

1.2 Types of notations assigned

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

a) class symbol

b) construction marks

c) service notations with additional service features, as applicable

d) navigation notations

e) additional class notations (optional).

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

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

I ✠ HULL ✠ MACH

(class symbol, construction marks)

Naval Conventional Submarine

(service notation and additional service features)

Unrestricted navigation

(navigation notation)

✠ REF-STORE

(additional class notation).

2 Class symbol

2.1 General

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

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

The period of class (or interval between class renewal surveys) assigned to class symbol **I** submarines is normally maximum 10 years, see Ch 2, Sec 2, [4].

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

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

3 Construction marks

3.1 General

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

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

The construction mark is placed before the symbol **HULL** for the hull, before the symbol **MACH** for the machinery installations, and before the following additional class notations: **REF-STORE**, **AIP**, **ANCHORING**, **REFUGE**.

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

3.2 List of construction marks

3.2.1 The mark ✠ is assigned to the relevant part of the submarine, when it has been surveyed by the Society during its construction in compliance with the new building procedure detailed in Ch 2, Sec 1, [2.1].

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

3.3 Certification of specific equipment

3.3.1 The certification of submarine specific equipment can be made on the basis of the compliance with the shipyard / designer specification. The list of specific equipment shall be agreed by the Society.

4 Service notations

4.1 General

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

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

4.1.2 The assignment of any service notation to a new submarine is subject to compliance with general rule requirements laid down in Part B, Part C, Part D and Part E of the Rules and in NR216 Materials and Welding.

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

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

4.2 Naval conventional submarines

4.2.1 The service notation **Naval conventional submarine** is assigned to warship having:

- a surface displacement above 500 t
- diesel electric propulsion type with possible AIP, electrical propulsion motors being located inside the pressure hull
- one or two shaft lines
- lead-acid main batteries
- main ballasts located outside of the pressure hull, in free communication with the seawater and blowed by compressed air
- steering powered by hydraulics
- safety actuators powered by permanent sources of hydraulics or compressed air.

Submarines designed according to different principles may be considered on case-to-case basis by the Society, additional requirements could be considered.

5 Navigation and operating area notations

5.1 Navigation notations

5.1.1 Every classed submarine is to be assigned one of the navigation notations listed in [5.2].

5.1.2 The assignment of a navigation notation, including the reduction of scantlings or specific arrangements for restricted navigation notations, is subject to compliance with the requirements laid down in Part B, Part C, Part D and Part E of the Rules and in NR 216 Materials and Welding.

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

5.2 List of navigation notations

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

5.2.2 Restricted navigation

The navigation notation **restricted navigation** is assigned to a submarine intended to operate in a limited area. The limits are reminded on the class certificate.

6 Additional class notations

6.1 General

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

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

6.1.3 The additional class notations **REF-STORE**, **AIP**, **ANCHORING**, **REFUGE** are assigned a construction mark, according to the principles given in [3.1.2].

6.1.4 The different additional class notations which may be assigned to a submarine are listed in [6.2] to [6.7], according to the category to which they belong.

6.2 Refrigerating installations

6.2.1 General

The additional class notation **REF-STORE** is assigned to submarines provided with refrigerating installations related to preservation of ship domestic supplies, complying with the requirement of Pt F, Ch 1, Sec 1.

6.3 Health, safety and environment (HSE)

6.3.1 General

The additional class notation **HSE** is assigned to submarines complying with the health, safety and environmental regulations of the Naval Authority (see Pt F, Ch 1, Sec 2).

6.4 Air independent propulsion (AIP)

6.4.1 General

The additional class notation **AIP** is assigned to submarines provided with an Air Independent Propulsion System (AIP).

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

6.5 Collision residual strength (CollRES)

6.5.1 General

The additional class notation **CollRES** is assigned to submarines provided with a transverse section resisting to collisions as defined in Pt F, Ch 1, Sec 4.

6.6 Anchoring

6.6.1 General

The additional class notation **ANCHORING** is assigned to submarines provided with one anchoring line and complying with the requirements of Pt F, Ch 1, Sec 5.

6.7 Refuge compartment

6.7.1 General

The additional class notation **REFUGE** is assigned to submarines provided with a refuge compartment intended for use during the survival period in the case the pressure hull is flooded.

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

APPENDIX 1 QUAY AND SEA TRIALS

1 General

1.1 Application

1.1.1 This Section covers shipboard tests, both ashore and during sea trials. Such tests are additional to the workshop tests required in the other Sections of this Chapter.

1.2 Purpose of shipboard tests

1.2.1 Shipboard tests are intended to demonstrate that:

a) ship is able to navigate safely on surface and diving

b) machinery and associated systems are functioning properly, in particular in respect of the criteria imposed by the Rules.

Tests are to be witnessed by a Surveyor.

1.3 Documentation to be submitted

1.3.1 A comprehensive list of the shipboard tests intended to be carried out by the shipyard is to be submitted to the Society.

For each test, the following information is to be provided:

- scope of the test
- parameters to be recorded
- performances to be achieved before starting the next step.

2 General requirements for shipboard tests

2.1 Trials ashore

2.1.1 Trials ashore are to demonstrate the following:

a) ability of submarine to electric energy production and storage: all safety and associated systems linked to these functions are to be tested, including gas tightness of relevant compartments

b) ability of submarine to be watertight and to float. Watertightness of all closing devices of hull openings has to be tested or proven by particular tests previously undertaken

A global test shall be done

A specific test for each rescue zone shall be done

c) partial propulsion system performance through bollard test

d) satisfactory operation of the machinery in relation to the service for which it is intended

e) quick and easy response to operational commands

f) Functional test of:

- communication and navigation systems
- ventilation emergency shut-down
- Schnorchel alarms
- water ingress alarms
- fire fighting systems
- rescue systems
- navigation lights

g) Control of the atmosphere:

- verification of the quality of the breathing air
- calibration of the atmosphere control system

h) safety of the various installations, as regards:

- the protection of mechanical parts
- the safeguards for personnel

i) accessibility for cleaning, inspection and maintenance.

Where the above features are not deemed satisfactory and require repairs or alterations, the Society reserves the right to require the repetition of the trials at the moorings, either wholly or in part, after such repairs or alterations have been carried out.

2.2 Sea trials

2.2.1 Scope of the tests

Sea trials are to be conducted after the trials ashore. The aim of these trials is to check performances and abilities of submarine while extending step by step the range depth and speed.

Sea trials are to include the following:

a) adequate submarine weight checking through low immersion static diving

b) demonstration of the proper operation of machinery on surface, under realistic service conditions, including:

- check of monitoring, alarm and safety systems
- check of the propulsion capability when one of the essential auxiliaries becomes inoperative
- detection of dangerous vibrations by taking the necessary readings when required
- urgent stop test

c) demonstration of ability of submarine to navigate in depth safely, including:
   - ability of hull and systems to withstand immersion pressure
   - tests included in item b) undertaken while diving
   - check of systems involved in atmosphere control of submarine
   - check of systems involved in flooding fighting
   - check of rescue systems
   - check of navigation and positioning systems

d) checks either deemed necessary for ship classification or requested by the interested parties and which are possible only in the course of navigation in open sea.

2.2.2 Exemptions

Exemption from some of the sea trials may be considered by the Society in the case of ships having a sister ship for which the satisfactory behaviour in service is demonstrated.

Such exemption is, in any event, to be agreed upon by the interested parties and is subject to the satisfactory results of trials at the moorings to verify the safe and efficient operation of the propulsion system.

3 Shipboard tests for machinery

3.1 Conditions of sea trials

3.1.1 Displacement of the ship

Except in cases of practical impossibility, or in other cases to be considered individually, the sea trials are to be carried out in a situation as close as possible to the reference situation described in Pt B, Ch 2, Sec 1, [4.1.1].

3.1.2 Power of the machinery

The power developed by the propulsion machinery in the course of the sea trials is to be as close as possible to the power for which classification has been requested.

3.1.3 Determination of the power and rotational speed

a) The rotational speed of the shafting is to be recorded in the course of the sea trials, preferably by means of a continuous counter.

b) In general, the power is to be determined by means of torsiometric readings, to be effected with procedures and instruments deemed suitable by the Society.

   Methods of determining the power may be considered by the Society on a case by case basis.

3.2 Navigation and manoeuvring tests

3.2.1 Speed trials

a) Where required by the Rules, the speed of submarine is to be determined using procedures deemed suitable by the Society.

b) The submarine speed is to be determined as the average of the speeds taken in not less than two pairs of runs in opposite directions.

3.2.2 Astern trials

a) The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, and so to bring the ship to rest within reasonable distance from maximum ahead service speed, shall be demonstrated and recorded, on surface and in depth. Provisions shall be taken in order to avoid reverse of speed during test in depth.

b) The stopping times, ship headings and distances recorded on trials shall be available on board for the use of the Master or designated personnel.

c) Where the ship is provided with supplementary means for manoeuvring or stopping, the effectiveness of such means shall be demonstrated and recorded as referred to in items a) and b).

3.2.3 Change of propulsion system configuration

a) Where several normal propulsion system configurations are possible, each of them are to be tested.

b) The normal transfers between these configurations are to be tested.

3.3 Tests of diesel engines

3.3.1 General

The scope of the trials of diesel engines is to include surface navigation and in depth navigation (periscopic immersion).

3.3.2 Engines driving generators for electric propulsion

a) Dock trials

   Dock trials are to include operation at 100% rated power during four hours. Arrangement shall be taken in order to enable constant load of engine with suitable shore devices connected with tested engine. Whenever 100% of engine is not reachable with shore devices, maximum load as practicable shall be used for this test.

b) Sea trials

   Sea trials of engines driving generators for electric propulsion are to include the following tests on surface and at periscopic immersion:

   1) operation of engines in the whole range of power
   2) operation at 100% load during four hours for each engine
   3) starting manoeuvres
   4) tests of the monitoring, alarm and safety systems.

Note 1: The above tests are to be performed at rated speed with a constant governor setting. The powers refer to the rated electrical powers of the driven generators.

3.4 Test of batteries

3.4.1 Dock trials

a) Capacity of batteries shall be tested by complete loading and unloading of each battery at various rates.

b) On board instrumentation and controls shall be checked during these tests.

3.5 Tests of electric propulsion system

3.5.1 Dock trials

a) The dock trials are to include the test of the electrical production system, the power management system and the load limitation.

b) A test of the propulsion plant at a reduced power, in accordance with dock trial facilities, is to be carried out. During this test, the following are to be checked:

- electric motor rotation speed variation
- functional test, as far as practicable (power limitation is to be tested with a reduced value)
- protection devices
- monitoring and alarm transmission including interlocking system.

c) Prior to the sea trials, an insulation test of the electric propulsion plant is to be carried out.

3.5.2 Sea trials

Testing of the performance of the electric propulsion system is to be effected in accordance with an approved test program for surface and in depth conditions.

This test program is to include at least:

- speed rate of rise
- endurance test:
  - 4 hours at maximum continuous power reachable with batteries loaded by diesel engines on surface only
  - maximum continuous load ahead admissible for electric motors developed during specificated duration (in depth and on surface). If different configurations of power supply exist, this test should be undertaken in each of these configurations. Temperature measurements are to be recorded
  - operation in reverse direction of propeller rotation at the maximum torque or thrust allowed by the propulsion system for 10 minutes (on surface only). Test may be adapted as follows:
    - maximum continuous torque or thrust applied, till a pre-determined astern speed limit is reached (equal or more than five knots)
    - remaining time
- check of the crash astern operation in accordance with the sequence provided to reverse the speed from full ahead to full astern, in case of emergency
- test of functionality of electric propulsion, when manoeuvring and during the submarine turning test.

3.6 Tests of main propulsion shafting and propellers

3.6.1 Shafting alignment

Where alignment calculations are required to be submitted in pursuance of Pt D, Ch 2, Sec 2, [3.3], the alignment conditions are to be checked on board as follows:

a) shafting installation and intermediate bearing position, before and during assembling of the shafts:
   - optical check of the relative position of bushes after fitting
   - check of the flanged coupling parameters (gap and sag)
   - check of the centring of the shaft sealing glands

b) engine (or gearbox) installation, with floating ship:
   - check of the engine (or gearbox) flanged coupling parameters (gap and sag)

Note 1: The ship is to be in the loading conditions defined in the alignment calculations.

c) load on the bearings:
   - check of the intermediate bearing load by means of jack-up load measurements
   - check of the bearing contact area by means of coating with an appropriate compound or any relevant measurement.

3.6.2 Shafting vibrations

Torsional, bending and axial vibration measurements are to be carried out where required by Pt D, Ch 2, Sec 2, [4]. The type of the measuring equipment and the location of the measurement points are to be specified.

3.6.3 Bearings

The temperature of the bearings is to be checked under the machinery power conditions specified in [3.1.2].

3.6.4 Stern tube sealing gland

The stern tube sealing gland system leakage is to be checked at relevant immersions and shaft rotational speeds.

3.7 Tests of piping systems

3.7.1 Functional tests

During the sea trials, piping systems serving propulsion and auxiliary machinery, including the associated monitoring and control devices, are to be subjected to functional tests at the nominal power of the machinery and at several immersion values (at least, surface, safety immersion, half nominal immersion, nominal immersion). Operating parameters (pressure, temperature, consumption) are to comply with the values recommended by the equipment manufacturer.

3.7.2 Performance tests

The Society reserves the right to require performance tests, such as flow rate measurements for bilge and weight control systems, should doubts arise from the functional tests.

3.8 Tests of steering gear

3.8.1 General

The steering gear is to be tested during the sea trials under the conditions stated in [3.1] in order to demonstrate, to the Surveyor's satisfaction, that the applicable requirements Pt D, Ch 3, Sec 7 are fulfilled.

3.8.2 Tests to be performed

Tests of the steering gear are to include at least:

a) functional test of the steering gear with demonstration of the performances required by Pt D, Ch 3, Sec 7

b) test of the steering gear power units, including transfer between steering gear power units

c) test of the steering performances in any failure conditions foreseen by analysis (for instance: power unit failure, control system failure...)

d) test of the hydraulic fluid refilling system

e) test of the steering gear controls, including transfer of controls and local control

f) test of the means of communication between the navigation bridge, the engine room and the steering gear compartment and other position of emergency steering

g) test of the alarms and indicators

h) test of automatic headings and immersion control systems.

3.9 Tests of other systems

3.9.1

Functional test of the following systems are to be performed:

- rescue and escape system for compliance with STANAG 1074, 1297 (as far as practicable), 1298, 1301, 1382
- emergency blowing system
- weight control system
- communication and navigation equipment
- Schnorchel alarms.

4 Inspection of machinery after sea trials

4.1 General

4.1.1

a) For all types of propulsion machinery, those parts which have not operated satisfactorily in the course of the sea trials, or which have caused doubts to be expressed as to their proper operation, are to be disassembled or opened for inspection.

Machinery or parts which are opened up or disassembled for other reasons are to be similarly inspected.

b) Should the inspection reveal defects or damage of some importance, the Society may require other similar machinery or parts to be opened up for inspection.

c) An exhaustive inspection report is to be submitted to the Society for information.

4.2 Diesel engines

4.2.1 In general, for all diesel engines, the following items are to be verified:

- the deflection of the crankshafts, by measuring the variation in the distance between adjacent webs in the course of one complete revolution of the engine when deemed necessary
- the cleanliness of the lubricating oil filters.

APPENDIX 2 SAFETY FILE

1 General

1.1 Safety file purpose

1.1.1 The purpose of the safety file is to demonstrate that the ship is able to deal with risks inherent to surface and in-depth operations.

The safety demonstration aims at demonstrating that the safety objectives of the ship are met. The ship safety objective vis-à-vis the most serious events is set at an AOF (annual occurrence frequency) of 10^{-5} per year and per submarine. Above this value, it shall be attempted to mitigate the consequences of the dreaded events and to meet the safety objective of the ship.

The seriousness is determined according to two aspects concerning the availability of the essential functions of the submarine and the impact on the crew's safety.

1.1.2 The safety file shall include any calculation, analysis, drawing and testing references necessary to check the good behaviour of submarine on relevant risks.

1.2 Risks

1.2.1 At least the following risks shall be contemplated:

- any type of collision:
  - with a surface vessel during resurfacing phase, Schnorchel and surface navigation
  - with the bottom
  - going aground

  The consequences of a collision are to be assessed quantitative analysis for any type of collision and qualitative analysis when this scenario is part of the safety objectives of the submarine
- loss of pressure hull integrity
- water leakage, including erroneous detection of water leakage
- loss of manoeuvring means
- atmosphere abnormal composition
- explosion of pressurized capacities
- process Gas mix Explosion
- pipe breaking
- process fluid pollution
- missile ejection
- electromagnetic internal effects
- fire
- explosion due to specific process (hydrogen accumulation in battery compartment, specific energy plants using embarked combustive, pyrotechnic events, vapour leaks, or any other risk of this kind)
- operator single failure
- depression situation onboard
- rescue of the crew from the submarine lying on the bottom.

1.2.2 Reaction of the crew

The reaction time of the crew as well as the possible errors due to a wrong evaluation of the nature of the danger are to be taken into consideration in the safety demonstration.

2 Composition of the safety file

2.1 Structure of safety file

2.1.1 Documents

The safety file shall include:

- a document making assessment of safety aspects aboard submarine including a list of essential services and essential safety services as defined in Ch 1, Sec 1, [1.2.1]
- a diagram showing immersions where the submarine is allowed to dive down to, regarding speed of ship. Justification file shall be included with this diagram (see [2.1.2])
- AIP safety file, when relevant.

Safety assessment shall contain any documents as mentioned in [1]. It shall explain as well:

- methodology used in analysis
- design provisions
- operational disposals proposed by manufacturer if any
- falling back disposals in case of abnormal situation of ships resulting from above mentioned risks (this shall include use of rescue devices).

2.1.2 Immersion versus speed diagram

Immersion versus speed diagram justification file shall explain and demonstrate that submitted cases of sea water leakage and loss of manoeuvring means scenarios won't lead the submarine to dive over extreme immersion and reach unacceptable climbing speed or trim or list during the submarine's way up to the surface of the sea. Specific hypotheses shall be mentioned:

- initial situation of submarine (immersion, speed, way, trim, unavailable equipment before failure if any)
- timing and details of crew reactions and equipment responses.

Part A
Classification and Surveys

Chapter 2

ASSIGNMENT, MAINTENANCE AND WITHDRAWAL OF CLASS

SECTION 1 **ASSIGNMENT OF CLASS**

SECTION 2 **MAINTENANCE OF CLASS**

SECTION 3 **SUSPENSION AND WITHDRAWAL OF CLASS**

APPENDIX 1 **PLANNED MAINTENANCE SURVEY SYSTEM**

SECTION 1 ASSIGNMENT OF CLASS

1 General

1.1 Criteria

1.1.1 Class is assigned to a submarine upon a survey, with the associated operations, which is held in order to verify whether it is eligible to be classed on the basis of the Rules of the Society (see Ch 1, Sec 1, [1.3.2]). This may be achieved through:

- the completion of the new building, during which a survey has been performed
- a specific admission to class survey, in cases where a submarine is classed with another Society or is not classed at all.

1.2 Confidentiality

1.2.1 The drawing approval activities and the necessary interventions for the class assignment are performed by authorized persons.

The drawings and documents required for the classification of a submarine are dealt with according to the level of confidentiality required by the Owner or the Naval Authority.

2 New building procedure

2.1 Submarines surveyed by the Society during construction

2.1.1 When a submarine is surveyed by the Society during construction, it is to comply with those requirements of the Rules which are in force and applicable depending on the class of the submarine, taking into account the provisions of Ch 1, Sec 1, [2.1] and Ch 1, Sec 1, [2.2].

2.1.2 The Society:

- approves the plans and documentation submitted as required by the Rules
- proceeds, if required, with the appraisal of the design of materials and equipment used in the construction of the submarine and their inspection at works
- carries out surveys or obtains appropriate evidence to satisfy itself that the scantlings and construction meet the rule requirements in relation to the approved drawings
- attends tests and trials provided for in the Rules
- assigns the construction mark ✠; refer to Ch 1, Sec 2, [3.2.1].

2.1.3 The Society defines in specific Rules which materials and equipment used for the construction of submarines built under survey are, as a rule, subject to appraisal of their design and to inspection at works, and according to which particulars.

2.1.4 As part of his interventions during the submarine's construction, the Surveyor will:

- conduct an overall examination of the parts of the submarine covered by the Rules
- examine the construction methods and procedures when required by the Rules
- check selected items covered by the rule requirements
- attend tests and trials where applicable and deemed necessary.

2.1.5 Use of materials, machinery, appliances and items

As a general rule, all materials, machinery, boilers, auxiliary installations, equipment, items etc. (generally referred to as "products") which are covered by the class and used or fitted on board submarines surveyed by the Society during construction are to be new and, where intended for essential services as defined in Ch 1, Sec 1, [1.2.1], tested by the Society.

Second hand materials, machinery, appliances and items may be used subject to the specific agreement of the Society and the Owner.

The requirements for the selection of materials to be used in the construction of the various parts of a submarine, the characteristics of products to be used for such parts and the checks required for their acceptance are to be as stated in Part C of the Rules and in NR216 Materials and Welding, as applicable, or in other Parts of the Rules or as specified on approved plans. In particular, the testing of products manufactured according to quality assurance procedures approved by the Society and the approval of such procedures are governed by the requirements of NR216 Materials and Welding, Ch 1, Sec 1, [3].

2.1.6 Defects or deficiencies and their repair

The Society may, at any time, reject items found to be defective or contrary to rule requirements or require supplementary inspections and tests and/or modifications, notwithstanding any previous certificates issued.

All repairs are subject to the preliminary agreement of the Society. When the limits of tolerance for defects are specified in the Rules concerned or by the Manufacturer, they are to be taken into account for repairs.

It is incumbent upon the Interested Party to notify the Society of any defects noted during the construction of the submarine and/or of any item not complying with the applicable requirements or in any case unsatisfactory. Proposals regarding remedial actions intended to be adopted to eliminate such defects or unsatisfactory items are to be submitted to the Society and, if accepted, carried out to the Surveyor's satisfaction.

2.1.7 Equivalence of Rule testing under certain conditions

Notwithstanding the provisions of [2.1.4], the Society may, at its discretion and subject to conditions and checks deemed appropriate, accept certain materials, appliances or machinery which have not been subjected to rule testing.

2.2 Other cases

2.2.1 When the procedure adopted does not comply with that detailed in [2.1] but the Society deems that it is acceptable for the assignment of class, the construction mark • is assigned in accordance with Ch 1, Sec 1.

2.3 Documentation

2.3.1 Documentation relevant to the class applied for is to be submitted for the approval of the Society.

2.3.2 The design data, calculations and plans to be submitted are listed in the relevant chapters of the Rules.

The Society may also call for additional information according to the specific nature of the submarine to be classed.

2.3.3 The documentation submitted to the Society is examined in relation to the class applied for in the request for classification.

Note 1: Should the Interested Party subsequently wish to have the class, in particular the service notation or navigation notation, granted to the submarine modified, plans and drawings are generally to be re-examined.

2.3.4 A copy of the submitted plans will be returned duly stamped, with remarks related to the compliance with the rule requirements should the need arise.

2.3.5 As a rule, modifications of the approved plans regarding items covered by classification are to be submitted.

2.3.6 Design data to be submitted to the Society are to incorporate all information necessary for the assessment of the design of the submarine for the purpose of assignment of class. It is the responsibility of the Interested Party to ascertain that the design data are correct, complete and compatible with the use of the submarine.

2.3.7 Design calculations are to be provided, when called for, as supporting documents to the submitted plans.

2.3.8 Design data and calculations are to be adequately referenced. It is the duty of the Interested Party to ascertain that the references used are correct, complete and applicable to the design of the submarine.

2.3.9 The submitted plans are to contain all necessary information for checking the compliance with the requirements of the Rules.

2.3.10 In the case of conflicting information, submitted documentation will be considered in the following order of precedence: design data, plans, design calculations.

2.3.11 It is the responsibility of the Interested Party to ascertain that drawings used for the procurement, construction and other works are in accordance with the approved plans.

3 Date of initial classification

3.1 Definitions

3.1.1 Date of build

For a new building the date of build is the date at which the new construction survey process is completed.

3.1.2 Date of initial classification for new buildings

As a general rule, for new buildings the date of initial classification coincides with the date of issuance of the classification certificate.

4 Reassignment of class

4.1 Conditions

4.1.1 At the request of the Owner, a submarine which was previously classed with the Society, subsequently withdrawn from class and has not been classed since may have the class reassigned subject to an admission to class survey. If applicable and appropriate, account may be taken of any periodical surveys held in the former period of class with the Society.

SECTION 2 MAINTENANCE OF CLASS

1 General principles of surveys

1.1 Survey types

1.1.1 Classed submarines are submitted to surveys for the maintenance of class. These surveys include the class renewal survey, bi-annual survey and surveys for the maintenance of additional class notations, where applicable. Such surveys are carried out at the intervals and under the conditions laid down in this Section. In addition to the above periodical surveys, submarines are to be submitted to occasional surveys whenever the circumstances so require; refer to [6].

Class renewal survey is carried out within the scope of the normal survey system where all the verifications are carried out by the Surveyors of the Society.

The bi-annual surveys are carried out within the scope of the PMS system where the verifications can be delegated to the person officially responsible for the maintenance or to the delegated technical personnel.

1.1.2 The different types of periodical surveys are summarised in Tab 1. The intervals at which the periodical surveys are carried out are given in the items referred to in the second column of Tab 1. The relevant extent and scope are given in Part A, Chapter 3 for all submarines and for service notations, respectively, while surveys related to additional class notations are given in Part A, Chapter 4.

Where the conditions for the maintenance of the class, service notations and additional class notations are not complied with, the class and/or the service notation and/or the additional class notations as appropriate will be suspended and/or withdrawn in accordance with the applicable Rules given in Ch 2, Sec 3.

Note 1: It is understood that requirements for surveys apply to those items that are required according to the Rules or, even if not required, are fitted on board and may have an impact on safety.

1.2 Change of periodicity, postponement or advance of surveys

1.2.1 When a survey becomes overdue during a mission, the following applies:

a) In the case of a class renewal survey, the Society may grant an extension to allow for completion of the class renewal survey, provided there is documented agreement to such an extension prior to the expiry date of the Certificate of Classification, adequate arrangements have been made for attendance of the Surveyor at the nearest opportunity and the Society is satisfied that there is technical justification for such an extension. Such an extension will be granted only until arrival at the first port of call after the expiry date of the Certificate of Classification.

   However, if owing to "exceptional circumstances" as defined in [2.1.7], the class renewal survey cannot be completed at the first port of call, the Society may grant an extension according to [4.1.1], but the total period of extension shall in no case be longer than three months after the original limit date of the class renewal survey.

b) In the case of bi-annual surveys, no postponement is granted. Such surveys are to be completed within their prescribed windows; see [2.1.3].

1.3 Extension of scope of survey

1.3.1 The Society and/or its Surveyors may extend the scope of the provisions in Part A, Chapter 3 and Part A, Chapter 4, which set forth the technical requirements for surveys, whenever and so far as considered necessary, or modify them in the case of special submarines or systems.

1.3.2 The extent of any survey also depends upon the condition of the submarine and its equipment. Should the Surveyor have any doubt as to the maintenance or condition of the submarine or its equipment, or be advised of any deficiency or damage which may affect the class, then further examination and testing may be conducted as considered necessary.

Table 1 : List of periodical surveys

Type of survey	Reference in this Section	Reference to scope of survey
Class renewal - hull	[4]	Ch 3, Sec 2
Class renewal - machinery	[4]	Ch 3, Sec 2
Class renewal - additional class notations	[1.1]	Part A, Chapter 4 **(1)**
Bi-annual - hull	[5]	Ch 3, Sec 1
Bi-annual - machinery	[5]	Ch 3, Sec 1
Bi-annual - additional class notations	[1.1]	Part A, Chapter 4 **(1)**
(1) As applicable, according to the additional class notations assigned to the submarine		

1.4 General procedure of survey

1.4.1 The general procedure of survey consists in:

- an overall examination of the parts of the submarine covered by the rule requirements and the extent of in service classification regime (see [1.1.1])
- checking selected items covered by the rule requirements
- attending tests and trials where applicable and deemed necessary by the Surveyor.

1.4.2 When a survey results in the identification of significant corrosion, structural defects or damage to hull, machinery and/or any piece of its equipment which, in the opinion of the Surveyor, affect the submarine's class, remedial measures are to be implemented before the submarine continues in service (see also [2.8]).

Note 1: The Society's survey requirements cannot be considered as a substitute for specification and acceptance of repairs and maintenance, which remain the responsibility of the Owner.

Note 2: In accordance with the provisions of Ch 1, Sec 1, [3.1.3], the Society will, at the request of the Owner, apply the regulations of Administrations concerning the scope and periodicity of surveys when they differ from those laid down in [4] and [5].

Note 3: During the surveys, the Surveyor does not check that the spare parts are kept on board, maintained in working order and suitably protected and lashed.

1.5 Appointment of another Surveyor

1.5.1 In compliance with the provisions of Ch 1, Sec 1, [2.4.1], should a disagreement arise between the Owner and the Surveyor during a survey, the Society may, at the request of the Owner, designate another Surveyor.

2 Definitions and procedures related to surveys

2.1 General

2.1.1 Period of class

Period of class means the period starting either from the date of the initial classification, see Ch 2, Sec 1, [3], or from the credited date of the last class renewal survey, and expiring at the limit date assigned for the next class renewal survey.

2.1.2 Anniversary date

Anniversary date means the day of the month of each year in the period of class which corresponds to the expiry date of the period of class.

2.1.3 Survey time window

Survey time window, or more simply window, mean the fixed period during which bi-annual surveys are to be carried out.

2.1.4 Overdue surveys

Each periodical survey is assigned a limit date specified by the relevant requirements of the Rules (end of survey interval or end date of window) by which it is to be completed.

A survey becomes overdue when it has not been completed by its limit date.

2.1.5 Recommendations

Any defect and/or deficiency affecting the class and to be dealt with within a specific period of time is indicated as a recommendation. A recommendation is pending until it is cleared. Where it is not cleared by its limit date, the recommendation is overdue.

2.1.6 Memoranda

Those defects and/or deficiencies which do not affect the maintenance of class and which may therefore be cleared at the Owner's convenience and any other information deemed noteworthy for the Society's convenience are indicated as memoranda. Memoranda are not to be regarded as recommendations.

2.1.7 Exceptional circumstances

"Exceptional circumstances" means:

- unavailability of dry-docking facilities, or
- unavailability of repair facilities, or
- unavailability of essential materials, equipment or spare parts, or
- delays incurred by action taken to avoid severe weather conditions
- military operations considered with combat risks

2.1.8 Prompt and thorough repair

A "Prompt and thorough repair" is a permanent repair completed at the time of survey to the satisfaction of the Surveyor, therein removing the need for the imposition of any associated recommendation. See also [2.8].

2.2 Terminology related to hull survey

2.2.1 Exostructures

All Structures or structural parts located outside the pressure resistant hull and not belonging to resisting structures. Volumes bounded by exostructures are permanently in communication with the external environment.

2.2.2 Capacity

Tank or space intended for the carriage of liquid.

2.2.3 Spaces

Spaces are separate compartments including tanks.

2.2.4 Overall survey

An overall survey is a survey intended to report on the overall condition of the hull structure and determine the extent of additional close-up surveys.

2.2.5 Close-up survey

A close-up survey is a survey where the details of structural components are within the close visual inspection range of the Surveyor, i.e. normally within reach of hand.

2.2.6 Critical structural areas

Critical structural areas are locations which have been identified from calculations to require monitoring or from the service history of the subject submarine or from similar submarines or sister ships (if available), to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the submarine.

2.2.7 Corrosion prevention system

A corrosion prevention system is normally considered a full hard protective coating.

2.2.8 Special consideration

Special consideration or specially considered (in connection with close-up surveys and other examinations and testing) means sufficient close-up survey and other examinations and testing are to be taken to confirm the actual average condition of the structure under the coating and sheathings.

2.3 Procedures for structural non destructive testing

2.3.1 When required as per the scope of surveys defined below, structural non destructive testing (NDT) including thickness measurements are normally to be carried out under the responsibility of the Owner, in the presence of the Surveyor.

2.3.2 For all submarines, the following applies:

- structural NDT required in the context of surveys of hull structure is to be witnessed by a Surveyor. This requires the Surveyor to be on board while the structural NDT are carried out, enabling him at any time to intervene and to control the process.
- prior to commencement of the survey, a meeting is to be held between the attending surveyor(s), the Owner representative(s) in attendance and the NDT firm's representative(s) so as to ensure the safe and efficient execution of the surveys, NDT to be carried out on board.

2.3.3 Thickness measurement is normally to be carried out by means of ultrasonic test equipment. The accuracy of the equipment used for NDTs is to be proven to the Surveyor as required. The NDT is to be carried out by a company authorised by the Society.

The Society reserves the right to limit the scope of authorisation of the Company.

Note 1: Rule Note NR533 Approval of Service Suppliers gives details about the certification.

2.3.4 A structural NDT reports is to be prepared. The report is to give the location of the measurements and testings, the thickness measured and NDTs records and the corresponding original thickness. Furthermore, the report is to include the date when the NDTs were carried out, the type of testing equipment and method, the names and the qualification of the operators and their signatures.

The Surveyor is to review the final report and countersign the cover page.

2.4 Preparations and conditions for surveys

2.4.1 The Owner is to provide the necessary facilities for the safe execution of the surveys, as per Ch 1, Sec 1, [3.2.2].

2.4.2 Tanks and spaces are to be safe for access, i.e. gas freed, ventilated and illuminated.

In preparation for survey and to allow for a thorough examination, all spaces are to be cleaned. Spaces are to be sufficiently clean and free from water, scale, dirt, oil residues, etc. to reveal corrosion, deformation, fractures, damages or other structural deterioration.

Sufficient illumination is to be provided to reveal corrosion, deformation, fractures, damages or other structural deterioration.

2.4.3 A communication or visual safety system is to be arranged between the survey party in the tank and the responsible officer on board.

2.4.4 Explosimeters, oxygen-meters, breathing apparatus, life lines and whistles are to be at hand during the survey.

2.4.5 When examination of associated structure is required, the following applies:

- floors are to be lifted to the necessary extent for examination of the structure
- insulation, covering or liners is to be removed when there is any doubt as to the condition of the plating underneath or when adherence to plating is not tight
- in the case of solid ballast spaces, the solid ballast is to be partially removed for examination of the condition of the structure in way. Should doubts arise, the Surveyor may require more extensive removal of the solid ballast
- insulation of compartments intended for refrigerated consumables is to be removed over the necessary extent for examination by the Surveyor of the condition of the structure, unless constructional arrangements make such inspections possible without removing the insulation.

2.5 Access to structures

2.5.1 For overall survey, means are to be provided to enable the Surveyor to examine the hull structure in a safe and practical way.

2.5.2 For close-up survey, one of the following means for access, acceptable to the Surveyor, is to be provided:

- temporary staging, or
- other equivalent means.

2.6 Equipment for surveys

2.6.1 One or more of the following fracture detection procedures may be required if deemed necessary by the Surveyor:

- radiographic equipment
- ultrasonic equipment
- magnetic particle equipment
- dye penetrant.

2.7 Repairs and maintenance during mission

2.7.1 Any repair and overhauls which affect or may affect the class are to be noted in the submarine's log and submitted at the earliest opportunity to the attending Surveyor for use in determining further survey requirements.

2.8 Repairs

2.8.1 Any defect over the allowable limits (including buckling, grooving, detachment or fracture), which affects or, in the opinion of the Surveyor, will affect the submarine's structural, integrity, is to be promptly and thoroughly (see [2.1.8]) repaired.

Areas to be considered include, as applicable for the different submarine types:

- pressure resistance hull and its closing devices and penetrations
- resisting structures and their closing devices and penetrations
- exostructures (ballast and external fuel tanks)
- all the systems related to the diving safety.

2.8.2 For locations where adequate repair facilities are not available, consideration may be given to allow the submarine to proceed directly to a repair facility under surface navigation.

2.8.3 Additionally, when a survey results in the identification of structural defects or corrosion or in the identification of a system failure, either of which, in the opinion of the Surveyor, will impair the vessel's fitness for continued service, remedial measures are to be implemented before the submarine continues in service.

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

3.1 Issue of Certificate of Classification

3.1.1 A Certificate of Classification, bearing the class notations assigned to the submarine and an expiry date, is issued to any classed submarine. This certificate is also provided with annexes supplying information necessary for the management of the certificate and for carrying out the class surveys.

3.1.2 A Provisional Certificate of Classification may serve as a Certificate of Classification in some cases, such as after an admission to class survey, after a class renewal survey, or when the Society deems it necessary.

3.1.3 The Certificate of Classification and relevant annexes are to be made available to the Society's Surveyors upon request.

3.2 Validity of Certificate of Classification, maintenance of class

3.2.1 According to Ch 1, Sec 1, [2.4], the Society alone is qualified to confirm the class of the submarine and the validity of its Certificate of Classification.

3.2.2 During the class period, a Certificate of Classification is valid when it is not expired.

The class is maintained during a certain period or at a given date, when during the said period or at such date the conditions for suspension or withdrawal of class are not met.

Refer also to Ch 1, Sec 1, [1.3.4].

3.2.3 At the request of the Owner, a statement confirming the maintenance of class may be issued by the Society based on the information in its records for that submarine at the time.

This statement is issued on the assumption that the Owner has complied with the Rules, in particular with [6].

Should any information which would have prevented the Society from issuing the statement and which was not available at the time subsequently come to light, the statement may be cancelled.

Attention is drawn to Ch 2, Sec 3, [1.2], whereby the Society, upon becoming aware of a breach of the Rules, is empowered to suspend class from the date of the breach, which may be prior to the date of the statement.

3.2.4 According to the same conditions as in [3.2.3], a statement declaring that the class is maintained "clean and free from recommendation" may be issued by the Society when there is no pending recommendation at that date.

3.2.5 Classification-related documents and information are liable to be invalidated by the Society whenever their object is found to differ from that on which they were based or to be contrary to the applicable requirements. The Owner is liable for any damage which may be caused to any third party from improper use of such documents and information.

3.3 Endorsement of Certificate of Classification

3.3.1 Text of endorsement

When surveys are satisfactorily carried out, the Certificate of Classification is generally endorsed accordingly, with the relevant entries in the appropriate annexes.

Each endorsement normally consists of sections for the description of:

- the surveys held
- the imposed, deleted and postponed recommendations (including the assigned limit date as applicable)
- the unchanged existing recommendations (given for information only).

Where applicable, memoranda are also endorsed in the appropriate annex.

3.3.2 Possible modifications to endorsements

The Society reserves the right to modify the endorsements made by Surveyors.

3.4 Status of surveys and recommendations

3.4.1 Information given in the Certificate of Classification, associated endorsements, Rules and specific documents enables the Owner to identify the status of surveys and recommendations.

3.4.2 The omission of such information does not absolve the Owner from ensuring that surveys are held by the limit dates and pending recommendations are cleared to avoid any inconvenience which is liable to result from the suspension or withdrawal of class; see Ch 2, Sec 3.

4 Class renewal survey

4.1 General principles

4.1.1 Class renewal surveys are to be carried out in principle at ten-years intervals. Other periodicities may be considered on case-by-case basis.

4.1.2 A new period of class is assigned to the submarine after the satisfactory completion of the class renewal survey, and a new Certificate of Classification with relevant annexes is issued for the new period of class.

4.1.3 The class renewal surveys are to be planned by the Owner, in cooperation with the Society so as to ensure relevant accessibility to the classed items. The Owner is to submit its overhauls schedule to the Society for this purpose.

The class renewal surveys are to be carried out in conjunction with a major (primary) overhauls.

The class renewal survey may be commenced 18 months before the anniversary date with a view to completion by its due date.

4.1.4 A general examination of the machinery, as applicable for bi-annual surveys is to be carried out at the end of the period of class (see Ch 3, Sec 1).

5 Bi-annual surveys

5.1 General principles

5.1.1 Bi-annual surveys are to be carried out within a window of ± six months before each anniversary date.

5.1.2 When bi-annual surveys are carried out within the PMS system, the requirements from [5.1.3] to [5.1.5] apply.

5.1.3 The conditions for approval of the planned maintenance survey system, the determination of survey item intervals and the general scope of surveys are detailed in Ch 2, App 1.

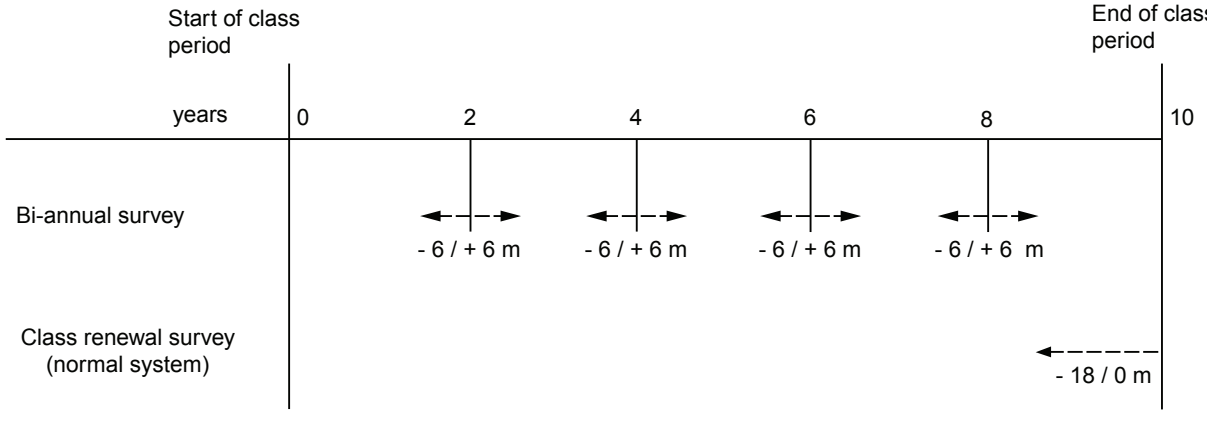
5.1.4 When the planned maintenance survey system is applied, this is indicated in the Certificate of Classification and notation PMS is entered in the Register.

5.1.5 The planned maintenance survey system may be discontinued at any time at the discretion of the Society, or at the request of the Owner, and a specific arrangement devised.

5.2 Links between anniversary dates, bi-annual surveys and class renewal surveys

5.2.1 The link between the anniversary dates, the class renewal survey and the bi-annual surveys is given in Fig 1.

Figure 1: Links between anniversary dates and bi-annual and class renewal surveys
10-year class period



6 Occasional surveys

6.1 General

6.1.1 An occasional survey is any survey which is not a periodical survey. The survey may be defined as an occasional survey of hull, machinery, refrigerating plants, etc., depending on the part of the submarine concerned.

Where defects are found, the Surveyor may extend the scope of the survey as deemed necessary.

6.1.2 Occasional surveys are carried out at the time of, for example:

- updating of classification documents (e.g. change of the Owner, name of the submarine)
- damage or suspected damage
- repair or renewal work
- alterations or conversion
- quality system audits
- postponement of surveys or recommendations
- return from mission.

6.2 Damage and repair surveys

6.2.1 In the event of damage which affects or may affect the class of the submarine, the Owner is to apply to the Society for a survey. Such application is to be made as soon as possible to enable the Surveyor to ascertain the extent of the damage and necessary repairs, if any.

6.2.2 All repairs to hull, machinery and equipment which may be required in order for a submarine to retain its class are to be to the satisfaction of the Surveyor.

During repairs or maintenance work, the Owner is to arrange so that any damage, defects or non-compliance with the rule requirements are reported to the Surveyor during his survey.

6.2.3 Damages and partial or temporary repairs considered acceptable by the Surveyor for a limited period of time are the subject of an appropriate recommendation.

6.2.4 Damages or repairs required by the Surveyor to be re-examined after a certain period of time are the subject of an appropriate recommendation.

6.3 Conversions, alterations and repairs

6.3.1 Conversions, alterations or repairs of/to structures and arrangements affecting the class are to be carried out in accordance with the requirements of the Society and to its satisfaction. Where necessary, documentation is to be submitted to the Society and/or made available to the attending Surveyor.

6.3.2 Materials and equipment used for conversions, alterations or repairs are generally to meet the requirements of the Rules for new submarines built under survey; see Ch 2, Sec 1, [2.1.5].

6.4 Quality System audits

6.4.1 The Society reserves the right to carry out occasional surveys in order to conduct audits as deemed necessary.

6.4.2 These surveys may also be attended by auditors external to the Society when authorized (see Ch 2 Sec 1 [1.2.1]).

6.4.3 The scope of these surveys is determined by the Society.

7 Change of ownership

7.1

7.1.1 In the case of change of ownership, the submarine retains its current class with the Society provided that:

- the Society is informed of the change sufficiently in advance to carry out any survey deemed appropriate, and
- the new Owner signs the appropriate request, involving acceptance of the Society's general conditions and Rules. This request covers inter alia the condition of the submarine when changing ownership.

Note 1: The submarine's class is maintained without prejudice to those provisions in the Rules which are to be enforced in cases likely to cause suspension or withdrawal of the class such as particular damages or repairs to the submarine of which the Society has not been advised by the former or, as the case may be, new Owner.

Note 2: No information whatsoever related to the class of the submarine will be provided or confirmed to any third party, unless the appropriate request for information is duly completed and signed by the party making the request and the authorisation of the current Owner is obtained.

8 Lay-up and re-commissioning

8.1 General principles

8.1.1 A submarine put out of commission may be subject to specific requirements for maintenance of class, as specified below, provided that the Owner notifies the Society of the fact.

If the Owner does not notify the Society of the laying-up of the submarine or does not implement the lay-up maintenance program, the submarine's class will be suspended and/or withdrawn when the due surveys are not carried out by their limit dates in accordance with the applicable requirements given in Ch 2, Sec 3.

8.1.2 When a submarine is put out of commission for a certain period, i.e. is laid-up, the normal survey requirements may no longer apply provided that the Owner notifies the Society of this fact. The Owner is also to submit a lay-up maintenance program to the Society for approval.

8.1.3 The lay-up maintenance program provides for a "laying-up survey" to be performed at the beginning of lay-up and subsequent "annual lay-up condition surveys" to be performed in lieu of the normal annual surveys which are no longer required to be carried out as long as the submarine remains laid-up.

The minimum content of the lay-up maintenance program is:

- the safety conditions to be kept throughout the lay-up period
- the measures taken to preserve the maintenance of the ship throughout the lay-up period
- the detailed informations on the lay-up site and mooring arrangements
- the survey requirements to be complied with for lay-up (laying-up survey), maintenance of class in lay-up (annual lay-up condition survey) and recommissioning (recommissioning survey).

The other periodical surveys which become overdue during the lay-up period may be postponed until the re-commissioning of the submarine.

8.1.4 Where the submarine has an approved lay-up maintenance program and its period of class expires, the period of class is extended until it is re-commissioned, subject to the satisfactory completion of the annual lay-up condition surveys as described in [8.1.3].

8.1.5 The periodical surveys carried out during the lay-up period may be credited, either wholly or in part, at the discretion of the Society, having particular regard to their extent and dates. These surveys will be taken into account for the determination of the extent of surveys required for the re-commissioning of the submarine and/or the expiry dates of the next periodical surveys of the same type.

8.1.6 When a submarine is re-commissioned, the Owner is to notify the Society and make provisions for the submarine to be submitted to the following surveys:

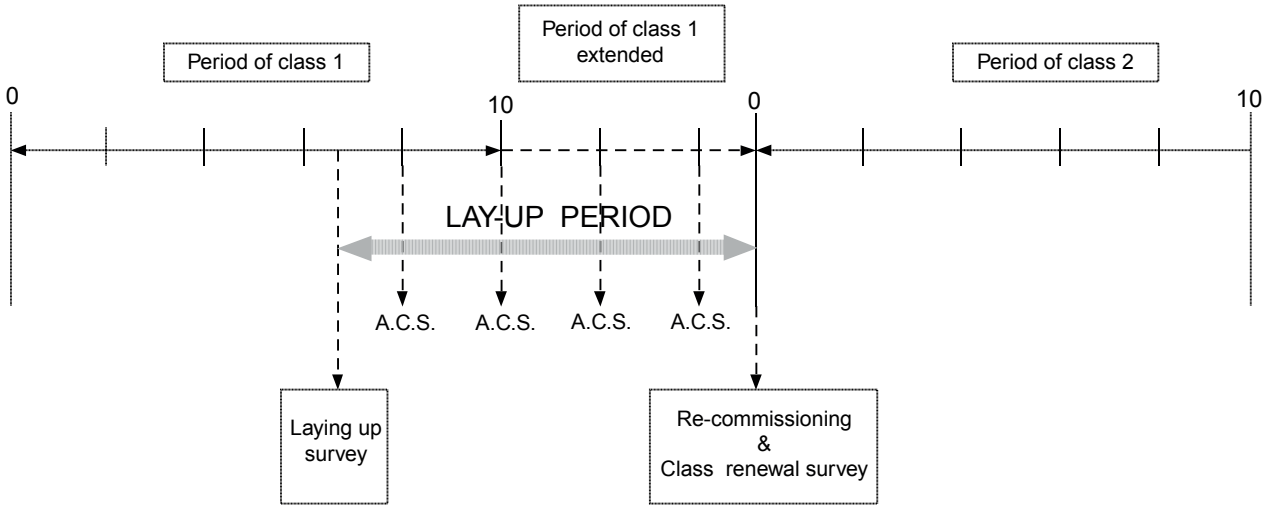
- an occasional survey prior to re-commissioning, the scope of which depends on the duration of the lay-up period
- all periodical surveys which have been postponed in accordance with [8.1.3], taking into account the provisions of [8.1.5].

8.1.7 Where the previous period of class expired before the re-commissioning and was extended as stated in [8.1.4], in addition to the provisions of [8.1.6] a complete class renewal survey is to be carried out prior to re-commissioning. Those items which have been surveyed in compliance with the class renewal survey requirements during the 15 months preceding the re-commissioning may be credited.

A new period of class is assigned from the completion of this class renewal survey.

8.1.8 The principles of intervals or limit dates for surveys to be carried out during the lay-up period, as stated in [8.1.1] to [8.1.7], are summarised in Fig 2.

Figure 2 : Survey scheme of a case of a lay-up going beyond the expiry date of the period of class



Note 1: A. C. S. means annual lay-up condition survey.

SECTION 3 SUSPENSION AND WITHDRAWAL OF CLASS

1 General

1.1 Discontinuance of class

1.1.1 The class may be discontinued either temporarily or permanently. In the former case it is referred to as "suspension" of class, in the latter case as "withdrawal" of class. In both these cases, the class is invalidated in all respects. In the case of withdrawal, a specific notation is entered in the supplement to the Register, until the submarine is deleted from the Register.

1.2 Suspension of class

1.2.1 Military operations

When a submarine is engaged in a particular operation, such as for example an operation considered with combat risks, the normal requirements for surveys are no more applicable within the condition that the Owner notified this fact to the Society). During the notified period, the class will be suspended.

At the end of the notified period the class will be reinstated once the surveys which have became overdue during the period of class suspension have been satisfactorily carried out. The endorsement on the Certificate of Classification has to confirm that all concerned surveys have been performed and mentions the period of the suspension of class.

It is the Owner responsibility to verify that the submarine parts not covered by the classification are in a satisfactory working conditions.

1.2.2 The class may be suspended either automatically or following the decision of the Society, or on the Owner request detailed in [1.2.1]. In any event, the submarine will be considered as not retaining its class from the date of suspension until the date when class is reinstated.

1.2.3 The class may be automatically suspended when one or more of the following circumstances occur:

- when a submarine is not operated in compliance with the rule requirements, such as in cases of services or conditions not covered by the service notation, or is operated outside the environmental and operational restrictions for which the class was assigned
- when a submarine proceeds to sea with a stability module (surface or submerged) is less than that assigned
- when the Owner fails to inform the Society in order to submit the submarine to a survey after defects or damages affecting the class have been detected
- when repairs, alterations or conversions affecting the class are carried out either without requesting the attendance of the Society or not to the satisfaction of the Surveyor. For voyage repairs, reference is to be made to Ch 2, Sec 2, [2.7].

Suspension of class with respect to the above cases will remain in effect until such time as the cause giving rise to suspension has been removed. Moreover, the Society may require any additional surveys deemed necessary taking into account the condition of the submarine and the cause of the suspension.

1.2.4 In addition, the class is automatically suspended:

- when the class renewal survey has not been completed by its limit date or within the time granted for the completion of the survey, unless the submarine is under attendance by the Society's Surveyors with a view to completion prior to resuming operations
- when the bi-annual survey has not been completed by the end of the corresponding survey time window (see Ch 2, Sec 2, [2.1.3]) unless the submarine is under attendance for completion of the survey.

Suspension of class with respect to the above cases will remain in effect until such time as the class is reinstated once the due items and/or surveys have been dealt with.

1.2.5 In addition to the circumstances for which automatic suspension may apply, the class of a submarine may also be suspended following the decision of the Society:

- when a recommendation is not dealt with within the time limit specified, unless it is postponed before the limit date by agreement with the Society
- when one or more surveys are not held by their limit dates (see Ch 2, Sec 2, [2.1.4]) or the dates stipulated by the Society also taking into account any extensions granted in accordance with the provisions of Part A
- when, due to reported defects, the Society considers that a submarine is not entitled to retain its class even on a temporary basis (pending necessary repairs or renewals, etc.)
- when the submarine has not been maintained in proper condition, as set forth in Ch 1, Sec 1, [3.3.2]
- in other circumstances which the Society will consider on their merits (e.g. in the event of non-payment of fees or where the Owner fails to subject the submarine to the occasional survey as per the requirement in Ch 2, Sec 2, [6.2.1]).

Suspension of class decided by the Society takes effect from the date when the conditions for suspension of class are met and will remain in effect until such time as the class is reinstated once the due items and/or surveys have been dealt with.

1.3 Withdrawal of class

1.3.1 The Society will withdraw the class of a submarine in the following cases:

- at the request of the Owner
- as a rule, when the causes that have given rise to a suspension currently in effect have not been removed within six months after due notification of suspension to the Owner
- when the submarine is reported as a constructive total loss
- when the submarine is lost
- when the submarine is reported scrapped.

Withdrawal of class may take effect from the date on which the circumstances causing such withdrawal occur.

The contract for the classification of the submarine is terminated as of right in the above cases.

The class is also withdrawn according to the provisions of article 7 of the Marine Division General Conditions in case of contract termination.

1.3.2 When the withdrawal of class of a submarine comes into effect, the Society will:

- forward the Owner written notice
- delete the submarine from the Register
- notify the Naval Authority.

1.4 Suspension/withdrawal of additional class notations

1.4.1 If the survey requirements related to maintenance of additional class notations are not complied with, the suspension or withdrawal may be limited to the notations concerned.

The same procedure may apply to service notations of submarines which are assigned with more than one service notation.

1.4.2 The suspension or withdrawal of an additional class notation or a service notation (where a submarine is assigned with more than one service notation) generally does not affect the class.

APPENDIX 1 PLANNED MAINTENANCE SURVEY SYSTEM

1 General

1.1

1.1.1 A Planned Maintenance survey system (hereafter referred to as PMS) is a survey system for hull and machinery items which may be applicable to the bi-annual surveys.

1.1.2 This survey scheme is to be approved by the Society before being implemented. When the PMS system is applied, the scope and periodicity of the class renewal survey are tailored for each individual item of hull and machinery and determined on the basis of recommended overhauls stipulated by the manufacturers, documented experience of the operators and, where applicable and fitted, condition monitoring. For instance, within the scope of a PMS system the following cases may occur:

- switchboard A is surveyed based on the regular expiry date of the class renewal survey
- lubricating oil pump B is surveyed based on PMS scope and periodicity
- diesel engine C is surveyed based on running hours
- turbo pump D is surveyed based on condition monitoring.

1.1.3 The person officially responsible for the maintenance or another technical personnel duly delegated shall be the responsible person in charge of the PMS.

Items surveyed by this authorised person officially responsible for the maintenance or delegated technical personnel will be subject to the confirmatory survey as detailed in [4.2.9].

Documentation on overhauls of items covered by the PMS are to be reported and signed by the person officially responsible for the maintenance or delegated technical personnel.

1.1.4 Record of surveys carried out

The surveys carried out by the person officially responsible for the maintenance or delegated technical personnel are to be recorded in the engine/machinery log-book and a survey report is to be prepared for each item surveyed.

The report is generally to be drawn up in English; however, for submarines trading in specific restricted areas the use of the language of the country concerned will be accepted.

The report may be provided in hard copy or using a computerised recording system.

The report is to indicate the following information:

- identification data:
  - name of submarine and register number
  - name of the person officially responsible for the maintenance or delegated technical personnel and Owner's attestation
  - date and place (port or voyage leg) of the survey
  - reference of the item in the PMS list, and description of the item
- inspection conducted:
  - type of inspection carried out: visual external examination, internal examination after dismantling, overhaul
  - readings performed, when applicable: clearances, measurements, working pressure, or other working parameters of the equipment
  - inspection findings: corrosion, fractures, pieces of equipment worn out, broken or missing
- maintenance and repairs carried out and parts replaced
- results of tests performed after the inspection, such as working test, pressure test.

For sake of completeness, other documentation such as sketches, photos, measurement reports may be attached to the report.

The report is to be signed by the person officially responsible for the maintenance or the delegated technical personnel.

2 Conditions and procedures for the approval of the system

2.1 General

2.1.1 The PMS is to be approved by the Society. To this end the Owner is to make a formal request to the Society and provide the documentation and information specified in [2.2], combined in a manual describing the proposed scheme and including sample copies of the different documents to be used during the implementation of the scheme.The PMS is to be programmed and maintained by a computerized system.However, this may not be applied to the current already approved schemes.

2.1.2 When using computerised systems, access for updating of the maintenance documentation and the maintenance programmes is only granted to the person responsible for the PMS or another person authorised by him.

The computerised systems are to include a back-up procedure, which is to be activated at regular intervals.

The functional application of these systems is to be approved by the Society.

2.2 Documentation

2.2.1 The documentation to be submitted is the manual mentioned above, which is to include:

a) a description of the scheme and its application as well as the proposed organisation chart identifying the areas of responsibility and the people responsible for the PMS

b) the list of items of structure, machinery and components to be considered for classification in the PMS, distinguishing for each the principle of survey periodicity used as indicated in [1.1.2]

c) the procedure for the identification of the items listed in b), which is to be compatible with the identification system adopted by the Society

d) the scope and time schedule of the maintenance procedures for each item listed in b), including acceptable limit conditions of the parameters to be monitored based on the manufacturers' recommendations or recognised standards and laid down in appropriate preventive maintenance sheets

e) the original reference data, monitored, for machinery undergoing maintenance based on condition monitoring

f) the list and specifications of the condition monitoring equipment, including the maintenance and condition monitoring methods to be used, the time intervals for maintenance and monitoring of each item and acceptable limit conditions

g) the document flow and pertinent filing procedure.

2.3 Information

2.3.1 The following information is to be available:

a) all the documentation listed in [2.2], duly updated

b) the maintenance instructions including routine tests and inspections for each item of machinery, as applicable (supplied by the manufacturer or by the shipyard)

c) the condition monitoring data of the machinery, including all data since the last dismantling and the original reference data

d) reference documentation (trend investigation procedures etc.)

e) the records of maintenance performed, including conditions found, repairs carried out, spare parts fitted

f) the list of personnel in charge of the PMS management.

3 Implementation of the system

3.1

3.1.1 When the documentation submitted has been approved and the PMS system has been implemented and used for a sufficient period (which is not to exceed 18 months) so that all personnel become familiar with it, a survey is to be carried out in order to start the system and make it officially operational. The scope of this survey, referred to as Implementation Survey, is given in [4.1.1].

3.1.2 Upon the successful outcome of the Implementation Survey, the PMS is considered approved. The relevant annex to the Certificate of Classification of the submarine is updated and the survey notation PMS is entered in the Register.

4 Surveys

4.1 Implementation survey

4.1.1 The implementation survey is to be carried out by a Surveyor of the Society, as stated in [3.1.1], within 18 months from the date of the documentation approval.

4.1.2 The scope of this survey is to verify that:

- the PMS is implemented in accordance with the approved documentation and is suitable for the type and complexity of the components and systems on board
- the documentation required for the bi-annual audit is produced by the PMS
- the requirements of surveys and testing for retention of class are complied with
- the personnel are familiar with the PMS procedures.

Upon the successful outcome of the survey confirming the proper implementation of the PMS, the system is considered operational subject to the submission to the Society of a report describing the system.

4.2 Bi-annual audit and confirmatory surveys

4.2.1 Once the PMS system is implemented, the continued compliance with the requirements for checks, overhauls and repairs, where needed, indicated in [2] is to be verified by means of bi-annual audits and confirmatory surveys in order to confirm the validity of the approved survey scheme system.

4.2.2 The bi-annual audit and confirmatory surveys are to be carried out in conjunction with the bi-annual class surveys.

4.2.3 The purpose of this audit is to verify that the scheme is being correctly operated, in particular that all items (to be surveyed in the relevant period) have actually been surveyed in due time. A general examination of the items concerned is carried out.

4.2.4 The maintenance and performance records are examined to verify that the machinery and all diving safety related systems and equipment have been functioning satisfactorily since the previous survey or audit or, if necessary, that the necessary measures have been taken in response to machinery operating parameters, that all modifications that may affect the weight and stability are not exceeding acceptable tolerances and that the overhaul intervals have been observed.

4.2.5 Written reports of breakdown or malfunction are to be made available.

4.2.6 The description of the repairs, if any, carried out is to be examined. Any machinery part or component which has been replaced by a spare due to damage is to be retained, where possible. On this occasion such replaced parts are to be submitted to the examination of the Surveyor.

4.2.7 The Surveyor also checks that the personnel in charge of the PMS have the appropriate authorisation.

4.2.8 A bi-annual report covering the two-year's service is to be supplied to the Society. It is to include the following information:

- the list of items of machinery and components (item b) in [2.2.1])
- the preventive maintenance sheets
- any changes to the other documentation in [2.2.1].

The Surveyor is to review this bi-annual report or verify that it has been reviewed by the Society. See [4.2.4] and [4.2.6].

4.2.9 Confirmatory survey

The Surveyor is to be supplied with a copy of this survey report and also shown in the log-books.

The Surveyor carries out an external examination of the relevant items.

The date of the execution of the surveys will be assumed to be the date of the confirmatory survey.

4.2.10 Upon the satisfactory outcome of this audit, the Surveyor confirms the validity of the PMS by endorsing the Certificate of Classification in accordance with Ch 2, Sec 2, [3.3].

4.3 Damage and repairs

4.3.1 Damage to components or items of machinery covered by the PMS which may affect the class is to be reported to the Society. Where applicable, a Surveyor will attend on board, survey the damaged items and, on the basis of the survey results, decide whether recommendations are to be imposed.

4.3.2 All parts of machinery or components which need to undergo substantial repairs are to be surveyed before, during and after the repairs, as deemed appropriate by the Surveyor. Any repair and corrective action regarding machinery under PMS system shall be recorded in the PMS logbook.

4.3.3 In the case of overdue recommendations or records of unrepaired damage which may affect the PMS, the relevant items are to be taken out of the PMS until the recommendations have been fulfilled or the repairs carried out.

5 Suspension of the authorization given to the person officially responsible for the maintenance or the delegated technical personnel

5.1

5.1.1 Where the condition of the items surveyed by the person officially responsible for the maintenance or the delegated technical personnel as specified in his or her reports does not correspond to the findings of the attending Surveyor, the Society may suspend the authorization given to the person officially responsible for the maintenance or delegated technical personnel.

5.1.2 The Society may also suspend the authorization given to the person officially responsible for the maintenance or delegated technical personnel in case of doubt on the general maintenance of the machinery installation.

Part A
Classification and Surveys

Chapter 3
SCOPE OF SURVEYS

SECTION 1 BI-ANNUAL SURVEY

SECTION 2 CLASS RENEWAL SURVEY

SECTION 1 BI-ANNUAL SURVEY

1 General

1.1

1.1.1 The requirements of this Section apply to bi-annual surveys of all submarines. The specific requirements for bi-annual surveys related to additional class notations assigned to submarines are addressed in Part A, Chapter 4.

1.1.2 The bi-annual survey is to be carried out in drydock conditions.

1.1.3 The requirements of this Section may be adjusted on case-by-case basis according to the type of submarine, the survey regime and the return of experience (see Ch 1, Sec 1, [1.3.1]).

1.1.4 At the time of bi-annual surveys, the submarine is to be generally examined. The survey is to include:

- examination of the naval submarine, logbooks, monitoring technical records
- a visual inspection of the hull, equipment and machinery of the submarine and some tests thereof, so far as necessary and practicable in order to verify that the submarine is in a acceptable general condition and is properly maintained
- throughout search of any starting corrosion and immediate treatment to be carried out
- a depression test to be carried out for pressure hull and means of closure including first and secondary ones, as far as practicable
- a diving test with water tightness control of the pressure hull at the maximum diving depth
- a Schnorchel navigation test
- the demonstration that the alarms and safety devices are functioning correctly.

1.1.5 Owners are reminded that, in compliance with the requirements in Ch 2, Sec 2, [6.3], any modification to the submarine's hull, equipment and machinery affecting its classification is to be made known to the Society.

2 Pressure hull, structures and hull equipment

2.1 Pressure hull and structures

2.1.1 The survey is to include a general external examination and testing, where appropriate, of the following items, as applicable:

a) Outer hull, exostructures and accessible parts of the rudder(s), including blades and fines, and internal examination of accessible parts of exostructures with particular attention to corrosion

   Sacrificial anodes are to be cleaned and renewed when deemed necessary.

b) Hull openings, doors and hatch covers, their securing arrangements and sealing arrangements

   Seawater hull penetrations with their sleeves, and weld connection to the hull, as far as practicable

   General external examination of mooring equipment

c) Spaces including compartments, cofferdams and tanks, as far as practicable, with particular attention to bilges and ballast tanks

d) Accessible resisting structures including torpedo tubes, trunks, seawater capacities and collective rescue platform

e) Fire doors and, as far as practicable, fire division integrity

f) Confirmation that gangways are practicable and not blocked.

2.2 Hull equipment

2.2.1 The survey is to include a general external examination and testing, where appropriate, of the following equipment:

a) lifelines, ladders

b) scuppers

c) obturating systems

d) shipboard fittings such as bollards, fairleads, and a functional test for retractable equipment.

3 Machinery and systems

3.1 General machinery installations

3.1.1 The survey of general machinery installations is to cover, as far as practicable, the following items:

a) general examination of machinery spaces with particular attention to the fire and explosion hazards

b) general examination of the machinery, hydraulic, pneumatic and other HP systems and their associated fittings, for confirmation of their proper maintenance

c) general examination of the ventilation system, their ducts, valves and fans including spare fan(s) with a functional test of the different modes

d) visual examination of the condition of flexible hoses and expansion joints

e) check that proper maintenance required since previous survey have been duly achieved on:

- sea water piping withstanding immersion pressure, their accessories, including operation of the pumps and safety devices
- pressure vessels, to be internally inspected at least at 48 months periodicity
- high pressure piping, their appurtenances, including safety devices
- high pressure blowing components and venting valves

f) functional test of hull opening moving equipment including air masts, air inlet valves and exhaust gas system

g) external examination of leakage indicators, drains with associated cocks

h) examination and functional test of main and auxiliary steering arrangements, including their associated equipment and control systems, and manoeuvring gear

i) examination of diesel engines

- check of condition monitoring records (see [3.2])
- check of crankshaft deflection readings
- check of bearing clearances (where possible)
- checks for signs of wiped or broken white metal in the crankcase or filters
- check of the witness marks of shrink fits of crankshafts
- check of the bedplate structure (inside and outside)
- check that the condition of crankpins, journals and associated bearings is duly recorded.

3.1.2 When the submarine is equipped with a refrigerating plant (whether or not covered by an additional class notation), the bi-annual survey is to include the external examination of:

- gas tightness of refrigerant piping, as far as practicable
- gas detection system.

3.2 Machinery items surveyed on the basis of condition monitoring

3.2.1 The extent of condition-based maintenance and associated monitoring equipment to be included in the maintenance scheme is decided by the Owner. The minimum parameters to be checked in order to monitor the condition of the various machinery for which this type of maintenance is accepted are indicated in [3.2.2] to [3.2.3].

3.2.2 For diesel engine(s) the parameters to be checked are the following:

- power output
- rotational speed
- indicator diagram (where possible)
- fuel oil temperature and/or viscosity
- charge air pressure
- exhaust gas temperature for each cylinder
- exhaust gas temperature before and after the turbochargers
- temperatures and pressure of engine cooling systems
- temperatures and pressure of engine lubricating oil system
- rotational speed of turbochargers
- vibrations of turbochargers or other type of compressor
- results of lubricating oil analysis
- crankshaft deflection readings
- temperature of main bearings.

3.2.3 For other auxiliary machinery the parameters to be checked are the following, as applicable:

- inlet and outlet temperatures of cooling systems
- inlet and outlet temperatures of heating systems
- vibrations and performance data of pumps and fans
- differential pressure at filters.

3.2.4 For electric propulsion motor the parameters to be checked are the following, as applicable:

- vibrations and noise of electric motor where applicable
- temperature of windings
- temperature of built-in coolers
- temperature of bearings
- temperature of cooling air
- insulation measurement
- winding resistance
- speed of electric motor
- current of electric motor
- voltage of electric motor in each phase
- current on field windings if applicable.

3.2.5 For propulsion convertors the parameters to be checked are the following, as applicable:

- temperature and flow of refrigeration system
- resistivity of cooling fluid
- insulation measurements.

3.3 Communication and navigation

3.3.1 Communication

Communication systems essential for manoeuvring and for safety actions and information are to be function tested. It is to be checked that the means of communication dedicated to rescue team are in place and they are to be tested if applicable.

Test of means of communication and order transmission between the control station and propulsion station is to be carried out.

3.3.2 Navigation

- Confirmation that the calibration of navigating and locating equipment including depth is still valid.
- Confirmation that navigation radar and gyro compass or inertial navigation units are in satisfactory working condition.
- Functional test of optical communication system.
- Confirmation that safety navigation equipment including navigation lights and sound signalling equipment are in satisfactory working conditions.
- Functional test of echo sounding.

3.4 Electrical machinery and equipment

3.4.1 The survey of electrical machinery and equipment is to cover the following items:

- general examination, visually and in operation, as feasible, of the electrical installations for power and lighting, in particular main and emergency source of electrical power if fitted, electric motors, switchboards, convertors, switchgears and circuit protective devices, indicators of electrical insulation and automatic starting, where provided, of emergency sources of power

  A functional test of lighting fittings including main and emergency is to be carried out.

- checking, as far as practicable, of the operation of emergency sources of power and, where they are automatic, also including the automatic mode.

- checking, as far as practicable, of proper operation of safety and ultimate functions defined in Pt B Ch 1 Sec 2 [3], that their instrumentation and safety devices are operational and that their alarms are satisfactory.

3.4.2 The Surveyor is to check that the control room allows to control the propulsion machinery, and related arrangements (alarms and safety devices), when fitted.

3.4.3 Main batteries

Main batteries log books are to be made available to the Surveyor for examination of the records since the last survey, and checking any unusual record, breakdown or defective items.

The survey of main batteries is to cover the following items:

a) general examination of battery compartments, piping and equipment fitted inside including battery cells and trays

b) examination of battery cells shoring and connections

c) examination and confirmation of the satisfactory operation of battery auxiliary systems, including ventilation system (see [3.1.1], item c)

d) checking that the hydrogen detection system is in working order and checking of calibration

e) function testing, as far as practicable, of detection, remote control and monitoring systems and alarms

f) verification of the tightness of the main batteries cells and the battery compartments.

3.5 Fire protection, detection and extinction

3.5.1 The survey of fire prevention and other general arrangements is to cover the following items:

- checking that relevant instructions are available
- examination and testing, as feasible, of the operation of fire doors, where fitted
- checking, as far as practicable, that the remote controls for stopping machinery and shutting off fuel supplies in machinery spaces and, the remote controls for stopping fans from a control station and the means of cutting off power to the galley are in working order
- examination, as far as practicable, and testing, as feasible and at random, of the fire and/or smoke detection systems and fire dampers.

3.5.2 The operational readiness and maintenance of fixed fire-fighting systems is to be checked. The survey requirements for all types of fire-fighting systems that are usually found on board submarines related either to machinery spaces including battery spaces or accommodation and service spaces when fitted, or torpedo room, are the following:

a) fixed gas fire-extinguishing system
   - external examination of receivers of CO_2 (or other gas) fixed fire-extinguishing systems and their accessories
   - examination of fixed fire-fighting system controls, piping, instructions and marking; checking for evidence of proper periodical maintenance and servicing, including date of last system tests and weighting of receivers
   - test of the alarm triggered before the CO_2 is released

b) water-spraying system or water mist system
   - examination of the system, including piping, nozzles, distribution valves and header tank
   - test of the automatic starting of the pump activated by a pressure drop (applicable only for machinery spaces)

c) fixed foam systems (low or high expansion)
   - examination of the foam system
   - checking the supplies of foam concentrate and receiving confirmation that it is periodically tested (not later than three years after manufacture and annually thereafter) by the manufacturer or an agent.

3.5.3 As far as other fire-fighting equipment is concerned, it is to be checked that semi-portable and portable fire extinguishers are in their stowed positions, with evidence of proper maintenance and servicing, and detection of any discharged containers

3.6 Human occupancy

3.6.1 Atmosphere control

The survey is also to include:

- examination and testing, as appropriate, of gas analysis equipment.
- confirmation of the availability and suitability of the portable gas detection equipment and instruments for measuring gas levels
- verification of calibration status of the measuring instruments. As a rule calibration is not to have been performed in compliance with applicable requirements
- checking that emergency breathing air appliances are in sufficient number, in satisfactory condition and properly stowed onboard

3.6.2 Flooding fighting

The bi-annual survey is to include examination and testing of all the:

- detection systems and their alarms. Level detectors shall be tested at default and incident levels
- flow detectors, as far as practicable
- flow detectors inhibition of automatic action, as far as practicable
- safety shut-off valves and their emergency system including hydraulic energy accumulators.

3.6.3 Emergency and rescue installations

Where relevant (see Pt E, Ch 3, Sec 4, [1.1]), the bi-annual survey is to include:

- verification of the alert and localization items including expiry date of main batteries, when applicable
- examination and functional test as far as practical of survival air regeneration systems including soda-lime, oxygen candle or unit, their fittings, valves and safety devices. Checking of their proper stowage, expiry date and that they are in appropriate quantities
- verification of proper stowage and expiry date of the food and fresh water emergency stock and that they are in appropriate quantities
- verification of proper stowage and expiry date of the medical supplies in each refuge compartment
- checking of the valve dedicated to ventilation from the outside, if applicable
- verification of airlock regulator relief valve of escape trunk.

3.7 General emergency alarm system

3.7.1 The general emergency alarm system is to be tested.

4 Stability

4.1 Documentation

4.1.1 Confirmation that the following documents are available inboard, well maintained and updated:

- weighing, trim and stability booklet
- damage control documentation in appropriate language.

4.2 Draught

4.2.1 Confirmation that the scales of draughts are permanently marked at the bow and stern.

SECTION 2 CLASS RENEWAL SURVEY

1 General

1.1

1.1.1 The requirements of this Section apply to class renewal surveys of all submarines. Those requirements may be adjusted on case-by-case basis with the agreement of the Society according to the type of submarines, the survey regime, the real conditions of utilization of the submarine and to the return of experience on the actual behaviour of the different components and systems (see Ch 1, Sec 1, [1.3.1]).

The specific requirements for class renewal surveys related to additional class notations assigned to submarines are addressed in Part A, Chapter 4.

1.1.2 The Owner in cooperation with the Society is to work out a specific Survey Programme prior to the commencement of any part of the Class Renewal Survey.

The Survey Programme will be developed based on the following documentation:

a) maintenance plan provided by the shipbuilder

b) maintenance follow-up from the Owner

c) survey status and basic ship information

d) relevant previous survey and inspection reports from both the Society and the Owner (including non destructive tests)

e) main structural plans of pressure hull, resisting structures, exostructures

f) previous operational and repair history

g) information regarding the relevant maintenance level during operation.

The Survey Programme is to include a written procedure about Non Destructive Tests to be carried out (locations, acceptance levels). This procedure is to be submitted to the Society for acceptance.

During the survey, NDT may be extended as deemed necessary by the Surveyor.

The Owner or his representative is to declare to the attending Surveyor that no significant changes have been made since the last renewal survey in the scope of classification.

Note 1: Attention is drawn to the provisions of Ch 1, Sec 1, [3.1.1] regarding compliance with any additional and/or more stringent requirements issued by the Naval authority or national or international regulations.

1.1.3 The class renewal survey is to include sufficiently extensive examination and checks to show that the structures, main and auxiliary machinery, systems, equipment and various arrangements of the submarine are in satisfactory condition or restored to such condition as to allow the submarine to operate for the new period of class to be assigned, provided that the submarine is properly maintained and operated and other surveys for maintenance of class are duly carried out during this period.

The examinations of the hull are to be supplemented by non destructive tests as required in [2.6], to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deformation that may be present.

1.1.4 The Owner is to provide the necessary facilities to enable this class renewal survey. The conditions for survey as detailed in Ch 2, Sec 2, [2.4] to Ch 2, Sec 2, [2.6] are to be met.

1.1.5 Quay and sea trials derivated from those described in Ch 1, App 1 have to be defined on case by case basis.

An hydrostatic proof test may be required depending on repair and structural work carried out on the pressure hull.

2 Pressure hull, structures and hull equipment

2.1 Pressure hull

2.1.1 The survey is to include:

- a close-up survey of the pressure hull
- Non Destructive Testing according to the specific Survey Programme
- the examination of the corrosion prevention system.

Particular attention is to be given to critical structural areas and the areas where stress concentration or corrosion are likely to develop, such as hull discontinuity and to connections including from exostructures.

2.1.2 Sea water hull penetrations are to be examined and corresponding NDTs will be carried out in accordance with the Survey Programme and extended if deemed necessary by the Surveyor.

Other hull penetrations for pipes and cables are examined as deemed necessary.

2.1.3 A diving test with control of the water tightness of the pressure hull at maximum diving depth is to be carried out.

2.2 Other structures

2.2.1 A close up survey of all resisting structures and capacities is to be carried out. Torpedo Launching Tubes, trunks and collective rescue platform are to be internally and externally examined.

Resisting structures are to be leak tested where applicable. NDTs will be carried out in accordance with the Survey Programme and extended if deemed necessary by the Surveyor.

2.2.2 Exostructures are to be internally examined. NDTs will be carried out if deemed necessary by the Surveyor.

Non resisting tanks containing sea water or corrosive products are to be internally examined.

2.3 Hull equipment

2.3.1 Throughout search of any starting corrosion and immediate treatment is to be carried out.

2.3.2 Sea water hull valves (internal and external) are to be opened up for internal examination and pressure tested.

2.3.3 Mechanical hull passages are to be examined after removal of equipment and, if practicable, pressure tested after reinstallation on board.

2.3.4 Steering and trimming devices are to be removed for survey. The survey includes:

a) removal of rudders including diving planes and their examination

b) complete withdrawal of stocks to permit the examination of bearings

c) examination by an appropriate crack detection method of the most stressed areas

d) examination of stock bearing surfaces, liners, joints, threaded end and nut

e) examination of tiller, quadrants or similar components, mechanical rudder stops with the necessary dismantling if applicable

f) measurements of clearances and/or weardown (prior to and after the survey) and their recording

g) disassembly as deemed necessary and operational tests of steering gear control systems and indication devices

h) the time to move from maximum angle on one side to maximum angle on the other side is to be checked for compliance.

2.3.5 Mooring anchoring and towing equipment are to be checked.

2.4 Other dry compartments

2.4.1 Gas tightness and watertightness of zones and compartment will be demonstrated through a depression test. Checking of manoeuvring of valves and if applicable from each side of bulkheads.

2.5 Hull opening moving equipment

2.5.1 Control and monitoring will be tested for air inlet, exhaust gas systems, trunks.

2.5.2 Actuators are to be opened up as deemed necessary by the Surveyor.

2.5.3 Hull sealing systems are to be examined (hull openings, mobile part, hull sleeves).

2.6 Non Destructive Testing

2.6.1 NDTs are to be carried out according to the procedure detailed in Ch 2, Sec 2, [2.3].

Their extent is to be detailed and agreed in the Survey Programme. The Surveyor may require additional NDTs as deemed necessary. These extended NDTs are to be carried out before the survey is credited as completed.

NDTs are to be selected to provide the best representative sampling of areas likely to be most exposed to stress concentration and corrosion, considering operational history, arrangement, condition of protective coatings and critical structural areas.

3 Machinery and systems

3.1 General

3.1.1 The survey items listed below are to be covered to the satisfaction of the Surveyor. However, other survey alternatives deemed equivalent by the Surveyor in relation to the characteristics and general condition of the submarine concerned may also be accepted.

Note 1: Attention is drawn to requirement Ch 2, Sec 2, [2.4.1] regarding safe execution of surveys, in particular as regards health hazards related to asbestos.

3.2 Main and auxiliary engines

3.2.1 General

The following parts are to be opened up as necessary for inspection. Parts and components are to be pressure tested as appropriate or as deemed necessary by the Surveyor. A working test is also to be carried out, including testing of alarms and safety devices.

3.2.2 Internal combustion engines

Extent of surveys depends on prescribed maintenance. It normally includes:

a) Columns and entablature

b) Cylinders with their liners, cylinder covers (together with valves and valve gear), pistons with their rods, crossheads, slippers and guides (or gudgeon pins), connecting rods (with their top and bottom end bearings), control gear, driven scavenge pumps, driven air compressors, driven fuel pumps, supercharging blowers, fuel injection pumps, turning gear, etc.

c) Crankshafts (together with their main bearings)

d) Reverse gear, reduction gear and clutches, if fitted.

3.2.3 Electric propulsion

A complete overhaul of the electric propulsion is required.

Where the propulsion machinery consists of an electrical system, the propulsion motors, generators, cables and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined and the insulation resistance to earth tested. Due attention is to be given to windings, commutations and sliprings. The operation of protective gear and alarm devices is to be checked, as far as practicable. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly.

3.2.4 Main batteries

Main batteries are tested ashore.

The survey of main batteries is to cover the following items:

a) general examination of main battery compartments, piping and equipment fitted inside including main battery cells and trays

b) examination of main battery cells shoring and connections

c) examination and confirmation of the satisfactory operation of main battery auxiliary systems, including ventilation system (see [3.1.1], item c)

d) checking that the hydrogen detection system is in working order and checking of calibration

e) function testing, as far as practicable, of detection, remote control and monitoring systems and alarms

f) verification of the tightness of main batteries cells and main battery compartments.

3.3 Reduction gears, main thrust and intermediate shaft(s) and tailshaft

3.3.1 Reduction gears complete with all wheels, pinions, shafts, couplings, bearings and gear teeth, including incorporated clutch arrangements, are to be opened up, as deemed necessary by the Surveyor, for visual inspection. For complicated assemblies, gears and roller bearings may be inspected without dismantling.

3.3.2 All shafts, shaft blocks, thrust blocks and bearings are to be dismantled and examined. Their connection to the hull is to be examined.

3.3.3 Visual examination of the screw once cleaned is to be carried out.

3.4 Systems resisting to sea water pressure

3.4.1 The requirements of this sub-article are to be adjusted according to the technology used.

3.4.2 Sea water piping and associated equipment are to be internally examined. Non destructive tests and pressure tests are to be carried out in accordance with the Survey Programme.

3.5 Pumps and other machinery items

3.5.1 General

As deemed necessary by the Surveyor, the items listed in [3.5.2] are to be opened up for visual inspection; their parts and components are to be pressure tested as appropriate and a working test is also to be carried out, including testing of alarms and safety devices.

3.5.2 Items to be surveyed

a) Air compressors with their intercoolers, filters and/or oil separators and safety devices

b) Heat exchangers, ventilation fans for main batteries and other equipment used for essential services

c) Ventilation system, its different modes and smoke release capability

d) Piston pumps and centrifugal pumps for sea water including regulating system, trimming system and bilge

e) Screw pumps, gear pumps and centrifugal pumps (opening up is not required)

f) Ballast vent valves

g) Ballast blowing system

h) Centralized greasing system.

3.6 Systems in machinery spaces

3.6.1 Valves, cocks and strainers of the bilge and ballast systems are to be opened up, as deemed necessary by the Surveyor, for visual inspection, and, together with the piping and safety devices, examined and tested under working conditions.

3.6.2 The fuel oil, lubricating oil, hydraulic fluid and cooling water systems, together with pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. Safety devices for the foregoing items are to be examined.

3.6.3 The compressed air system together with its valves, fittings and safety devices is to be examined, as considered necessary by the Surveyor. The quality and distribution of breathable air at each plugging point are to be checked.

3.6.4 Compressed air receivers and other pressure vessels are to be cleaned internally and examined internally and externally and pressure tested. Their fittings, valves and safety devices are to be opened up, as deemed necessary by the Surveyor, for visual inspection and pressure tested as appropriate.

3.6.5 When the submarine is equipped with a refrigerating plant (whether or not covered by an additional class notation), the class renewal survey is to include examination and test at the design pressure of the parts of the plant under pressure. Sea water system connected to immersion pressure will be surveyed according to [3.4.2].

3.7 Electrical equipment and installations

3.7.1 An electrical insulation resistance test is to be performed on the electrical equipment and cables. If needed, for the purpose of this test, the installation may be subdivided or equipment which may be damaged disconnected.

3.7.2 The following minimum values, when performing the insulation test, are to be considered:

- for main and emergency switchboards, and propulsion convertors, feeder circuit breakers being open, busbar circuit closed, measuring and monitoring instruments disconnected, the resistance of insulation measured across each insulated busbar and the hull, and across insulated busbars, should not be less than 1 megohm
- for generators and propulsion motors and for equipment and circuits normally connected between the generator and the first circuit breaker being connected, the resistance of insulation (preferably at working temperature whenever possible), in ohms, is to be greater than 1 000 times the rated voltage, in volts. If appropriate, the Surveyor checks also that the insulation resistance of generators separate exciter gear is not less than 1 megohm
- the insulation resistance of the entire electrical system is to be checked with all circuit breakers and protective devices closed, except for generators; in general, the resistance should not be less than 100 000 ohms. However, the variation of the resistance with time is to be checked, comparing the current figure with previous readings. If the insulation resistance was to drop suddenly or be insufficient, the defective circuits are to be traced, disconnecting the circuits as much as necessary.

3.7.3 The prime movers of generators are to be surveyed in accordance with [3.2] and their governors tested. All generators are to be presented for inspection, clean and with covers opened and examined under working conditions.

3.7.4 Main and emergency switchboards, section boards and distribution boards are to be cleaned and doors or covers opened for examination of their fittings. The condition of overcurrent protective devices and fuses is to be checked. Circuit-breakers of generators are to be tested, as far as practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily. The tightening of busbar connections is to be checked.

3.7.5 Electrical cables and cable runs are to be examined at random, in particular in places where deterioration is likely to occur; terminal boxes of essential services are also to be subjected to a random check.

3.7.6 The motors and starters concerning essential services together with associated control and switchgear are to be examined and, if considered necessary by the Surveyor, checked, as far as practicable, under working conditions.

3.7.7 The emergency sources of electrical power, their automatic arrangements and associated circuits are to be tested.

3.7.8 Emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

3.7.9 The visible condition of electrical equipment and installations is also to be checked as regards precautions against shock, fire and other hazards of electrical origin.

3.7.10 A general examination of the electrical equipment in areas where there may be flammable gas or vapour and/or combustible dust is to be carried out to ensure that the integrity of the electrical equipment of a safety type has not been impaired owing to corrosion, missing bolts, etc., and that there is not an excessive build-up of dust on or in dust-protected electrical equipment. Cable runs are to be examined for sheath and armouring defects, where practicable, and to ensure that the means of supporting the cables are in satisfactory condition. The proper condition of bonding straps for the control of static electricity is to be checked. Alarms and interlocks associated with pressurised equipment or spaces are to be tested for correct operation.

Note 1: Owners are reminded that maintenance, repairs or renewal of certified electrical equipment of a safe type remains their responsibility or that of their representatives.

3.8 Controls

3.8.1 Where remote and/or automatic controls, not covered by an additional class notation related to automated installation, are fitted for essential machinery, they are to be tested to demonstrate that they are in satisfactory condition.

3.9 Communication and navigation

3.9.1 Navigation

Navigation light indicators are to be tested under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

Checking that calibration of echo sounding and speed loch system has been carried out.

3.10 Fire protection, detection and extinction

3.10.1 The class renewal survey of fire prevention arrangements is to cover the following items.

a) Visible parts of items forming part of structural fire protection arrangements in accommodation and service spaces and in machinery spaces such as bulkheads, decks, doors, are to be examined, due attention being given to their integrity and that of the insulating material.

b) Remote controls for stopping machinery and shutting off fuel supplies in machinery spaces and, remote controls for stopping fans from a control station.

c) Fire detection and alarm systems are to be tested.

3.10.2 The survey requirements for different types of fixed fire-fighting systems are the following:

a) fixed gas fire-extinguishing system

Components of CO_2 (or other gas) fixed fire-extinguishing systems are to be externally examined together with all stationary fittings and devices. In addition, the following applies:

- the total loss of CO_2 is not to exceed 10% of the installed quantity
- after being repaired or discharged, containers are to be subjected to a hydrostatic test
- hydrostatic testing of high pressure CO_2 containers is to be carried out at intervals not exceeding 10 years.

It is to be checked that the distribution pipework is proved clear.

b) water spraying system, water mist system or other system
   - the associated pumps are to be opened up and examined at the Surveyor's discretion
   - a working test is to be carried out as far as reasonable and appropriate.

c) fixed foam systems (low or high expansion)
   - the associated pumps are to be opened up and examined at the Surveyor's discretion.

3.11 Human occupancy

3.11.1 Atmosphere control

The survey is to include:

- oxygen containers according to [3.6.4]
- the air regeneration systems including soda-lime, oxygen candle or unit, their fittings, valves and safety devices
- calibration of gas analysers
- emergency breathing air system and quality of the air.

3.11.2 Flooding fighting

The survey is to include:

- examination and a test of the detection systems and of their alarms. Level detectors shall be tested at default and incident levels
- function testing of detectors inhibition system will be carried out when fitted
- examination and function testing of the safety shut-off valves
- the safety shut-off valves emergency system is to be tested. The hydraulic energy accumulators are to be surveyed according to [3.6.4].

3.11.3 Emergency and rescue installations

When relevant (see Pt E, Ch 3, Sec 4, [1.1]), the survey is to include examination and test of system and components of:

- emergency blowing or emergency lightening
- alert and localisation
- air generation system dedicated to survival condition
- free individual or collective escape if applicable
- external ventilation if applicable.

4 Stability

4.1 Permanent ballast

4.1.1 Checking that permanent ballast is located in accordance with approved plan and the stability booklet and that it is properly secured.

4.1.2 Confirmation that weighting and stability checks required in Pt B, Ch 2, Sec 2 have been carried out in due time.

Chapter 4

SCOPE OF SURVEYS RELATED TO ADDITIONAL CLASS NOTATIONS

SECTION 1 GENERAL

SECTION 2 REF-STORE NOTATION

SECTION 3 OTHER NOTATIONS

SECTION 1 GENERAL

1 General

1.1

1.1.1 The purpose of this Chapter is to give details on the scope of surveys of specific equipment and systems fitted on board the ship, which are covered by an additional class notation. Unless otherwise specified in Ch 1, Sec 2, [6], the scope of these surveys provides the requirements to be complied with for the maintenance of the relevant additional class notation.

1.1.2 These specific requirements are additional to those laid down in Part A, Chapter 3. These surveys are to be carried out at intervals as described in Ch 2, Sec 2, as far as possible concurrently with the surveys of the same type, i.e. bi-annual or class renewal survey.

1.1.3 The equipment and systems are also to be submitted to occasional survey whenever one of the cases indicated in Ch 2, Sec 2, [6] occurs.

1.1.4 Where specific requirements are given for the class renewal survey, they are additional to the requirements for the bi-annual survey, which, in accordance with Ch 2, Sec 2, [4.1.4], is to be carried out at the completion of the class renewal survey.

1.1.5 For the assignment of the additional class notations, ships are to be submitted to an admission to class survey as described in Ch 2, Sec 1, [2].

2 Additional class notations subject to additional surveys

2.1

2.1.1 The specific requirements detailed in this Chapter are linked to the additional class notation(s) assigned to the ship. Where a ship has more than one additional class notation, the specific requirements linked to each additional class notation are applicable as long as they are not contradictory.

2.1.2 Tab 1 indicates which additional class notations are subject to specific requirements, and in which Section and/or Article they are specified.

Table 1 : Additional class notations for which specific survey requirements are applicable

Additional class notation	Section or Article applicable in this Chapter	Type of surveys affected b these specific requirements
REF-STORE	Ch 4, Sec 2	bi-annual survey class renewal survey
Other notations: **ANCHORING** **REFUGE**	Ch 4, Sec 3	as applicable in accordance with the related Articles in Ch 4, Sec 3

SECTION 2 REF-STORE NOTATION

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the additional class notations **REF-STORE** related to refrigerating installations, as described in Ch 1, Sec 2, [6.2].

2 Bi-annual survey

2.1 General

2.1.1 The bi-annual survey of refrigerating installations (plants and spaces) is to be carried out with the installation in running condition and, whenever possible, during unloading operations or without goods in refrigerated spaces.

2.1.2 The refrigeration installation log-book (or other similar record) is to be made available to the Surveyor for examination of the records since the last survey, and checking any unusual consumption of refrigerant, breakdown or defective items.

2.1.3 Decks, bulkheads or ship sides adjacent to refrigerated spaces are to be checked as far as practicable in order to verify the absence of cold spots.

2.1.4 The Owner or his representative is to declare to the attending Surveyor that no significant modifications have been made to the installations that could affect the class notations without the prior approval by the Society.

2.2 Refrigerating plant

2.2.1 Refrigerating machines and related accessories, including compressors, condensers, pumps and piping are to be examined externally and in running condition. Insulation of insulated parts is to be checked for possible signs of humidity or wear. The tightness of the system is to be ascertained.

2.2.2 The electrical installation is to be generally examined, and the insulation resistance of the installation is to be checked as deemed necessary by the Surveyor.

2.2.3 If independent from the electrical installation of the ship, the generators supplying electrical power to the refrigerating installation are to be examined to the same extent as described in Ch 3, Sec 1, [3.4].

2.3 Refrigerated spaces

2.3.1 Refrigerated spaces are to be generally examined to ascertain the condition of:

- insulation lining; removable panels or covers may be dismantled for examination of insulation, as deemed necessary by the Surveyor
- doors, access panels (including gaskets and securing devices) and dampers of ventilation ducts
- air coils, coolers, fans, air ducts, brine piping systems and associated equipment; cleanliness of grids
- bilge wells
- protection of fans and other rotating machinery, battens for air circulation within the space.

2.4 Instrumentation and safety devices

2.4.1 Thermometers used for measurement of temperature in refrigerated spaces, air ducts and other elements of the installation are to be examined and checked for their accuracy. The Surveyor may require the calibration of one or more thermometers and one or more automation devices to be checked in his presence or, failing this, a certificate of calibration is to be presented to him.

2.4.2 The following alarm and safety devices are also to be checked, as required or fitted:

- alarm and emergency shutdown devices
- CO_2 detectors, if any
- refrigerant leakage detectors
- access to spaces, with regard to possibilities of escape and prevention of personnel being trapped within spaces.

3 Class renewal survey

3.1 General

3.1.1 The installation is to be surveyed out of operation in order to enable examinations in opened condition of certain items.

3.1.2 After completion of these examinations, the installation is to be checked while cooling down from the ambient temperature to the lowest design temperature for the refrigerated spaces. The plant is to be examined for ability to maintain stable air temperatures and defrosting operation is to be checked.

3.2 Refrigerating plant

3.2.1 The equipment is to be dismantled to a sufficient extent to enable the following examinations:

- reciprocating compressors: examination of cylinders, valves, crankshaft, connecting rods, pistons, bearings and safety devices
- screw compressors, turbo compressors and pumps: parts subject to wear and tear; the equipment may not need to be opened up if log-book records and a running test show proper functioning.

3.2.2 Prime movers of pumps, compressors and fans are to be examined to the same extent as required in Ch 3, Sec 2, [3] for similar equipment for the class renewal survey of machinery.

3.2.3 Condensers and coolers are to be opened up for examination of tube plates, tubes and end covers.

Condensers are to be pressure tested to 1,2 times the rated working pressure.

3.2.4 Insulation of insulated parts (such as piping and pressure vessels) may need to be removed at random, to ascertain the condition of such parts and of the insulation itself.

3.2.5 The electrical installation of the plant is to be examined and insulation tests checked.

3.2.6 If independent from the electrical installation of the ship, the generators supplying electrical power to the refrigerating installation are to be examined to the same extent as described in Ch 3, Sec 2, [3.7].

3.2.7 Sea connections to condenser circulating pumps are to be opened up and piping examined.

3.2.8 Other equipment, such as oil separators on refrigerant systems, filters and dehydrators, are to be examined to the satisfaction of the Surveyor.

3.3 Refrigerated spaces

3.3.1 The lining and insulation in the refrigerated spaces may need to be partly removed for examination of its condition. The condition of the hull part under the insulation is then ascertained, as well as that of girders, meat rails, hooks and coil/cooler supports.

3.3.2 Air coolers and coils are to be examined and pressure tested at the rated working pressure and at 1,2 times such pressure in the case of hydraulic test after repairs.

3.3.3 Air cooler fans are to be examined and their prime movers are to be checked to the same extent as stated in [3.2.2].

3.3.4 The electrical installation in the refrigerated spaces is to be examined and insulation tests checked.

3.3.5 Defrosting and heating systems are to be examined to the satisfaction of the Surveyor.

3.4 Instrumentation and safety devices

3.4.1 Pressure relief valves and safety disks are to be checked. Discharge piping is to be examined with regard to integrity and non-obstructed flow.

SECTION 3 OTHER NOTATIONS

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations:

ANCHORING (see Ch 1, Sec 2, [6.6])

REFUGE (see Ch 1, Sec 2, [6.7]).

2 ANCHORING

2.1 Bi-annual survey

2.1.1 The Owner or his representative is to declare to the attending Surveyor that no significant modifications have been made without prior approval by the Society.

2.1.2 The survey is to include an examination of the windlass, chain stopper if applicable, and equipment of chain cables for anchors.

2.1.3 Test of remote operation of the following items is to be carried out:

- windlass in case of retractable anchor
- chain stopper when fitted.

2.2 Class renewal survey

2.2.1 General

The following examinations and checks are usually carried out during the bottom survey held concurrently with the class renewal survey.

2.2.2 Anchors, windlass(es) and chain cables are to be ranged and examined, and the required complement and condition are to be checked. The equipment is to be disassembly as deemed necessary to verify the condition.

When the submarine is more than 5 years old, chain cables are to be gauged. Any length of chain cable which is found to be damaged or excessively worn is to be renewed.

Hawse pipe is to be examined.

2.2.3 Control and safety devices are to be checked including the remote release of end shackle.

2.2.4 Chain lockers are to be internally examined, while the anchor chains are ranged as required in [2.2.2]. The pumping arrangement of the chain lockers is to be tested if applicable.

3 REFUGE

3.1 Bi-annual survey

3.1.1 The Owner or his representative is to declare to the attending Surveyor that no significant modifications have been made without prior approval by the Society.

3.1.2 The survey is to cover:

- atmosphere control according to Ch 3, Sec 1, [3.6.1]
- emergency and rescue installation according to Ch 3, Sec 1, [3.6.3]
- access door
- random checking of valves fitted on the refuge compartment bulkhead
- emergency lighting
- means of communication with rescue teams.

3.1.3 A depression test of the rescue compartment is to be carried out.

3.2 Class renewal survey

3.2.1 The survey is to cover:

- atmosphere control according to Ch 3, Sec 2, [3.11.1]
- checking of valves fitted on the refuge compartment bulkhead
- verification of the presence and expiry date of the means of survival: water, air, food, medicines, signalisation and lighting.

RULES FOR THE CLASSIFICATION OF NAVAL SUBMARINES

Part B

Main Design Principles and Stability

Chapters **1 2**

CHAPTER 1 DEFINITIONS AND MAIN DESIGN PRINCIPLES

CHAPTER 2 STABILITY

September 2016

Part B

Main Design Principles and Stability

Chapter 1

DEFINITIONS AND MAIN DESIGN PRINCIPLES

SECTION 1 APPLICATION

SECTION 2 SYMBOLS AND DEFINITIONS

SECTION 3 ENVIRONMENTAL CONDITIONS AND OPERATIONAL LIMITS

SECTION 4 MAIN DESIGN PRINCIPLES AND DOCUMENTATION TO BE SUBMITTED

SECTION 1 APPLICATION

1 General

1.1 Requirements

1.1.1 Part B of the Rules contains the requirements for determination of the main design principles and stability, applicable to all submarines of normal form, speed and proportions, made in welded steel construction. These requirements are to be integrated with those specified in Part F, as applicable, depending on the additional class notations assigned to the ships.

1.1.2 Ch 1, Sec 3 is applicable for all equipment on the ship.

1.1.3 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.

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 symbol	Units
Ship's dimensions	see [2]	m
Density	ρ	t/m^3

2 Symbols

2.1

2.1.1

L_{pp} : Length between perpendiculars, in m, defined in [3.8.1]

P_N : Nominal diving pressure

P_A : Accidental diving pressure

P_C : Collapse diving pressure

B : Extreme breadth, in m, defined in [3.11.1].

3 Definitions

3.1 Submarine ship

3.1.1 Submarine ship or submarine refers to any autonomous manned vehicle able to dive underwater and to move in full submersion and in zero apparent weight condition, without physical link with a surface or underwater installation, fixed or mobile. Naval submarines are normally engaged in military operations or operated by a crew under military status.

3.2 Designer

3.2.1 The designer is the person or entity which carries out the definition file, that is to say the set of documents necessary and sufficient to carry out the construction of the submarine.

3.3 Builder

3.3.1 The builder is the person or entity which carries out the construction of the submarine.

3.4 Operator

3.4.1 The operator is the person or entity which endorses the responsibility of the operation of the submarine.

3.5 Crew

3.5.1 The crew is the personnel in charge of the control and operation of a submarine.

Special personnel refers to the persons on board the submarine but not belonging to the crew.

3.6 Naval Authority or Administration

3.6.1 Naval Authority or Administration refers to the competent services of the Government of the State the flag of which the submarine is allowed to carry or in which it is registered.

3.7 Depth

3.7.1 Nominal diving depth

Maximum operating depth, in m, for which the submarine is designed to dive for a given number of time specified by the Designer. Unless otherwise specified, an unlimited number of dives is considered. This depth corresponds to the nominal diving pressure. The depth is measured to the underside of the pressure hull (keel horizontal).

3.7.2 Accidental diving depth

The accidental diving depth is the maximum depth, in m, to which the submarine is capable to withstand in emergency circumstances (i.e. seawater inrush or steering dysfunction) for a short period of time. The depth is measured to the underside of the pressure hull (keel horizontal).

3.7.3 Accidental transient over-submersion

The accidental transient over-submersion is the difference, in m, between the accidental diving depth and the nominal diving depth.

3.7.4 Collapse diving depth

The collapse diving depth is the water depth, in m, corresponding to a calculated external pressure liable to cause collapse of the pressure hull. The depth is measured to the underside of the pressure hull (keel horizontal).

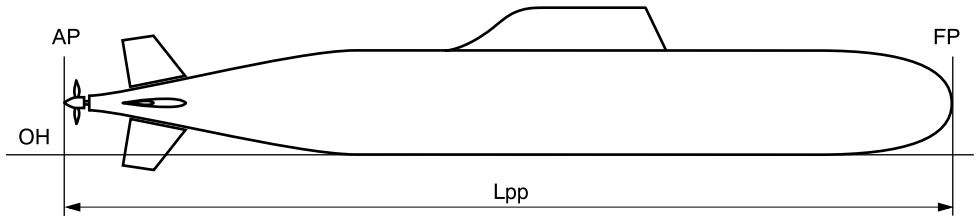
3.7.5 Periscopic depth

The periscopic depth is the depth, in m, at which the submarine uses its hoistable mast. The depth is measured to the underside of the pressure hull (keel horizontal).

3.7.6 Safety depth

The safety depth is the minimum depth, in m, at which the submarine operates without risk of collision with a large draught surface ship.

Figure 1 : Length and perpendiculars



3.8 Length

3.8.1 Length between perpendiculars or length overall

The length between perpendiculars or length overall L_{pp} is the distance, in m, measured from the aft perpendicular to the fore perpendicular (see Fig 1).

3.8.2 Pressure hull length

The pressure hull length is the distance, in m, measured from the aft extreme point of the pressure hull to the fore extreme point of the pressure hull.

3.9 Perpendiculars

3.9.1 Fore perpendicular

The fore perpendicular (FP) is the perpendicular to the horizontal at the fore extreme point of the ship (see Fig 1).

3.9.2 Aft perpendicular

The aft perpendicular (AP) is the perpendicular to the horizontal at the aft extreme point of the aft framework (see Fig 1).

3.10 Baseline

3.10.1 The baseline or OH is the horizontal line at the extreme lowest point of the ship.

3.11 Breadth

3.11.1 Extreme breadth

The extreme breadth B, in m, is the pressure hull diameter.

3.11.2 Breadth overall

The breadth overall, in m, is the length between the baseline and the bridge without taking the casing into account.

3.12 Reference density

3.12.1 The reference density is the mean value of seawater density of waters where the ship is able to operate. When no value is given, reference density equals 1,026 t/m^3.

3.13 Height overall

3.13.1 The height overall is the distance, in m, between the baseline and the highest point of the ship considering that the hoistable mast is lowered.

3.14 Bilge zone

3.14.1 A bilge zone is a bilge where the water level is monitored.

3.15 Accidental level

3.15.1 The accidental level in a bilge zone is the minimum water level for which it is considered that there is a sea water ingress.

3.16 Default level

3.16.1 The default level in a bilge zone is the water level for which the bilge is required to be drained.

3.17 Platform attitudes

3.17.1 The platform attitudes refer to the set of data heel and trim of the submarine.

3.18 Keeping situations

3.18.1 Off keeping situation

The off keeping situation is the situation when the submarine is secured alongside harbour.

3.18.2 Navigation keeping situation

The navigation keeping situation is the situation when the submarine is in navigation at the surface.

3.18.3 Watch diving situation

The watch diving situation is the situation when the submarine is in diving navigation.

3.19 Ship safety functions

3.19.1 A ship safety function is a function required for satisfying a safety target of the ship or necessary in a reply in case of accident.

3.20 Ship ultimate function

3.20.1 A ship ultimate function is a function required for satisfying an ultimate target of the ship.

3.21 Safety target of the ship

3.21.1 The safety target of the ship is to fight against accidents and warranty surfacing and maintain a surface condition of the ship.

The accidents are the following:

- fire
- flooding
- uncontrolled platform attitudes
- internal explosions
- sea risks (i.e. collision, grounding)
- abnormal atmosphere composition.

3.22 Ultimate target of the ship

3.22.1 The ultimate target of the ship is, following an accident and dysfunctions of safety functions, to warranty survival, escape and rescue of the crew in case of impossibility for the ship to surface or maintain a surface condition.

4 Reference co-ordinate system

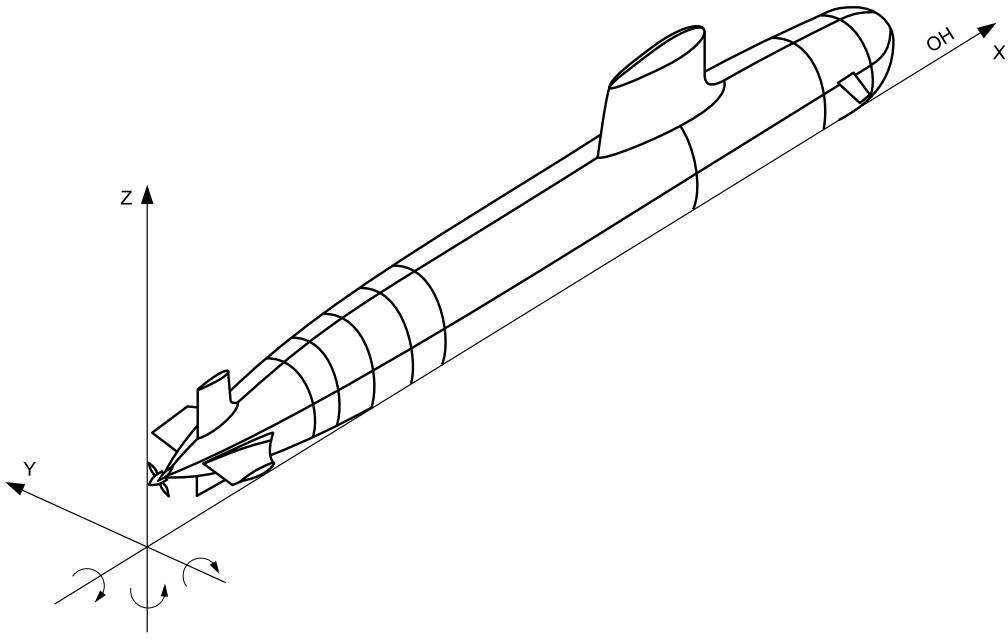
4.1

4.1.1 The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand co-ordinate system (see Fig 2):

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

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

Figure 2 : Reference co-ordinate system



SECTION 3 ENVIRONMENTAL CONDITIONS AND OPERATIONAL LIMITS

1 Application

1.1

1.1.1 Limits mentioned in this Section may be modified according to submarine concept of operation. In this case, they are to be submitted to the agreement of the Naval Authority and of the Society.

2 Definitions

2.1 Normal environment

2.1.1 The normal environment corresponds to conditions where all systems are able to operate. It is tolerated that some systems operate with deteriorated performances when they are not related to ship safety.

2.2 Exceptional environment

2.2.1 The exceptional environment corresponds to an extension of the normal environment. The ship does not manoeuvre deliberately in exceptional environment. The exceptional environment covers at once exceptional climatic conditions and conditions linked to replies following damage. In exceptional environment systems related to ship safety must operate at their nominal performances or at deteriorated performances.

3 External environmental conditions

3.1 General

3.1.1 Air parameters

Air external environmental conditions for normal and exceptional environments are listed in Tab 1.

Table 1 : Air external environmental conditions

	Normal environment	Exceptional environment
Outside air temperature	–5°C to 40°C	–10°C to 45°C
Outside air hygrometry	20 to 80%	15 to 95%
Outside air enthalpy	< 100 kJ/kg	< 110 kJ/kg

3.1.2 Sea parameters

Sea environmental conditions for normal and exceptional environments are listed in Tab 2.

Table 2 : Sea external environmental conditions

	Normal environment	Exceptional environment
External pressure	$P \leq P_N$	$P \leq P_A$
Seawater temperature	D < 40m: 0°C to 32°C	D<40m: –2°C to 35°C
	D ≥ 40m: 0°C to 25°C	D ≥ 40m: 0°C to 25°C
Seawater density	1,015 to 1,035 t/m³	1,005 to 1,035 t/m³
Heavy sea	5 t/m² 4 t/m² for high dimension surfaces parallel to the longitudinal axis of the ship	

4 Internal environmental conditions

4.1 General

4.1.1 Internal air parameters

Internal air environmental conditions for normal and exceptional environments are listed in Tab 3.

Table 3 : Air internal environmental conditions

	Normal environment			Exceptional environment		
	Accommodation and operational spaces	Auxiliary and equipment spaces	Engine room	Accommodation and operational spaces	Auxiliary and equipment spaces	Engine room
Internal temperature	18 - 25°C	10 - 40°C	10 - 55°C	13 - 30°C	5 - 45°C	5 - 60°C
Hygrometry	30 - 70%	30 - 80%	30 - 80%	10 - 90%	10 - 90%	10 - 100%
Enthalpy of inside air	<100kJ/kg			<110kJ/kg		
Internal pressure	800 to 1200 mbar			700 to 1300 mbar		

Table 4 : Vibration internal environmental conditions

	Normal environment			Exceptional environment		
	Accommodation and operational spaces	Auxiliary and equipment spaces	Engine room	Accommodation and operational spaces	Auxiliary and equipment spaces	Engine room
Vibrations	From 2 Hz to 20 Hz: amplitude 0,025mm From 20 Hz to 100 Hz: acceleration 40 mg			From 2 Hz to 20 Hz: amplitude 0,125mm From 20 Hz to 100 Hz: acceleration 200 mg		

4.1.2 Vibrations

Internal vibrations conditions for normal and exceptional environments are listed in Tab 4.

5 Platform attitudes

5.1 General

5.1.1 Platform attitudes for normal and exceptional environments are listed in Tab 5.

6 Electromagnetic compatibility

6.1 General

6.1.1 Electromagnetic compatibility is treated in Pt D, Ch 5, Sec 5, [1].

7 Peace time shock

7.1 Definition

7.1.1 Equipment is to withstand a shock of 15g 1/2sinus according to the IEC 68-2-6.

Table 5 : Platform attitudes

Motion	Normal environment	Exceptional environment
Roll	± 30° Period: 10 seconds	± 45° Period: 10 seconds (during one hour)
Pitch	± 10° Pseudo-period: 1 minute	± 15° Pseudo-period: 1 minute (during one hour)
Heel	Maximum angle: 18° (during 10 minutes)	Maximum angle: 45° (during 1 minute)
Trim	Maximum angle: 30° (during 10 minutes)	Maximum angle: 45° (during 5 minutes)

SECTION 4 MAIN DESIGN PRINCIPLES AND DOCUMENTATION TO BE SUBMITTED

1 General design principles

1.1

1.1.1 This Section intends to describe the general design principles that contribute to achieve:

- availability of the main functions enabling the submarine to dive, operate under water and surface in safety
- pressure hull integrity.

1.1.2 Principles applicable to the design of the systems

- 1st principle: installations dedicated to safety functions

  Installations dedicated to safety functions (essential safety services as defined in Pt A, Ch 1, Sec 1, [1.2.1]) shall not be used for the normal operation of the submarine.

- 2nd principle: duplication and segregation of the essential services other than essential safety services (see Pt A, Ch 1, Sec 1, [1.2.1])

  Essential services other than essential safety services are generally duplicated in two subsystems, each able to provide the half of the function. In order to avoid common failure, segregation of the two subsystems is achieved through:

  - a geographical separation (portside/starboard) or aft/forward
  - different electrical, fluid or hydraulic sources of power
  - diversification of actuating means (local, remote, downgraded).

- 3rd principle: dedicated source of supply of essential safety systems

  The source of supply (hydraulic, compressed air or electrical) of safety actuators is to be supplied by a dedicated permanent source of reserve (buffer reservoir, failover power supply).

1.1.3 Principles applicable to the pressure hull

- 1st principle: hull penetrations

  Hull penetrations dedicated to mechanical shafts are to be provided with at least two dynamic seals.

  Watertightness of the external seal is to be able to be checked at sea.

  Watertightness of the internal seal is either always operational or made operational only in case of failure of the external one.

- 2nd principle: piping dedicated to fluids other than seawater

  Piping dedicated to fluids other than seawater and going through the pressure hull have to be provided with a valve located inside the pressure hull, as close as possible to the pressure hull.

  The valve is to be locally and easily closed.

- 3rd principle: pressure hull obturations

  Pressure hull obturations (hatches, plugs, penetrations for cables, pipes and shafts) are to be, as far as practicable, fitted so that the seawater pressure effect keep them in place and reinforce their water tightness.

  Shafts going through the pressure hull and actuators located outside the pressure hull are so designed that they reach a safety position under seawater pressure effect in case of mechanical or energy failure.

- 4th principle: trunks (weapon tubes included)

  Trunks are to be provided with safety devices avoiding the opening of the external barrier when the internal one is not closed. The safety devices are to be of mechanical and inviolable type in case of major flooding risk.

  Same requirements apply to seawater piping associated to the trunk.

  Other safety devices may be considered on case by case basis by the society.

2 Documentation to be submitted for all ships

2.1 Ships surveyed by the Society during the construction

2.1.1 Plans and documents to be submitted for information

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
- lines plan
- hydrostatic curves.

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.

2.2 Ships for which the Society acts on behalf of the relevant Administration

2.2.1 Plans and documents to be submitted for approval

The plans required by the National Regulations concerned are to be submitted to the Society for approval, in addition to those in [2.1]. Such plans may include:

- arrangement of lifesaving appliances and relevant embarking and launching devices (davits and winches)
- arrangement of compasses
- arrangement of navigation lights
- order transmission.

3 Further documentation to be submitted for ships with additional class notations

3.1 General

3.1.1 Depending on the additional class notation (see Pt A, Ch 1, Sec 2) assigned to the ship, plans or documents may be required to be submitted to the Society in addition to those in [2.1].

3.2 Additional class notations

3.2.1 The plans or documents to be submitted to the Society for approval or for information are listed in Part F.

Part B
Main Design Principles and Stability

Chapter 2
STABILITY

SECTION 1 GENERAL

SECTION 2 INTACT STABILITY

SECTION 3 DAMAGE STABILITY

SECTION 4 WEIGHT CONTROL

APPENDIX 1 INCLINING AND WEIGHING TEST

APPENDIX 2 WEIGHING, TRIM AND STABILITY BOOKLET

APPENDIX 3 EVALUATION OF THE HEELING MOMENT DUE TO ATHWART WIND

SECTION 1 GENERAL

1 Definitions

1.1 Definitions

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 General

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. In any case, the level of intact and damage stability is not to be less than that provided by the requirements in Ch 2, Sec 2 and Ch 2, Sec 3.

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 Definitions

3.1 Reference situation

3.1.1 The reference situation is a conventional situation defined for a submarine, used for stability and weighing calculations and for periodic comparisons.

The reference situation of a submarine corresponds to the ship completely built, weighed underwater, with a speed equal to zero, no heel and no trim, in a water of reference density, with nominal crew on board at action stations, with consumables, margin weight and systems as defined below:

- all systems in accordance with the requirements, taking into account modifications officially decided and entirely achieved with fluids in circuits
- all mobile weights on board
- all variable weights on board.

With the reference situation is associated a reference depth corresponding to a submerged volume. This reference depth is equal to periscopic immersion. For this depth, it is considered that volume contraction is negligible compared to its geometric definition at the surface.

3.2 Surface situation

3.2.1 The surface situation is obtained from the reference situation from which the weight of the total water contained in the water ballast tanks is deducted.

3.3 Submerged displacement

3.3.1 The submerged displacement D_p is the product of submerged submarine volume, comprising ballast tanks and external hull appendages (V_p), by reference density. When change in depth may, by compressibility effects on volumes submitted to hydrostatic pressure, affect the submerged displacement, this value is defined for a 30 m depth. When there is a keel, it contributes in V_p for the volume it defines.

3.4 Surface displacement

3.4.1 The surface displacement is the submerged displacement decreased of the mass of water contained in ballast tanks.

3.5 Geneva displacement

3.5.1 The Geneva displacement is the surface displacement of the ship completed (without water contained in non-watertight compartments) with full crew, engine, ready to go at sea, with all commissioning, ammunitions, systems, pieces of equipment, provisions for the crew, miscellaneous set of tools and spares to take at sea in war time, but without fuel, lubricating oil, fresh water or sea water ballast of all types. In this definition, "sea water ballast of all types" includes regulating tanks, trimming tanks and compensating tanks. Geneva displacement is expressed in long tons.

3.6 Form displacement

3.6.1 Form volume V_f corresponds to V_p at which volume of water trapped in superstructures free-communicating with the sea is added. V_f corresponds to the total volume defined by external hull. Form displacement D_f is the product of V_f by the reference density.

3.7 Zero trim

3.7.1 Zero trim corresponds to the submarine position when its keel line is horizontal.

3.8 Surface draught

3.8.1 The surface draught is the draught corresponding to the surface situation.

3.9 Weighing test at the surface and submerged

3.9.1 The weighing test 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 reference situation. The weight and longitudinal, transverse and vertical location of each item are to be accurately determined and recorded. The weight in reference situation, the lead ballast weight and the longitudinal centre of gravity (LCG) can be obtained in the submerged situation with a zero trim, a zero heel and a minimum traction on the static buoy. The surface situation is confirmed using the static waterline of the ship at the time of the surface inclining test as determined by measuring the draught of the ship, the ship's hydrostatic data relevant to the actual trim and the sea water density. This situation is to be checked just after the submerged inclining test.

3.10 Inclining test at the surface and submerged

3.10.1 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. Using this information and applying basic naval architecture principles, the ship's vertical centre of gravity (VCG or KG) is determined.

3.11 Weighing

3.11.1 The weighing is an operation consisting in establishing the equilibrium weight-buoyancy at a given depth.

3.12 Permanent ballast

3.12.1 The permanent ballast is the ballast weight permitting to adjust the weight estimate of the ship in order to perfect the weighing.

3.13 Submerged stability module

3.13.1 The submerged stability module a_p corresponds to the difference between the vertical position of the submerged longitudinal centre of buoyancy and the submerged centre of gravity. Without particular indication, a_p is corrected from free surface effects.

a_{pmini} corresponds to the minimum value of a_p.

3.14 Surface stability module

3.14.1 The surface stability module ρ-a_s or GM corresponds to the distance between surface centre of gravity and transverse metacentre. Without particular indication, ρ-a_s is corrected from free surface effects.

4 Examination procedure

4.1 Documents to be submitted

4.1.1 List of documents

For the purpose of the examination of the stability, the documentation listed in Ch 1, Sec 4, [2.1.1] is to be submitted for information.

The stability documentation to be submitted for examination, as indicated in Ch 1, Sec 4, is as follows:

- weighing and inclining test report for the ship, as required in [4.2]
- trim and stability booklet, as required in Ch 2, App 2
- damage stability calculations, as required in Ch 2, Sec 3, [1.1.1]
- damage control documentation, as required in Ch 2, Sec 3, [1.2].

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

4.1.2 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 reference situation.

4.1.3 Final documentation

Final stability documentation based on the results of the inclining test and weighing test is to be submitted for examination.

4.2 Inclining test - Weighing test

4.2.1 General

Any ship, for which a stability investigation is requested in order to comply with class requirements, is to be subjected to a weighing test and an inclining test permitting the evaluation of the reference situation weight and position of centre of gravity, so that the stability data can be determined.

The weighing test and inclining test are to be attended by a Surveyor of the Society.

4.2.2 Weighing test and inclining test

The weighing test and inclining test are required in the following cases:

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

4.2.3 Detailed procedure

A procedure for conducting an inclining test is detailed in Ch 2, App 1. For the weighing test, the same procedure applies, except as provided for in Ch 2, App 1, [1.1.10].

5 Draught marks

5.1

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

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 of 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 2, App 2.

1.1.2 Periodical weighing and stability check

At a time not exceeding ten years of the delivery and at each class renewal survey, a weighing test is to be carried out to verify any changes in reference situation displacement and longitudinal centre of gravity.

The full process as defined in Ch 2, App 1 is to be applied.

1.2 Permanent ballast

1.2.1 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 stability booklet.

1.2.2 The documentation showing details of the lead ballast weight adjustment is to be submitted to the approval of the Society. Permanent solid ballast adjustment is to be installed under the supervision of the Society.

1.2.3 Lead ballast weight 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 and maintenance. This evolution is defined in each project as margin weight. The lead ballast weight is to be adjusted after each weighing test.

2 Submerged intact stability

2.1 General submerged intact stability criteria

2.1.1 General

The submerged intact stability criteria specified in [2.1.2] are to be complied with for the loading conditions mentioned in Ch 2, App 2, [1.2].

These criteria set minimum values, but no maximum values are recommended. It is advisable to avoid excessive values of metacentric height, since these might lead to acceleration forces which could be prejudicial to the ship and to the manoeuvring.

2.1.2 Submerged intact stability criteria

The minimum submerged intact stability criterion ap_{mini} is 0,20 m. For all the loading conditions, the ship is to have a value of a_p greater than a_{pmini} .

3 Surface intact stability

3.1 General surface intact stability criteria

3.1.1 General

The surface intact stability criteria specified in Article [3] are to be complied with for the loading conditions mentioned in Ch 2, App 2, [1.2].

These criteria set minimum values, but no maximum values are recommended. It is advisable to avoid excessive values of metacentric height, since these might lead to acceleration forces which could be prejudicial to the ship and to the manoeuvring.

3.1.2 Elements reducing stability

Provisions are to be made for a safe margin of stability at all stages of the voyage.

Effect of wind and rolling, icing and liquid free surfaces are covered by, respectively, [3.2], [3.3] and [4].

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

a) righting arms (GZ curve) of the ship in the different loading conditions (refer to Ch 2, App 2)

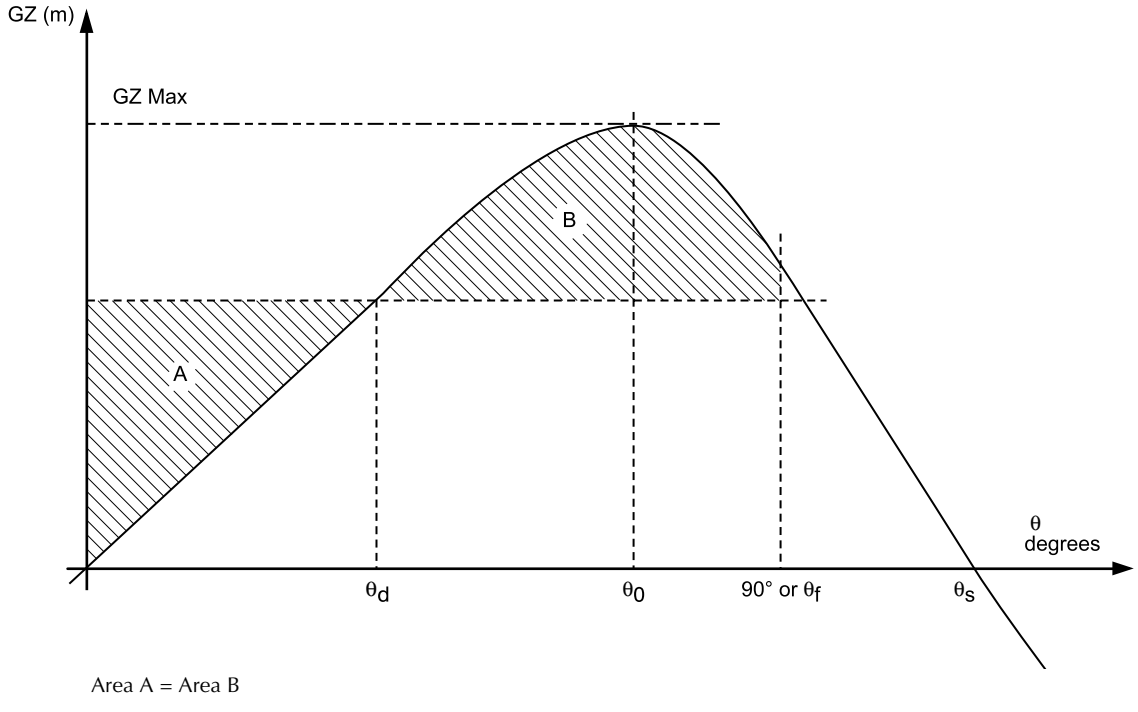
b) behaviour of the ship under heeling actions such as:

   1) severe wind and rolling

   2) combined effect of wind and rolling plus ice accretion.

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

Figure 1 : Righting arms curve



Area A = Area B

3.1.3 Definition of angles of 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 sustain 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 (see Fig 1)

θ_0 : Limit of static stability. It is the angle corresponding to the maximum heeling moment which the ship may sustain 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). It is the angle corresponding to the minimum angle of heel to which at least one unprotected point (see [3.1.4]) 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).

3.1.4 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. access panel (see Fig 2) or ballast tank openings when they come to the surface (a depression in the ballast tanks will be created leading to the filling of the tanks) (see Fig 3).

3.1.5 Righting arms curve

In calculating 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 into account the change of trim and the free surface effects.

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

a) 90°

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

c) θ_s (capsizing angle).

Figure 2 : Down flooding points - Access panel

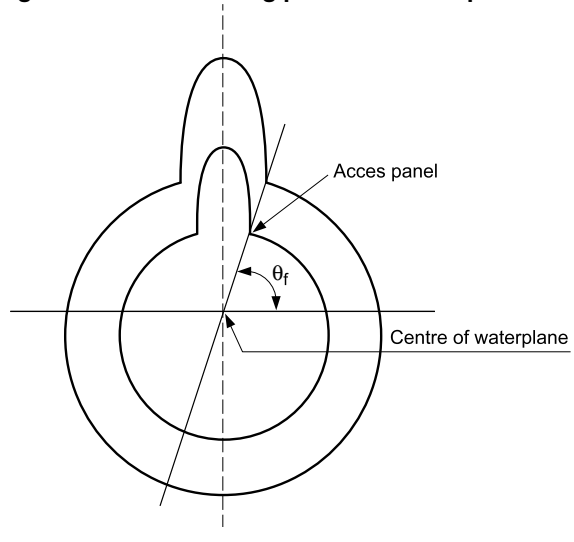
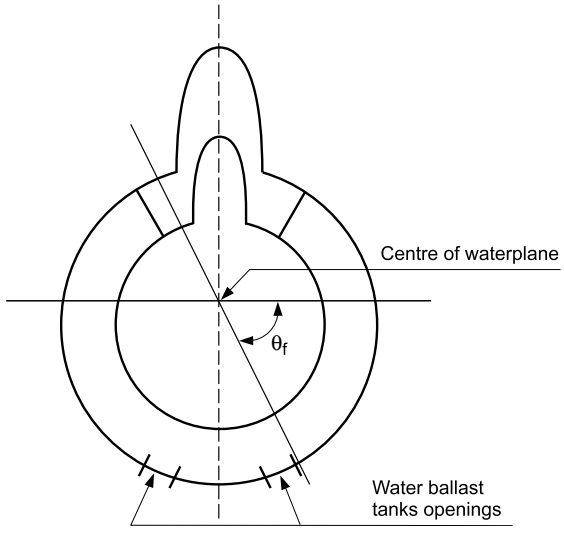


Figure 3 : Down flooding points - Ballast tanks



3.1.6 Requirements for the righting arms curve

The righting arms curve is to achieve at least the requirements listed in Tab 1 and represented in Fig 4.

3.2 Severe wind and rolling criteria

3.2.1 Purpose

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

The stability requirements for wind and rolling specified in [3.2.7] are to be complied with for the loading conditions having the most important windage area (see Ch 2, App 2, [1.2]).

Table 1 : Minimum values required for the righting arms curve in intact condition

Area under the righting arm curve (GZ) up to 30°	not less than 0,027 m rad
Area under the righting arm curve (GZ) between 30° and 45°	not less than 0,034 m rad
Value of the maximum righting arm curve	not less than GM_{corr}
Heeling angle corresponding to the maximum righting arm curve (GZ_{Max})	not less than 60°
Value of the initial metacentric height corrected for free surface effect (GM_{corr})	not less than 0,20 m

3.2.2 Stability requirements

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

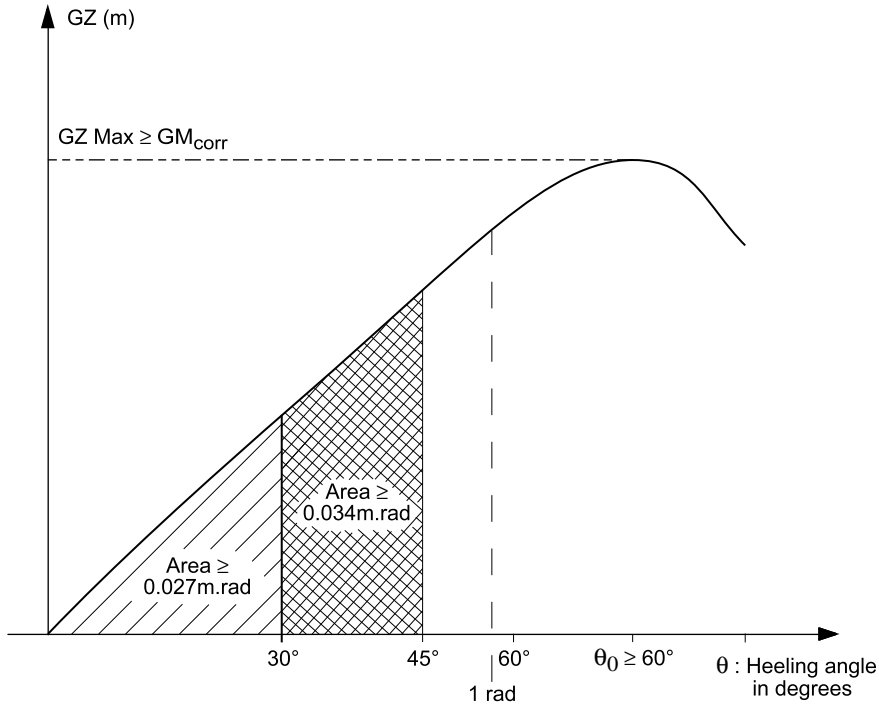
The characteristics of speed and distribution of wind are specified in [3.2.3].

3.2.3 Wind speed

The wind action is to be considered cross directed, its speeds are those reported in Tab 2.

The heeling action of the wind is to be carried out according to Ch 2, App 3.

Figure 4 : Righting arms curve, minimum values required



θ_0 : Extreme angle of static stability

Table 2 : Theoretical speed of the wind

Service of the ship	Speed
Ships employed in very heavy conditions as the peculiar ones of the North Atlantic Sea	100 knots
Ships not employed in storms but having to be able to face other heavy weather conditions	80 knots

3.2.4 Dynamic effects

For the purpose of taking account of the heeling caused by wind combined with rolling, the value of GZ1 (the heeling arm at the angle of static equilibrium θ_c) is to be less than or equal to 60% of the maximum value of the righting arm (GZ_{Max}).

3.2.5 Rolling and reserve of stability

The value of the rolling angle used for the check is to be 30°.

The ship is considered in condition of static equilibrium (point C in Fig 5); from that point a rolling angle of 30° is taken into account.

The following areas are considered:

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

Area "A1" is to be at least 40% greater than area "A2".

3.2.6 Maximum value of the angle of static equilibrium

The maximum allowable value of the static equilibrium θ_c is 15°.

3.2.7 Stability requirements for wind and rolling

The stability requirements for wind and rolling actions are the following:

a) $GZ1 \leq 0,6\ GZ_{Max}$

b) $A1 \geq 1,4\ A2$

c) $\theta_c \leq 15°$

3.3 Icing

3.3.1 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, ice accretion on superstructures and decks is to be taken into account.

In such areas, an ice mass is expected in the exposed zones of the ship, with the triple effect of:

- increasing the displacement
- changing the trim
- elevating the vertical centre of gravity.

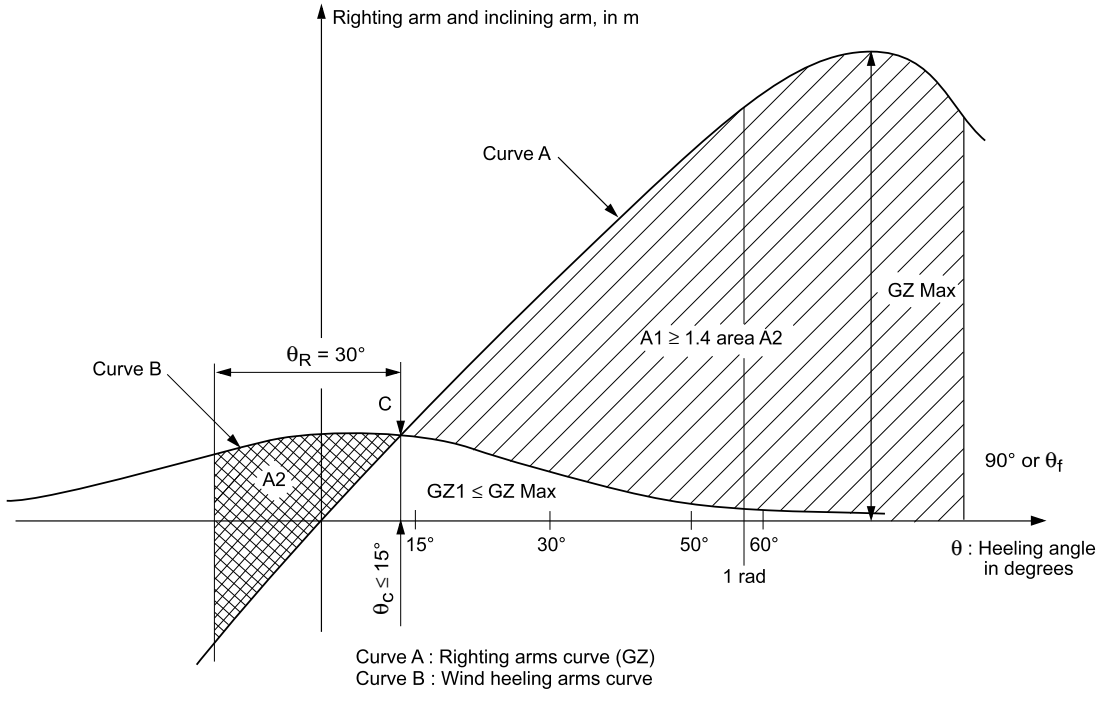
3.3.2 Calculation assumption

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

a) The righting arms curves relevant to the loading conditions are to take into account the effects of ice accretion mass and 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 [3.2], but taking into account values of wind speeds 30% less than those in Tab 2.

Figure 5 : Righting arms curve severe wind and rolling conditions



3.3.3 Guidance relating to ice accretion

For ships operating in area where ice accretion is likely to occur, a uniform ice mass, of 140 kg/m^2 for the horizontal areas and 70 kg/m^2 for the vertical or oblique areas, is to be considered embarked on both sides of the ship.

3.3.4 Centre of gravity of ice

The centre of gravity of ice is to be considered in its own position.

3.3.5 Stability requirements for icing and wind

The effect of ice accretion is to be considered in accordance with the requirements of Tab 1 and Fig 4.

For the effects of wind and rolling, the following criteria are to be complied with (see Fig 5):

a) $GZ1 \leq 0,6\ GZ_{Max}$

b) $A1 \geq 1,4\ A2$

c) $\theta_c \leq 15°$

4 Effect of free surfaces of liquids in tanks

4.1 General

4.1.1 Tanks containing 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.

4.1.2 Bridge

When surfacing, water can be entrapped in the bridge. The resulting free surface effects of entrapped water in the bridge are to be investigated.

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

4.2 Consideration of free surface effects

4.2.1 Free surface effects are to be considered whenever the filling level in a tank is less than 100% of full condition.

Free surface effects for small tanks may be ignored when the volume is less than 100 l.

4.3 Categories of tanks

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

- Tanks with fixed filling level

  The free surface correction is to be defined for the actual filling level to be used in each tank.

- Water ballast tanks

  The free surface correction is considered for surface situation only for water which has not been blown out of the tanks. When water ballast tanks are partially filled, two cases must be considered for semi-symmetrical ballast tanks:

  - independent ballast tanks
  - communicating ballast tanks.

- Tanks with variable filling level which are compensated by sea water (e.g. consumable liquids such as fuel oil)

  Free surface effects considered correspond to an additional liquid of density the difference between sea water density and consumable liquid density.

4.4 GM_0 and GZ curve corrections

4.4.1 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 [4.3.1].

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 [4.3.1]
   - 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 [4.3.1].

   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.

4.5 Remainder of liquid

4.5.1 The free surface effects correction for the usual remainder of liquids in the empty tanks need to be taken into account in calculating the corrections when the volume of the considered remainder is more than 100 l.

5 Diving and resurfacing phases

5.1

5.1.1 The evolution of stability parameters during diving and resurfacing phases are to be assessed.

The stability module is to be positive

In case the stability module is transitionally negative, operational precautions to be taken in each situation shall be proposed and justified.

The situation taken into account for the calculation is the situation of reference of the submarine.

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 waterballast tank which can be damaged

b) subdivision bilge plan

c) 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: water-resistant 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

d) accidental level in each bilge zone

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

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

g) the capacity plan

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

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.

1.2.2 Damage control documentation

The damage control documentation is to include the trim and heel after the damage of adjacent ballast tanks as well as the corrective actions to be done to provide a better situation.

2 Conditions and criteria for surface damaged stability

2.1 General

2.1.1 Loading conditions

The damage stability criteria specified in [2.2.5] are to be complied with for the loading conditions mentioned in Ch 2, App 2.

2.1.2 Calculation assumptions

Calculations are to be performed in accordance with [2.2.2] to [2.2.4].

2.2 Damage and criteria

2.2.1 Introduction

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

2.2.2 Waterballast tanks damage

Following a combat shot or an event at sea, the damage to be considered is a damage involving two consecutive water ballast tanks.

All positions of the damage along the ship where the waterballast tanks are located are to be considered (pressure hull excluded).

If any damage of a lesser extent than above, 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.

2.2.3 Permeability

For the damage stability calculations, the volume and surface permeabilities of water ballast tanks are to be duly justified.

2.2.4 Free surface effects

For partially filled tanks, a free surface effect is to be considered as defined in Ch 2, Sec 2, [4.2].

2.2.5 Residual stability after damage

The residual stability of the ship at the final stage 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:

- the calculation of the righting arms at several angles is to be performed at equilibrium of longitudinal moment (free trim), corrected for free surface effects
- the righting arms curves are limited to the smaller angle between θ_f and 60°, where:

θ_f : Angle at which the first opening results submerged

2) Stability criteria required

At the final stage of flooding (see Fig 1):

- survival condition

Except if particular requirements are specified in the contract or in the specification, the heel at the equilibrium of the final stage of flooding, considering two adjacent ballast tanks damaged, is to be less than 15° before any voluntary action in order to compensate the heel after damage (e.g. half ballast blowing): $\theta_e < 15°$

- initial metacentric height

The initial metacentric height value at a null angle is to be positive: $GM_{corr} > 0$

- one access panel is to be above the final waterline after flooding
- Area (θ_e – 45°) ≥ 0,019 m·rad
- Area (45° – 60° or θ_f) ≥ 0,023 m·rad.

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 2, Sec 2, [3.2]. Nevertheless, the values of rolling and speed of wind to be taken into account are 30° for rolling angle and 60 knots for wind speed

2) Stability requirements

At the final stage of flooding (see Fig 2):

- the value of the area A1 is to be not less than area A2 increased by 40%: A1 > 1,4 A2

The area A2 is limited to the value of rolling angle $\theta_r = 30°$

- $\theta_c < 22,5°$.

Figure 1 : Righting arms curve minimum value required

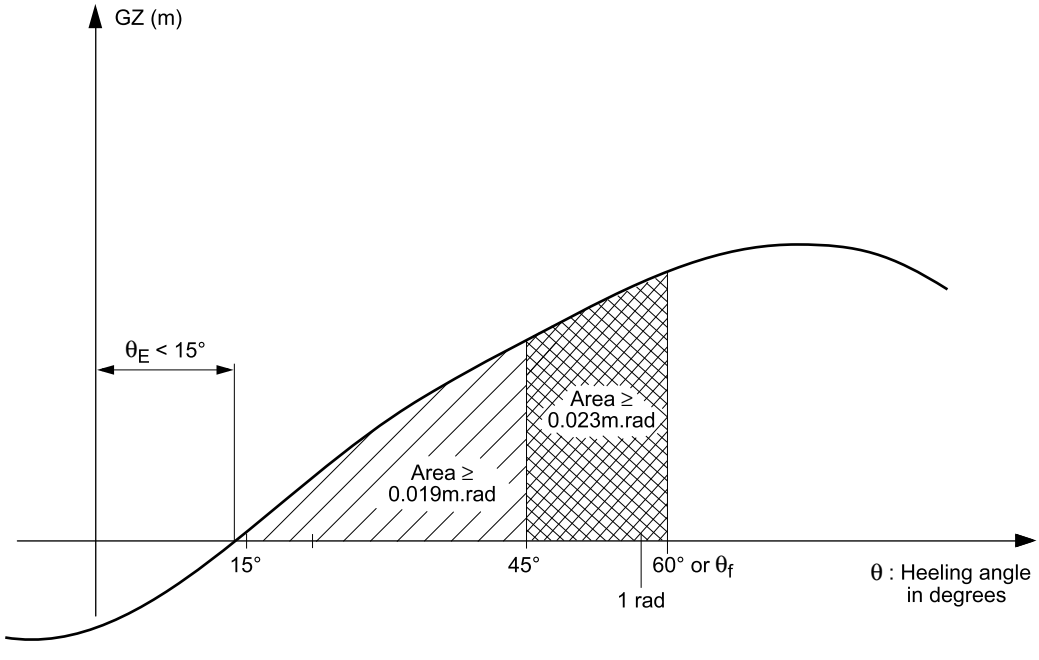
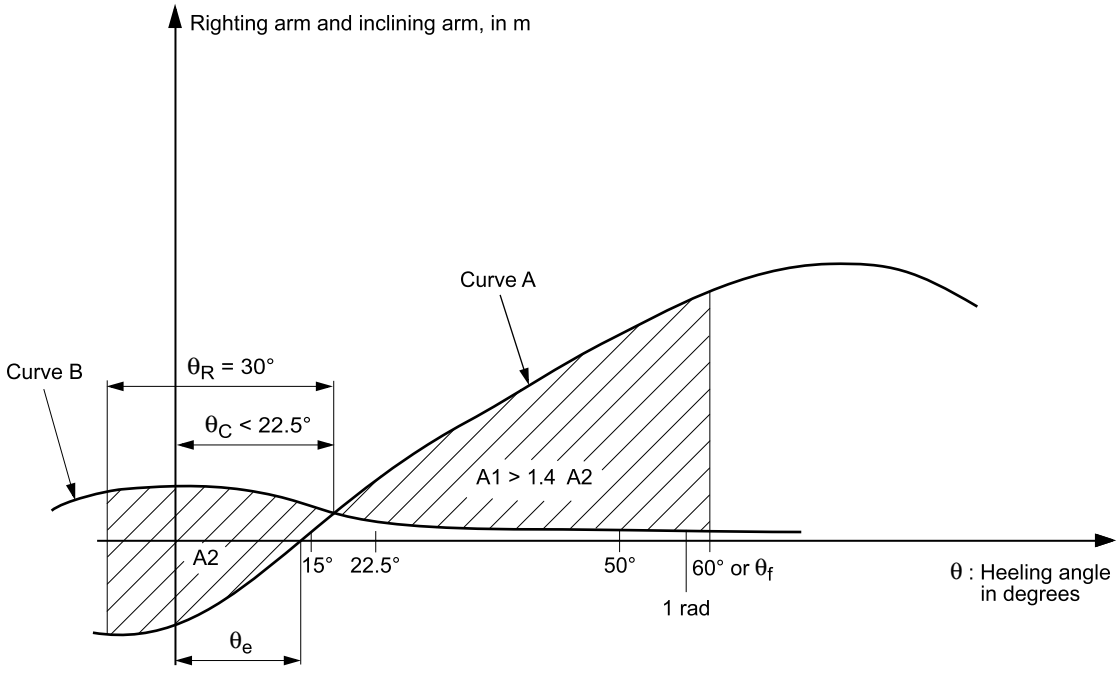


Figure 2 : Righting arms curve severe wind and rolling criteria



Curve A : Righting arms curve at the end of flooding
Curve B : Heeling arms curve caused by severe wind and rolling

SECTION 4 WEIGHT CONTROL

1 General

1.1

1.1.1 Systems related to weight control, diving operations control and depth, trim and buoyancy control are to be designed to operate at any time during the mission of the ship and in any condition for which the ship is designed.

1.1.2 This Section contains only the rules concerning stability.

Rules concerning structural design of capacities are treated in Part C.

Rules concerning design of systems contributing to weighing but other than control systems are treated in Part D.

2 Diving

2.1 Water ballast tanks

2.1.1 When empty, water ballast tanks are to ensure sufficient buoyancy to the ship in order that surface stability requirements are complied with (see Ch 2, Sec 2).

2.1.2 Water ballast tank arrangement is to be designed in order that diving is possible at any time with a sufficient stability margin.

2.1.3 The access trunk is to be designed in such a way that at sea the fin bridge access hatch is located at least 1 m above the waterline. Other access panels which could be opened at sea will have to be clearly identified and their impact on the risk of flooding to be investigated.

2.1.4 Water ballast tanks are to be designed in such a way that at least one access panel is accessible after damage of two consecutive water ballast tanks.

2.1.5 Water ballast tanks are to be, as far as possible, symmetrical in relation to the longitudinal axis to ensure a zero heel at the surface.

2.1.6 Water ballast tanks are to be located in such a way that the ship has a small positive trim at the surface.

2.1.7 Each water ballast tank is to be fitted with a vent valve. Associated venting circuit is to have no common part with other water ballast tank circuits.

2.1.8 Venting circuit arrangement is to be designed in such a way that all the air contained in water ballast tanks is evacuated when the ship dives.

3 Weighing and platform attitudes

3.1 Weighing devices

3.1.1 Weighing devices are to be able to restore the equilibrium weight-buoyancy at any time during the mission of the ship and in any condition for which the ship is designed.

3.1.2 It is to be possible to check water level in the capacities at all times.

3.1.3 Regulating tanks

Volume of regulating tanks is to be sufficient to compensate for all the changes in buoyancy expected to arise during the planned diving duties.

Regulating tanks are to be designed in accordance with trim polygon included in the trim and stability booklet.

The quantity of water admitted during flooding and expelled during freeing is to be indicated. For that purpose, regulating tanks are to be fitted with contents gauges giving a continuous reading.

3.1.4 Removable solid ballast weight

When removable calibrated solid ballast weights are used, they are to be located in a manner that prevents shifting of position.

3.2 Trim and heel devices

3.2.1 The ship is to be fitted with a system, visible from the control station, permitting to know its attitudes at any time.

3.2.2 Trimming corrections

Trimming correction is to be possible at all times in normal environment.

3.2.3 Trimming tanks

Volume of trimming tanks is to be sufficient to compensate for all the changes in trim expected to arise during the planned diving duties.

Trimming tanks are to be designed in accordance with trim polygon included in the trim and stability booklet.

To achieve maximum leverage, trimming tanks are to be located as far forward and as far aft on the ship as possible.

The quantities of water used for trimming are to be indicated.

3.2.4 Heeling corrections

Heeling correction is to be possible at all times in normal environment.

3.2.5 Heeling tanks

Capacities are to be able to compensate for all the changes in heel expected to arise during the planned diving duties. It is not mandatory to have capacities dedicated only to heeling corrections.

APPENDIX 1 INCLINING AND WEIGHING TEST

1 Inclining and weighing test

1.1 General

1.1.1 General conditions of the ship

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

- the weather conditions are to be favourable, the sea state is to be lower than 2 for the submerged inclining test (see Tab 1)
- 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
- in submerged condition, the ship is to have a positive traction on a buoy of about $D_s/10000$
- the ship is to be transversely upright and the trim is to be taken not more than 0,1°. Otherwise, hydrostatic data and sounding tables are to be available for the actual trim
- 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 influence of structural elements except for weighing tanks. 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 but crew directly involved in the operation of the ship is to be on board
- 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.

Table 1 : Sea state 2

Wind speed (knots)	Sea state	Significant wave (m)	Significant range of periods (s)	Average period (s)	Average length of waves (m)
7 - 10	2	0,1 - 0,6	1,5 - 5,0	3	7,93

1.1.2 Weighing buoy

The weighing buoy used for the weighing test is to be marked with draught corresponding to the traction of the submarine. The draught can be read to know the force. The buoy is fixed on the submarine near the vertical of the centre of buoyancy. Its volume is to be approximately equal to $D_s/2000$. The cable used to fix the buoy has a length which is calculated to have the submarine totally submerged near the surface.

1.1.3 Inclining weights

The total weight used is preferably to be sufficient to provide a minimum inclination of one degree and a maximum of three degrees of heel to each side. 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 group of weights 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. Water is generally not acceptable as inclining weight.

1.1.4 Water as inclining weight

Where the use of solid weights to produce the inclining moment is demonstrated to be impracticable, the movement of water between two symmetrical transverse tanks 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 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 are to 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 whenever it is possible
- vertical, longitudinal and transverse centres are to be calculated for each movement
- accurate sounding/ullage tables are to be provided. The ship 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 and stream over long periods of time.

1.1.5 Pendulums and inclinometers

A minimum of two pendulums or similar devices are to be used to allow identification of bad readings at any one measurement station. They are each to be located in a protected area. 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 inclinometers is allowed but should be subject to at least the following recommendations:

- the accuracy should be equivalent to that of a pendulum
- the sensitivity of the inclinometer should be such that the unsteady heeling angle of the ship can be recorded throughout the measurement
- the recording period should be sufficient to accurately measure the inclination. The recording capacity should be generally sufficient for the whole test
- the instrument should be able to plot or print the recorded inclination angles on paper
- the instrument should have linear performance over the expected range of inclination angles
- the instrument should be supplied with the manufactured's instructions giving details of calibration, operating instructions and details of approvals
- it should be possible to demonstrate the required performance to the satisfaction of the Society during the inclining test
- a calibration certificate is to be provided.

1.1.6 Means of communications

Efficient two-way communications are to be provided between central control and the weight handlers and between central control and each measurement station. One person at a central control station is to have complete control over all personnel involved in the test.

1.1.7 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 test weights, tanks, etc. When water is used as inclining weight, the transverse and vertical centres of gravity for the applicable tanks, for each angle of inclination, are to be available
- tank sounding tables
- submerged drawing with buoy position and draught mark on the fin which gives the volume of non-submerged appendages
- surface drawing with the position of draught marks
- weighing buoy drawing with draught marks indicating the traction
- Water ballast filling openings drawing (in order to know where to measure the quantity of water not blown).

1.1.8 Determination of the submerged displacement

The operations necessary for the accurate evaluation of the submerged displacement of the ship at the time of the inclining test, as listed below, are 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 reference situation. Each item is to be clearly identified by weight and location of the centre of gravity
- ballast tanks are filled with sea water
- weighing tanks are partially filled in order that the ship is completely submerged
- draught mark readings are to be taken on the weighing buoy
- 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. 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 at three different depths and the readings averaged. 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 tanks and compartments which can contain liquids are to be checked, particular attention being paid to air pockets which may accumulate due to the ship trim and the position of air pipes, and to the provisions of [1.1.1] which are also to be taken into account
- 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 solid permanent ballast is to be clearly identified and listed in the report.

1.1.9 Determination of the surface displacement

The operations necessary for the accurate evaluation of the surface displacement of the ship at the time of the inclining test, as listed below, are to be carried out:

- 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 reading) 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.

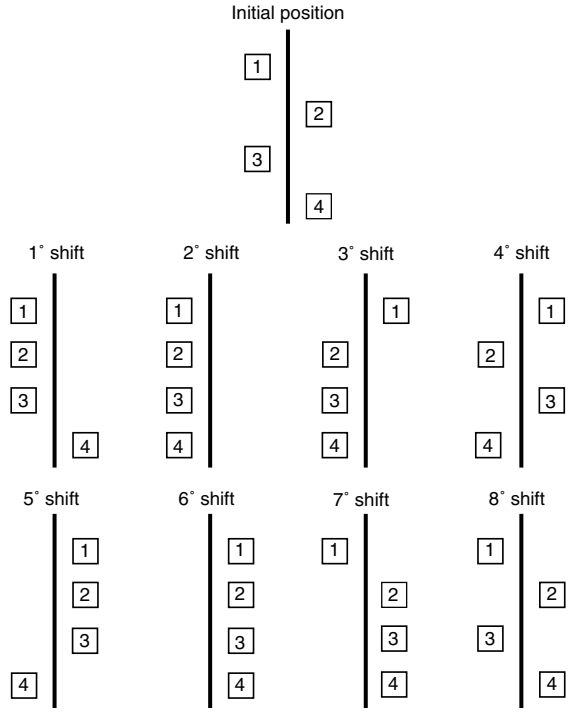
  A correction to water specific gravity is not necessary if the specific gravity is determined at the inclining experiment site. Correction is necessary if specific gravity is measured when the sample temperature differs from the temperature at the time of the inclining (e.g., if the check of specific 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 tanks and compartments which can contain liquids are to be checked, particular attention being paid to air pockets which may accumulate due to the ship trim and the position of air pipes, and to the provisions of [1.1.1] which are also to be taken into account. In particular, the quantity of water which has not been blown out of water ballast tanks is to be measured
- 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 reference condition. Each item is to be clearly identified by weight and location of the centre of gravity
- the solid permanent ballast is to be clearly identified and listed in the report.

1.1.10 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 trim and vertical position of the centre of gravity.

Figure 1 : Weight shift procedure



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

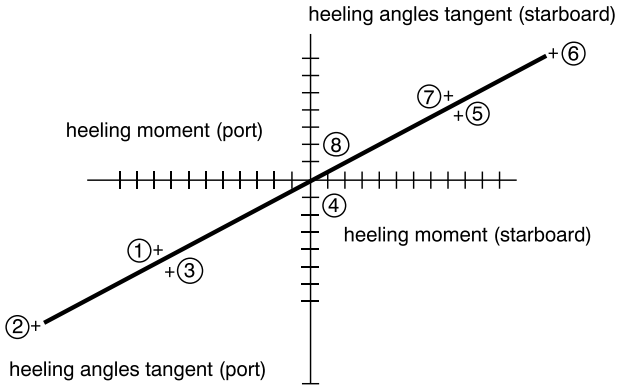
After each weight movement, the distance the weight was moved (centre to centre) is to be measured and the heeling moment calculated by multiplying the distance by the amount of weight moved. The tangent is calculated for each pendulum by dividing the deflection by the length of the pendulum. The resultant 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.

The angle is to be recorded after balanced during two minutes to be sure there are no remaining movements.

During the reading or record, no movements of personnel are allowed.

Figure 2 : Graph of resultant tangents



APPENDIX 2 WEIGHING, TRIM AND STABILITY BOOKLET

1 Weighing, trim and stability booklet

1.1 Information to be included in the weighing, trim and stability booklet

1.1.1 General

A weighing, trim and stability booklet is a stability manual, to be approved by the Society, which is to contain 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 weighing, trim and stability booklet:

- a general description of the ship, including the:
  - ship name and Society classification number
  - ship type
  - class notations
  - yard, hull number and year of delivery
  - moulded dimensions
  - draught corresponding to the surface reference situation
  - displacement corresponding to the above-mentioned draught
  - displacement corresponding to the submerged reference situation
- 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 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 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
- reference situation from the inclining test, as indicated in Ch 2, Sec 1, [4.2], including reference situation displacement at the surface and submerged, centre of gravity coordinates, 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
- standard loading conditions as indicated in [1.2] 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 coordinates, draughts at perpendiculars, GM, GM corrected for free surfaces effect, GZ values and curve, criteria as indicated in Ch 2, Sec 2, [2] and Ch 2, Sec 2, [3], 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 [1.3]
- damage stability results (total displacement and its centre of gravity coordinates, draughts at perpendiculars, GM, GM corrected for free surfaces effect, GZ values and curve, criteria as indicated in Ch 2, Sec 3, [2], 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 [1.3]
- information on weighing restrictions (maximum and minimum values of sea water density, maximum depth, description of trim polygon)
- information about openings (location, tightness, means of closure), pipes or other progressive flooding sources
- any other guidance deemed appropriate for the operation of the ship
- a table of contents and index for each booklet.

1.2 Loading conditions

1.2.1 General

The standard loading conditions to be included in the weighing, trim and stability booklet are:

- reference situation
- surface situation
- ship at the surface with ballast tanks partially filled
- several loading conditions representing the impact of different consumptions and of the program of density at several steps of the typical mission
- loading conditions due to the weapon ejection
- loading conditions due to special operations.

Further loading cases may be included when deemed necessary or useful.

1.3 Stability curve calculation

1.3.1 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.

The calculations are to take into account the volume to the upper surface of the deck sheathing.

1.3.2 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.

APPENDIX 3 EVALUATION OF THE HEELING MOMENT DUE TO ATHWART WIND

1 Evaluation of the heeling moment due to athwart wind

1.1 Intact stability

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

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

where (see Fig 1):

V : Wind speed, in knots, equal to 100. Another value of wind speed may be accepted, in accordance with the specification or the contract

h : Vertical distance, in m, between the windage surface centre and the driftage surface centre (which may be considered at mid-draught)

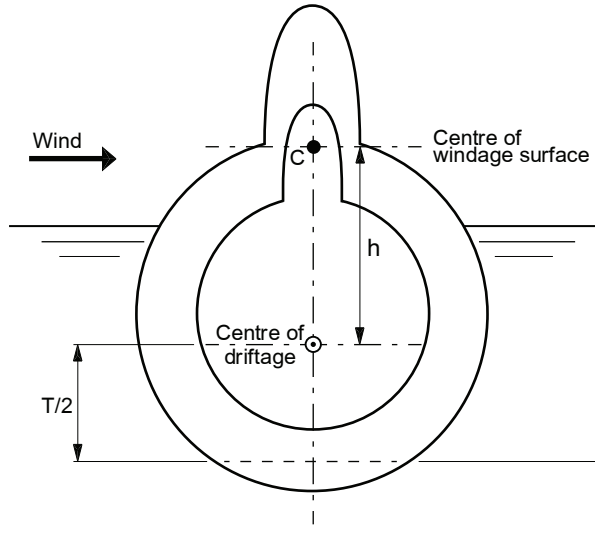
A : Area of windage surface, in m^2, above the waterline

θ : Transverse heeling angle, in degree.

1.2 Damage stability

1.2.1 The same approach as in [1.1.1] is to be applied, taking account that h is the vertical distance, in m, between the windage surface centre and the driftage surface centre (which may be considered at mid-draught) in the final equilibrium after damage.

Figure 1 : Example showing the elements used for calculation of the heeling arms caused by the wind



RULES FOR THE CLASSIFICATION OF NAVAL SUBMARINES

Part C
Pressure Hull and Structures

Chapters **1 2 3 4 5 6 7**

CHAPTER 1 STRUCTURE DESIGN PRINCIPLES

CHAPTER 2 PRESSURE HULL

CHAPTER 3 RESISTING STRUCTURES

CHAPTER 4 EXOSTRUCTURE

CHAPTER 5 NON-RESISTING STRUCTURES

CHAPTER 6 HULL OUTFITTINGS

CHAPTER 7 CONSTRUCTION AND TESTING

September 2016

Part C

Pressure Hull and Structures

Chapter 1

STRUCTURE DESIGN PRINCIPLES

SECTION 1 DEFINITIONS

SECTION 2 MATERIALS

SECTION 3 LOADS

SECTION 4 PAINTING AND PROTECTION AGAINST CORROSION

SECTION 1 DEFINITIONS

Symbols

P_N : Nominal diving pressure, in bar

P_A : Accidental diving pressure, in bar

P_{AO} : Accidental transient over-submersion pressure, in bar

P_C : Collapse diving pressure, in bar

χ : Safety factor of the pressure hull

g : Gravity acceleration in m/s^2.

1 Units

1.1

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

Table 1 : Units

Designation	Usual symbols	Units
Ship's dimensions	L,R	m
Density	ρ	t/m^3
Concentrated loads	F	kN
Surface distributed loads (pressures)	p	bar
Thickness	t	mm
Stresses	σ, τ	N/mm^2

2 Definitions

2.1 General

2.1.1 Definitions given in the present Article are applicable to Part B and Part C.

2.2 Depth

2.2.1 Nominal diving depth

Maximum operating depth, in m, for which the submarine is designed to dive for a given number of time specified by the Designer. Unless otherwise specified, an unlimited number of dives is considered. This depth corresponds to the nominal diving pressure. The depth is measured to the underside of the pressure hull (keel horizontal).

2.2.2 Accidental diving depth

Maximum depth, in m, likely to be reached by the submarine after a damage to a manoeuvring device, an accidental over-weighting or a thrust decrease.

2.2.3 Accidental transient over-submersion

Difference, in m, between the accidental diving depth and the nominal diving depth.

2.2.4 Collapse diving depth

Maximum calculated depth, in m, beyond which the first failure mode of the pressure hull is theoretically reached. The maximum depth is derived from the nominal diving depth and safety factors.

2.2.5 Safety depth

Minimum depth, in m, beyond which the risk of collision between the submarine and a surface sea ship is null.

2.3 Categories of structures

2.3.1 Pressure hull

Main component of the submarine exposed to the diving pressure and intended to maintain strength and watertightness of the submarine.

2.3.2 Resisting structures

Structures designed to withstand a given diving depth (equal or lower than the nominal diving depth) or a given pressure, and not belonging to the pressure hull.

2.3.3 Exostructures

All Structures or structural parts located outside the pressure hull and not belonging to resisting structures. Volumes bounded by exostructures are permanently in communication with the external environment.

2.3.4 Non resisting structures

All structures or structural parts located inside the pressure hull and not belonging to resisting structures. Typically, non resisting structures gather tanks, cradle, seating, bulkhead, etc.

2.4 Components of the pressure hull

2.4.1 Elementary plate panel

Band of shell corresponding to one frame spacing, measured between axis of ring stiffeners.

2.4.2 Frame

Circular frame composed by a ring stiffener and the associated band width of shell corresponding to one frame spacing.

2.4.3 Deep frame

Circular frame composed by a band width of shell corresponding to one frame spacing and a ring stiffener of increased scantling and designed to act as a support for the pressure hull.

2.4.4 Dished end

Spherical or elliptical fore or aft end of the pressure hull.

2.4.5 Main bulkhead

Watertight bulkhead extending over the whole transverse section of the pressure hull and dividing the ship in two distinct areas.

2.4.6 Cofferdam

Watertight cofferdam (enclosed watertight space surrounded by two parallel bulkheads structurally connected to each other) extending over the whole transverse section of the pressure hull and dividing the ship in two distinct areas.

2.4.7 Connecting parts

Connecting structures or connecting frames in way of pressure hull geometrical or scantling discontinuity.

2.4.8 Hatch cover

Cover of large openings in the pressure hull used for maintenance during surveys or cover of manhole used in harbour operation.

2.4.9 Hull passage

Opening in the pressure hull dedicated to the access of personnel and equipment into the submarine.

2.5 Other definitions

2.5.1 Trunk

Closed space designed to allow communication between the inside of the pressure hull and the external environment and designed to withstand the diving pressure on either side.

2.5.2 Built in trunk

Trunk having one of its boundary made up by the pressure hull.

2.5.3 Secondary bulkheads

Structural bulkheads not contributing to the strength of the pressure hull.

Table 2 : Documentation to be submitted

Drawing or document	Containing information on
General arrangement **(1)**	Main data of the submarine
Pressure hull	Nominal diving depth and Accidental over submersion Frame: scantling and spacing Main bulkheads and dished ends location Hatch covers location Materials
Hull sub-section	Openings size and location Strakes and welds Seating and other connected structures
Hatch covers	Sealing and securing arrangement
Resisting structures	Operational conditions Design loads Connection with the pressure hull
Fore and aft ends Bridge fin Exposed deck	Connection with the pressure hull Information on equipment accommodated Materials
Seatings	Mass and center of gravity of the supported equipment For engine seating: type power and r.p.m. of the engine
Decks and suspended decks	Connection with the pressure hull Supporting point
Internal bulkheads	Connection with the pressure hull, if any Design pressure if submitted to an overpressure
Capacity plan **(1)**	Volume, positing and centre of gravity of compartments and tanks
Protection against corrosion	Specification of corrosion protection systems Position and type of anode if any
Trimming and steering devices	Design loads, and operational conditions
Anchoring and mooring reinforcements	Design loads Location of bitts, windlass, chain stopper, as applicable and the associated reinforcements
(1) Document to be submitted for information only.	

2.5.4 Capacity

Tank or space intended for the carriage of liquid.

2.5.5 Built in capacity

Tank or space intended for the carriage of liquid and having one of its boundaries made up by the pressure hull.

2.5.6 Seating

Structure attached to the pressure hull or other structure and intended to support an equipment.

2.5.7 Suspended deck

Structure designed to support deck and equipment fitted into the submarine and resiliently hanged on the pressure hull.

3 Documentation to be submitted

3.1 General

3.1.1 The designer is to submit the drawings of all components of the submarine structure subjected to classification. The drawings are to contain all the information and detail necessary to check the design of the various components.

As a rule, the drawings and document to be submitted to the Society are listed in Tab 2.

3.1.2 The various calculation reports supporting the design of the various components and requested in the Rules are to be submitted together with the drawing of the associated structural components.

SECTION 2 MATERIALS

1 General

1.1 Scope

1.1.1 This Section gives the requirements for the materials that may be used for the construction of the submarine structure.

1.2 Materials properties

1.2.1 The materials selected are to have properties satisfying the intended use and suitable for the construction techniques used.

1.2.2 Mechanical properties for all structural material used on board are to be submitted to the Society.

As a general rule, the following characteristics for steel used on board are to be submitted:

- minimum guaranteed mechanical characteristics of parent metal and welding joint
- weldability
- corrosion behaviour
- applicable Wöhler curves.

1.2.3 The manufacturing process and the testing of the materials are to comply with the applicable requirements of NR216 "Rules on Materials and Welding for the Classification of Marine Units".

1.2.4 Materials complying with international, national or proprietary specifications may be accepted by the Society, provided such specifications give reasonable equivalence to these Rules, NR216 Materials and Welding and other relevant Society's Rules.

Such specifications are to be submitted to the Society.

2 Steel grade for pressure hull and resisting structures except cofferdam

2.1 General

2.1.1 High strength steel in quenched and tempered condition is generally used for rolled products, castings and forgings.

2.2 Toughness requirements

2.2.1 The toughness specification of the steel grade selected by the Builder is to be submitted to the Society for consideration.

2.2.2 The Builder has to supply documented evidences to the Society to demonstrate that the toughness specification has been established to take into account the fracture behaviour under dynamic loading. To this end the Society considers that tests made on representative full thickness specimens like Bulge Explosion Test or Explosion Crack Starter Tests are recognized methods to assess this behaviour. Other methods are to be presented to the Society for consideration.

3 Steel grade for cofferdam and exostructures

3.1 General

3.1.1 Rolled products, castings and forgings in normal or higher strength steel grades are generally used for the construction of cofferdam and exostructures.

3.2 Toughness requirements

3.2.1 Steel grade specification for Charpy V-notch impact test is to comply with Tab 1.

Table 1 : Requirements for Charpy V impact test Temperature of steel grade for cofferdam and exostructures

Thickness of part, in mm	t ≤ 40	40 < t ≤ 60	60 < t ≤ 100
Minimum T	– 20°C	– 40°C	– 60°C
Typical grade as per NR216 Materials & Welding	D DH32 to DH40 D420 to D690	E EH32 to EH40 E420 to E690	FH32 to FH40 F420 to F690

4 Steel grade for internal non-resisting structures

4.1 General

4.1.1 Rolled products, castings and forgings in normal or higher strength steel grades are generally used for the construction of internal non resisting structures.

4.2 Toughness requirements

4.2.1 Steel grade specification for Charpy V-notch impact test is to comply with Tab 2.

Table 2 : Requirement for Charpy V impact test Temperature of steel grade for internal non-resisting structures

Thickness of part, in mm	t ≤ 60	60 < t ≤ 100
Minimum T	0°C	– 20°C
Typical grade as per NR216 Materials & Welding	B AH32 to AH40 A420 to A690	D DH32 to DH40 E420 to E690

5 Other metallic materials

5.1 General

5.1.1 Metallic materials other than ferritic steels may be used and are considered by the Society on a case-by-case basis.

5.1.2 The use of grey cast iron is not permitted.

5.2 Aluminium alloys

5.2.1 Aluminium alloys are authorized only for structural elements of exostructures or internal non-resisting structures provided that adequate precautions are taken with regards to corrosion risks and fire protection.

6 Non-metallic materials

6.1 Composites

6.1.1 Composites materials covered by this sub-article are plastic reinforced composites made from the association of thermosetting synthetic materials (polyester resins, vinyl-ester, epoxide,...) with fibrous or textile reinforcements such as fibres of glass, carbon, kevlar, ...

6.1.2 The use of composite materials is authorized only for structural elements of exostructures or internal non-resisting structures provided their constituent are not prohibited by other safety requirements.

6.1.3 Standard of calculation and control

Strength and resistance of structural elements built in composite materials are to comply with a recognized standard agreed by the Society.

6.2 Other materials

6.2.1 Non metallic materials other than composites materials as defined in [6.1] may be used for structural members of internal non-resisting structures provided they have been proved suitable for the intended application and agreed by the Society.

SECTION 3 LOADS

1 General

1.1 Principles

1.1.1 When designing a submarine, all the loads likely to be exerted on the structure are to be taken in account. The basic loads to be considered when determining the scantlings of the structural components are the most severe loads acting in the normal conditions and operational limits, as well as in emergency conditions.

See Pt A, Ch 1, App 2 for normal and emergency conditions.

1.1.2 Loads resulting from situations likely to occur at the same time are to be considered simultaneously so as to take into account the most severe combination of their effects under the intended normal conditions and emergency condition. More especially, the effect of the basic loads which may happen simultaneously are to be associated with their maximum intensity.

1.2 Application of loads

1.2.1 Loads listed in Article [2] are usual basic loads to be considered for submarine. However, this list is not exhaustive. The Society may require additional loads to be considered if they are likely to occur.

1.2.2 Loads listed in Article [2] are to be used for scantling calculation according to the following chapters of part C.

2 Basic loads

2.1 Sea pressure

2.1.1 Diving pressure

The diving pressure is the sea hydrostatic pressure exerted on the pressure hull in the most unfavourable way. Under normal condition, the diving pressure to be considered is the nominal diving pressure P_N taken at the lowest point of the submarine (keel or equivalent) at the nominal diving depth.

The nominal diving pressure P_N is to be evaluated from the nominal diving depth considering the gravity g and the specific density of sea water as constant so that 10 metre of immersion equal to 1 bar of sea pressure.

For low nominal diving pressure (less than 100 m), the vertical variation of the hydrostatic pressure along the submarine may be considered by the Society on a case by case basis.

2.1.2 Green seas and wave loads

In surface condition, submarines are subjected to wave and green seas loads. Wave and green seas loads should be applied to all parts of the submarine likely to be emerged. As a general rule, green seas and wave loads should be taken equal to $5t/m^2$.

However, the Society may accept wave and green sea loads lower than $5t/m^2$ if duly justified by designer.

2.1.3 Water current

In surface and imerged condition the fore end of the submarine is subjected to sea water resistance. The related pressure is to be calculated considering the submarine at its maximum speed. The calculation of the sea water resistance is to be submitted by the designer.

2.2 Internal pressure

2.2.1 Tank pressure

Pressure on tank bulkhead is to be determined considering hydrostatic load of the liquid in the tank and the service pressure of the dedicated circuit, if relevant. For large tanks, the inertial load resulting from the motion of the fluid in the tank should be considered.

In addition, where over pressure is likely to occur in tanks, tank liquid pressure is to be increased by a given accidental over pressure which must be submitted by designer and taken in accordance with tank valve threshold.

2.2.2 Ballast blowing

Blowing pressure is to be given by the designer. If no values are given, default values are to be taken equal to 2 bar for normal blowing and 3 bar for emergency blowing.

2.3 Equipment

2.3.1 Mass and equipment

The loads due to the mass of accommodation, equipments and various cargoes are to be to be taken in account considering their weight and the associated inertial loads due to the accelerations of the submarine.

The inertial loads are to be evaluated considering a vertical acceleration equal to 2 g. Transversal and longitudinal accelerations can be disregarded.

The designer is to submit to the Society the design loads of each compartment of the submarine.

At a preliminary design stage, where the detail and weight of equipments in each compartment is not known, the design loads are to be taken as specified in Tab 1.

Table 1 : Still water deck pressure in operational and accommodation compartments

Type of operational and accommodation compartments	p_S, in kN/m^2
Operational rooms	7,5
Cabins, baggage rooms, kitchens, lounges, restaurant, meeting rooms, briefing rooms, hospitals, corridors	5,0
Storages intended for mineral water, wine, oil	15,0
Galleys and other storages	10,0
Ammunition storages	15,0

2.3.2 Mooring, towing and anchoring

Forces transmitted to the submarine structure through cables, chain cables, towing and anchoring devices are to be considered in normal condition and normal operational limits, as well as in emergency situations. These forces are to be taken in accordance with requirements of Ch 6, Sec 2.

2.3.3 Trimming and steering devices

Forces transmitted to the submarine structure by trimming and steering devices are to be evaluated considering:

- the wave and green seas loads when surfaced
- the trimming, steering and drag forces when submerged.

2.4 Other loads

2.4.1 Over pressure

In spaces where accidental internal over pressure is likely to occur, over pressure load is to be considered on the most unfavourable side for the design of internal bulkhead. Design over pressure is to be submitted by the designer.

2.4.2 Fire weapon load

Where applicable, fire weapon loads are to be submitted and justified by the designer.

SECTION 4 PAINTING AND PROTECTION AGAINST CORROSION

1 General

1.1 Application

1.1.1 The following requirements apply to anti corrosion devices of submarines steel structures.

1.2 General principles

1.2.1 Structure of submarines is generally designed with no corrosion allowance. Therefore structure of submarines is to be efficiently protected against corrosion by a combination of the following methods:

- protective coating and/or painting
- galvanic protection.
- impressed current.

1.2.2 Structure of submarines is to be designed to allow efficient control of corrosion protection devices by one of the following methods:

- visual examination if both sides of the structure are accessible
- thickness measurement if only one side is accessible.

Accessible structures include structures which can be examined by means of remotely operated camera or after dismantling of other structures or equipments during maintenance period in dry condition.

1.2.3 The schedule of corrosion control for the various categories of structure is to be done according to Pt A, Ch 2, Sec 2.

1.2.4 Design specification and calculation notes of corrosion protection system of the submarine are to be submitted to the Society for approval.

2 Design of corrosion protection systems

2.1 General

2.1.1 Corrosion protection systems for steel structures are to be designed according to a recognized standard.

If the design is conducted without reference to a recognized standard, the methodology and all the data used are to be documented and justified to the satisfaction of the Society.

2.2 Galvanic anode

2.2.1 The number and mass of galvanic anode and their locations are to be chosen in accordance with International code or standard agreed by the Society.

2.2.2 Galvanic anodes are to be designed for a minimum service life time in accordance with forecasted intervals between surveys in dry conditions, unless particular arrangements are made for their replacement afloat.

2.2.3 Material certificates of the galvanic anodes are to be submitted to the Society.

2.3 Painting and coating

2.3.1 All parts of the submarine structure are to be painted and/or coated.

2.3.2 Anti corrosion coating or painting applied on the interior of the submarine is to comply with safety requirement defined in Part E, Chapter 1.

2.3.3 Painting and/or coating applied on the submarine structure is to have a design life time in accordance with forecasted intervals between surveys in dry conditions.

2.3.4 The application and surface preparation procedure are to comply with coating or painting manufacturer recommendations, giving particular attention to the required environmental conditions.

Part C

Pressure Hull and Structures

Chapter 2

PRESSURE HULL

SECTION 1 SCANTLING OF PRESSURE HULL

SECTION 2 HULL INTEGRITY AND PENETRATION

APPENDIX 1 SCANTLING OF EXTERNALLY PRESSURIZED VESSEL

SECTION 1 SCANTLING OF PRESSURE HULL

1 General

1.1 Application and definitions

1.1.1 The following requirements apply to the pressure hull. Pressure hull includes the following component units, according to Ch 1, Sec 1, [2.4]:

- frame in cylindrical or conical parts
- fore and aft dished ends
- main bulkhead or cofferdam
- connecting parts.

1.2 Principles of scantling examination

1.2.1 Loads and special features to be considered for determining the scantling of the pressure hull are defined in Article [2]. Collapse modes to be investigated and checking criteria are defined in Article [3].

1.2.2 Designer is to submit to the Society a calculations report on which the pressure hull design is based. Submitted documents are to include scantling determination of all components listed in [1.1.1].

1.2.3 Irrespective of the theoretical and experimental structural methods used by the designer from the sole viewpoint of structural resistance, the calculation report must show how the calculations have been performed and how assessments and choices have been made at the following stages of the design:

- stress analysis
- calculation of buckling pressures
- analysis of connections and structural discontinuity
- assessment of safety margins and safety factors.

1.2.4 Whenever scantling calculations are computer assisted, input and output data and any other relevant information allowing to check the validity of calculation are to be submitted. For computer programs on which sufficient experience has not been gained, a reference file is to be submitted.

2 Design and scantling principles

2.1 Loads

2.1.1 As a general rule, scantling of pressure hull is to be determined considering only the sea hydrostatic pressure corresponding to the nominal diving depth.

2.1.2 However, where other forces are likely to exert simultaneously with the nominal diving pressure, load cases are to be considered, considering all forces.

2.2 Structure attached to pressure hull

2.2.1 As a general rule, internal or external structures attached to the pressure hull are to be connected in way of stiffening members.

2.2.2 Where not possible, the connection is to be so designed as to not to create any stress concentration.

2.2.3 Calculation report to be submitted by designer is to include calculation of stress and fatigue analysis according to [3.7.6] of details in way of connection of surrounding structure with pressure hull.

2.3 Construction tolerances

2.3.1 Out-of-roundness

Resistance to nominal diving pressure of the pressure hull highly depends on construction out-of-roundness. Out-of-roundness is to be carefully controlled and in accordance with calculation hypothesis.

Safety factors defined here below and formulae defined in Ch 2, App 1 are set for a maximum out-of-roundness of 0,004 when measured according to Ch 2, App 1, [5.1.1].

Where out-of-roundness tolerances stated above is exceeded, the admissible maximum diving pressure is to be recalculated according to Ch 2, App 1 or formulae deemed as equivalent by the Society. The new maximum admissible diving pressure is to comply with all criteria defined in Article [3].

2.3.2 Angularity of ring stiffeners

Resistance to nominal diving pressure of the pressure hull highly depends on construction angularity of ring stiffeners. Angularity is to be carefully controlled and in accordance with calculation hypothesis.

Safety factors defined here below and formulae defined in Ch 2, App 1 are set for a maximum ring stiffeners angularity deviation of ± 1° measured between associated plating and stiffener web and ± 3° measured between stiffener web and stiffener flange.

Where maximum angularity deviation stated above is exceeded, the acceptance criteria is to be decided by the designer, and justification is to be submitted to the Society.

2.3.3 Out-of-straightness of plating

Resistance to nominal diving pressure of the pressure hull highly depends on the out-of-straightness of elementary plate panels. The out-of-straightness is to be carefully controlled and in accordance with calculation hypothesis.

Safety factors defined here below and formulae defined in Ch 2, App 1 are set for a maximum out-of-straightness of 1/200 of width of elementary plate panel, as defined in Ch 1, Sec 1, [2.4.1].

Where maximum out-of-straightness stated above is exceeded, the acceptance criteria is to be decided by the designer, and justification is to be submitted to the Society.

2.3.4 Shape deviation of convex dished ends or convex main bulkheads

Resistance to nominal diving pressure of the pressure hull highly depends on the shape deviation of the convex dished ends and the convex main bulkheads, if any, where the loads applied on these components result in compressive stress. The shape deviation of these components is to be carefully controlled and in accordance with calculation hypothesis.

Safety factors defined here below and formulae defined in Ch 2, App 1 are set for a maximum shape total amplitude of 1/2 of thickness, when measured according to Ch 2, App 1, [5.1.3].

Where maximum shape deviation stated above is exceeded, the acceptance criteria is to be decided by the designer, and justification is to be submitted to the Society.

3 Calculation

3.1 Principles

3.1.1 The following modes of collapse are to be investigated to assess the scantlings of the pressure hull:

- yielding
- buckling
- fatigue.

3.2 Frame

3.2.1 Yield strength

A linear stress analysis is to be carried out in way of the following locations:

- in way of current frame
- in way of connections between pressure hull and structure attached to it.

Stress in way of current frame are to be calculated as detailed in Ch 2, App 1 or any method deemed as equivalent by the Society. As a general rule, stress calculations for other locations are to be performed using computer assisted calculation.

3.2.2 Buckling

The three following buckling modes are to be investigated:

- Wave buckling:

  Shell plating alone is subjected to deformation, shape of stiffeners being supposed as unaffected
- Frame instability:

  Stiffeners located on cylindrical and conical parts are subjected to buckling or tripping
- General instability:

  Shell plating and reinforcements are both affected by deformations.

The buckling pressure (or depth) for which these various changes of shape may appear are to be calculated according to Ch 2, App 1 or any other method deemed as equivalent by the Society.

3.2.3 Fatigue

A fatigue analysis of the most stressed parts of the frame (as a rule, in way of connection between plating and ring stiffener) is to be performed and documented in the calculation report submitted by the designer.

3.3 Dished ends

3.3.1 Yield strength

A linear stress analysis is to be carried out in way of the following locations:

- in way of dished ends
- in way of connections between pressure hull and structure attached to it.

As a general rule, stress calculations are to be performed using computer assisted calculation.

3.3.2 Buckling

The buckling of dished ends is to be investigated for the nominal diving pressure.

The dished ends buckling pressure is to be calculated according to Ch 2, App 1 or any other method deemed as equivalent by the Society.

3.3.3 Fatigue

A fatigue analysis of the most stressed parts of the dished ends is to be performed and documented in the calculation report submitted by the designer.

3.4 Main bulkheads and cofferdams

3.4.1 The following requirements apply to main watertight bulkheads and cofferdam as defined in Ch 1, Sec 1, [2.4.5] and Ch 1, Sec 1, [2.4.6].

3.4.2 Load cases

As a general rule, bulkhead and cofferdam are to be designed considering the sole two following load cases:

- hull contraction
- flooding condition.

However, any other load which is likely to be applied on the bulkhead or cofferdam is to be considered for the scantling of bulkheads and cofferdam.

3.4.3 Design principles

For bulkhead and cofferdam, the following collapsing modes are to be considered:

- yielding failure of plate and stiffeners
- buckling of plate panel under compression.

Consequence of pressure hull contraction on bulkhead or cofferdam is to be investigated for pressure hull submitted to the nominal diving pressure.

Bulkhead and cofferdam may be designed in flooding condition to withstand a design pressure lower than the nominal diving pressure. This reduced design pressure is to be submitted and justified by the designer.

A cofferdam fitted in a ship having only one rescue area may be designed to withstand the flooding pressure only on its side opposed to the rescue area.

3.4.4 Yield strength

A linear stress analysis is to be carried out in way of the following locations:

- main bulkheads or cofferdams
- pressure hull in way of connection to main bulkheads or cofferdams.

As a general rule, stress calculations are to be performed using computer assisted calculation or other method deemed equivalent by the Society.

3.4.5 Buckling of main bulkheads or cofferdams

The buckling of main bulkheads or cofferdams is to be investigated for the various pressures inducing compression in these components.

In case of plane bulkheads or cofferdam, the buckling analysis is to be based on Euler linear elastic buckling stress.

In case of convex bulkheads submitted to in plan compression, the buckling analysis is similar to dished end. Therefore the buckling pressure is to be calculated according to Ch 2, App 1 or any other method deemed as equivalent by the Society.

3.4.6 Fatigue

A fatigue analysis of the most stressed parts of the main bulkheads and cofferdams under hull contraction is to be performed and documented in the report submitted by the designer.

3.5 Deep frames

3.5.1 Failure mode defined for usual frame in [3.2] are applicable for deep frames and must be investigated. Stress in way of deep frame and "frame instability" pressure of deep frame are to be calculated according to Ch 2, App 1 or any other method deemed as equivalent by the Society.

3.5.2 In way of deep frames, a reinforced hull plating is to be fitted.

3.6 Connecting parts

3.6.1 Connecting parts or reinforced hull plating are required in way of bulkheads, deep frame or hull discontinuity.

3.6.2 Connecting parts are to be designed and adequately tapered in order to prevent possible stress concentration.

3.6.3 A linear stress analysis is to be carried out in way of connecting parts. As a general rule, stress calculations are to be performed using computer assisted calculation.

Calculation of connecting parts is to be included in the calculation report to be submitted by the designer.

3.7 Checking criteria

3.7.1 Safety factor

The safety factor χ is the ratio of the collapse diving depth to the nominal diving depth.

3.7.2 The safety factor χ defined in [3.7.1] must not be lower than specified in Fig 1.

For values of the nominal diving pressure P_N and of the accidental transient over-submersion P_{AO}, the safety factor χ is defined from Fig 1 by linear interpolation.

3.7.3 Maximum stress

For yielding collapse mode (tensile, compressive and bending stresses), the combined Von Mises stress calculated for locations listed in [3.2.1], [3.3.1], [3.4.4] and [3.6.3] shall not exceed $R_{p0,2} / \chi$.

3.7.4 Buckling collapse pressures

"Wave buckling pressure", "Frame instability pressure" and "General instability pressure" calculated according to Ch 2, App 1 or other method deemed as equivalent by the Society must not be lower than $P_N \cdot \chi$.

3.7.5 Elastic buckling

For bulkheads and cofferdams, buckling of plate panels subjected to compressive stress, the theoretical critical elastic linear buckling stress of the plate panel is to be at least twice as the calculated stress in the plate panel.

3.7.6 Fatigue

Design number of cycles is to be taken as:

$$N = 365\ N_d\ \alpha_0\ T_{fl}$$

where:

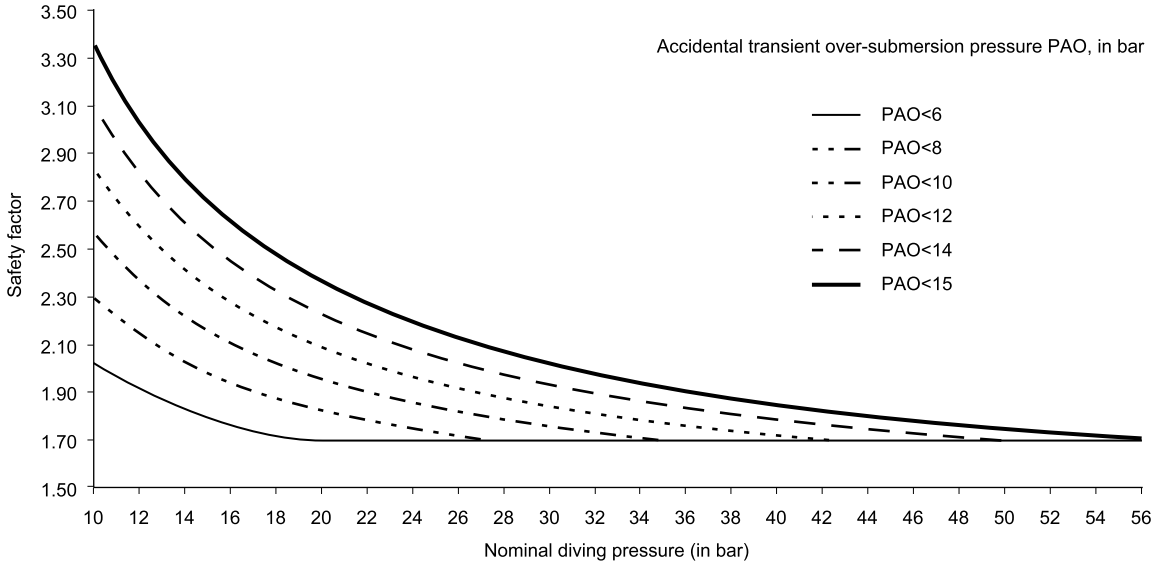
N_d : Number of dives per operating day, taken equal to 0,75 except if otherwise specified

α_0 : Sailing factor taken equal to 0,8 except if otherwise specified

T_{fl} : Design fatigue life, in years, to be taken not less than 30.

Alternative method to equivalent number of cycles calculation may be considered by the Society.

Figure 1 : Pressure hull safety factor χ



SECTION 2 HULL INTEGRITY AND PENETRATION

1 General

1.1 Application

1.1.1 The following requirements apply to reinforcements of openings of the pressure hull.

Requirements defined in Article [2] apply to reinforcement of hatch covers as defined in Ch 1, Sec 1, [2.4.8] where referring to large openings dedicated to maintenance of large equipments.

Requirements defined in Article [3] apply to reinforcement of hull penetrations.

2 Hatch covers

2.1

2.1.1 Hatch covers and the reinforcement of hatch covers are to be designed in order not to significantly modify the stress field of the pressure hull where subjected to the diving pressure.

2.1.2 Geometry of the hatch cover is to be such that the resultant force applied by the surrounding structure of the pressure hull where subjected to the diving pressure tend to close the hatch cover, however still allowing the opening of the hatch cover where in dry condition.

2.1.3 Hatch covers are to be built with the same material as the pressure hull and with a strength safety level equivalent to the one of the pressure hull. Especially, the pressure hull safety factor χ defined in Ch 2, Sec 1, [3.7.2] is applicable to hatch covers.

2.1.4 As a general rule, scantling of hatch cover is to be assessed considering the sole yield strength for the pressure hull submitted to the nominal diving pressure.

The designer is to submit to the Society a design calculation note on the hatch covers. The calculation note must show how calculations have been performed and how assessments and choices have been made at all stages of the design.

3 Hull penetration

3.1 Definition

3.1.1 Integrated hull penetration

Hull penetrations are said to be integrated where they have a diameter, ϕ, verifying:

$\phi \geq$ MIN (0,04 D ; s/2)

where:

D : Diameter of the submarine

s : Spacing between stiffeners.

3.1.2 Non integrated hull penetration

Hull penetrations are said to be non integrated if they do not comply with [3.2.1].

3.2 General principles

3.2.1 Hull penetrations are to be suitably reinforced with hull sleeves or equivalent rounded flange in order not to create any weak point on the pressure hull.

3.2.2 Hull penetrations are to be built with the same material as the pressure hull and with an equivalent safety level.

3.2.3 As a general rule, scantling of hull penetration reinforcement is to be assessed considering the sole yield strength for the pressure hull submitted to the nominal diving pressure.

3.3 Integrated hull penetration

3.3.1 Scantling of integrated hull penetration reinforcement is to be assessed by direct calculation, in general by means of computer assisted calculation, and must take into account the local geometry of the pressure hull and possible interference with surrounding structures.

3.3.2 The combined Von Mises stress in way of integrated hull penetration is not to exceed $R_{p0,2} / \chi$, where χ is the safety factor of the pressure hull defined in Ch 2, Sec 1, [3.7.2].

3.3.3 The designer is to submit to the Society the design calculation notes of integrated hull penetration reinforcements. The calculation notes must show how the calculations have been performed and how assessments and choices have been made at all stages of the design.

3.4 Non Integrated hull penetration

3.4.1 Reinforcements of non integrated hull penetrations are to comply with a recognized standard such as the CODAP or any standard agreed by the society.

3.4.2 Non integrated hull penetrations are to be spaced from each other as far as practicable.

In case where several non integrated hull penetrations are to be located not far from each other, either reinforcement by hull sleeves or a reinforced plate of increased thickness is to be fitted.

The thickness of the reinforced plate is to be such that the stress in the plate with hull penetration remains equal or lower than without hull penetration.

APPENDIX 1 SCANTLING OF EXTERNALLY PRESSURIZED VESSEL

Symbols

a : Shell plating thickness, in mm

b : Shell width in connection with the stiffeners, in mm

z_0 : Distance between the mean radius of the submarine and the neutral fibre of the stiffener considered without any associated plating, in mm

E : Young modulus, in N/mm^2

E_a : Thickness of stiffener web, in mm

E_s : Thickness of stiffener face plate, in mm

H_c : Height of stiffener, in mm

I_c : Stiffener moment about circumferential axis, in mm^4

I_z : Stiffener moment about longitudinal axis, in mm^4

L_e : Effective width of associated plating, in mm

L_s : Length of stiffener face plate, in mm

M : Length of shell between stiffeners, in mm

n : Harmonic number

P_C : Nominal collapsing pressure, in N/mm^2

P_{GI} : General instability critical pressure, in N/mm^2

P_N : Nominal diving pressure, in N/mm^2

P'_{WI} : KSRI wave instability critical pressure, in N/mm^2

$P_{WI,VM}$: Von Mises wave instability critical pressure, in N/mm^2

R' : Maximum radius of curvature of a convex dished end or convex main bulkhead, in mm

R_{int} : Internal radius of the submarine, in mm

R_m : Mean radius of the submarine, in mm

R_{HB} : Overall radius of the submarine, in mm

$R_{p0.2}$: Minimum guaranteed yield stress of steel, in N/mm^2

S : Section of the stiffener without associated plating, in mm^2, given by the following formula:

$S = (H_c - E_s)\, E_a + L_s\, E_s$

ξ : Out-of-roundness

ν : Poisson's ratio

η_f : Out-of-straightness, in mm

ζ : Shape deviation of convex dished end, in mm

θ : Angle of conical section, in °

$\sigma_{\varphi e}$: Circumferential stress on the exterior side of shell plating, in N/mm^2

$\sigma_{\varphi i}$: Circumferential stress on the interior side of shell plating, in N/mm^2

$\sigma_{\xi e}$: Longitudinal stress on the exterior side of shell plating, in N/mm^2

$\sigma_{\xi i}$: Longitudinal stress on the interior side of shell plating, in N/mm^2

$\sigma_{\varsigma M}$: Von Mises stress, in N/mm^2

σ_σ : Compressive stress in stiffener face plate, in N/mm^2.

1 General

1.1 Application

1.1.1 This Appendix presents a method to calculate the stress levels and buckling pressures of cylindrical or conical stiffened vessel under external pressure.

Associated safety factors and admissible limits are given in Pt B, Ch 2, Sec 1.

1.2 Definition of frame characteristics

1.2.1 The geometric properties of usual frame are to be taken as shown in Fig 1.

1.3 Length between support

1.3.1 Definition

The length between support L_c is a key factor for the general stability of a vessel under external pressure. This length relies on the geometry of the vessel, and is defined for several possible configurations in [1.3.2], [1.3.3], [1.3.4] and [1.3.5].

1.3.2 Length between support for a cylindrical vessel

For a cylindrical vessel, the length between support relies on the existence and position of structural bulkhead. There are three possible configurations (see Fig 2):

a) Cylindrical shell between two dished ends:

$$L_c = L_{Cylindre} + \frac{f_1 + f_2}{2}$$

b) Cylindrical shell with a dished end at one end and a structural bulkhead at the other end:

$L_c = L_{Cylindre}$

c) Cylindrical shell between two structural bulkheads:

$L_c = L_{Cylindre}$

Figure 1 : Current frame parameter

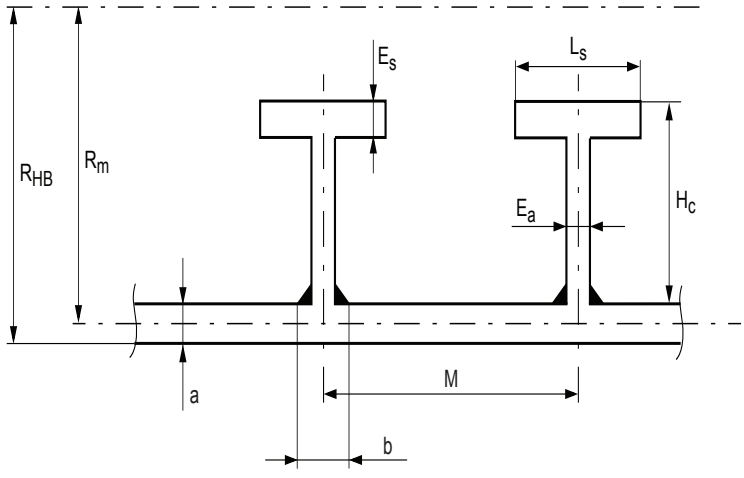
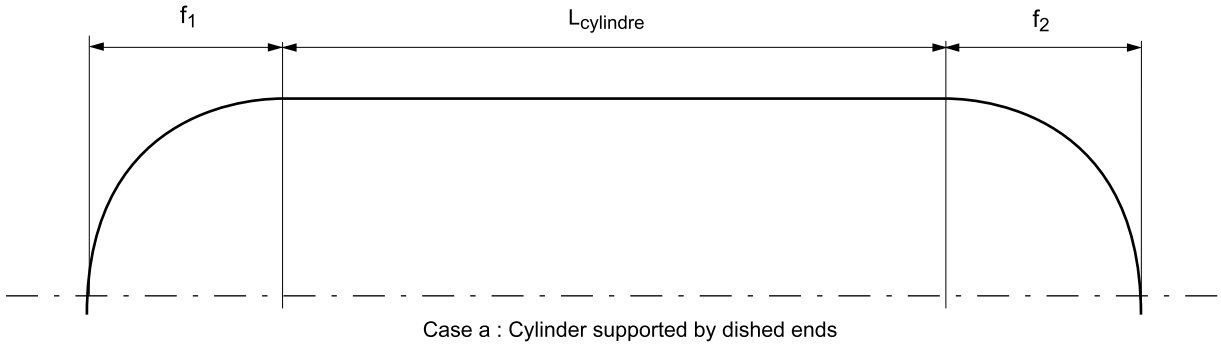
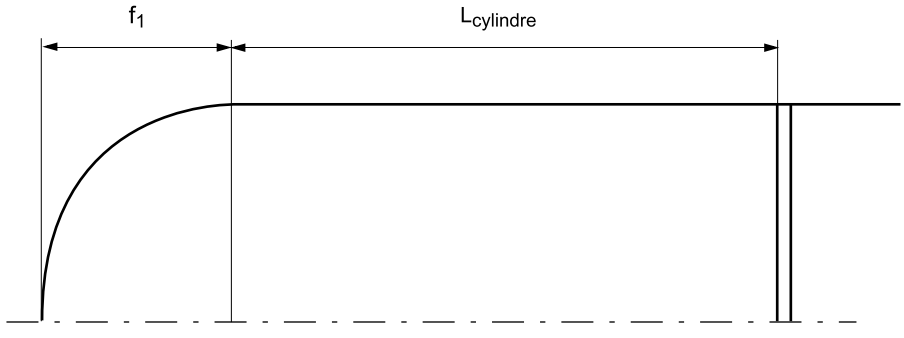


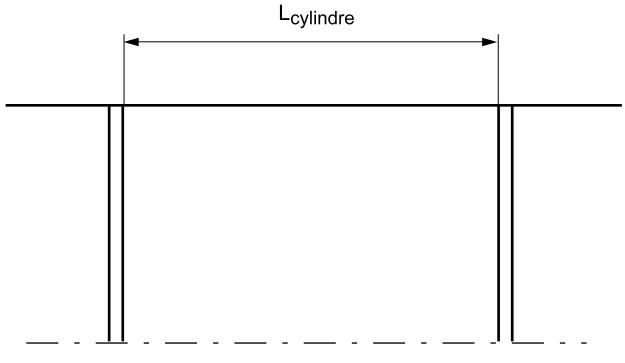
Figure 2 : Length between support for a cylindrical vessel



Case a : Cylinder supported by dished ends



Case b : Cylinder supported by a dished end at one end and a bulkhead at the other end



Case c : Cylinder supported by bulkheads

1.3.3 Length between support for a vessel with a conical part at end

In such a case, the length between support depends on the angle of the cone (see Fig 3):

a) if $\theta \geq 15°$, the cone is considered as a support, then two sections are to be considered with two associated lengths between support:

$L_c^1 = L_{Cylindre}$

$L_c^2 = L_{Cone}$

b) if $\theta < 15°$, the cone is not considered as a support then:

$$L_c = L_{Cylindre} + L_{Cone} + \frac{f_1}{2}$$

In the above definitions, $L_{Cylindre}$ is to be defined in accordance with [1.3.2].

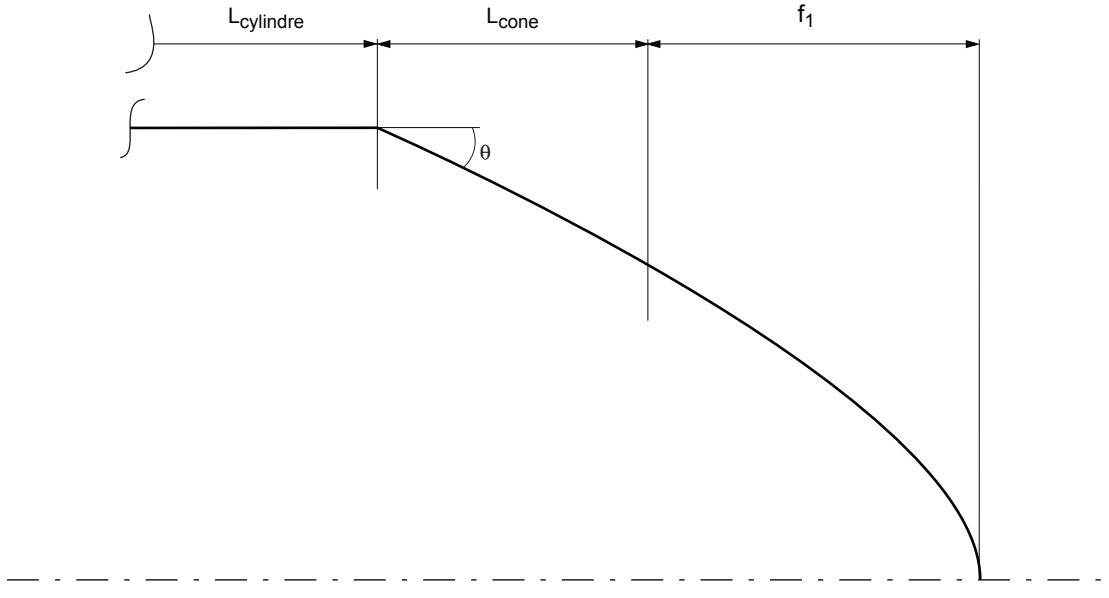
1.3.4 Length between support for a vessel with an intermediate conical part

In such a case, ends of the conical part are not considered as support and the length between support is defined as follows (see Fig 3):

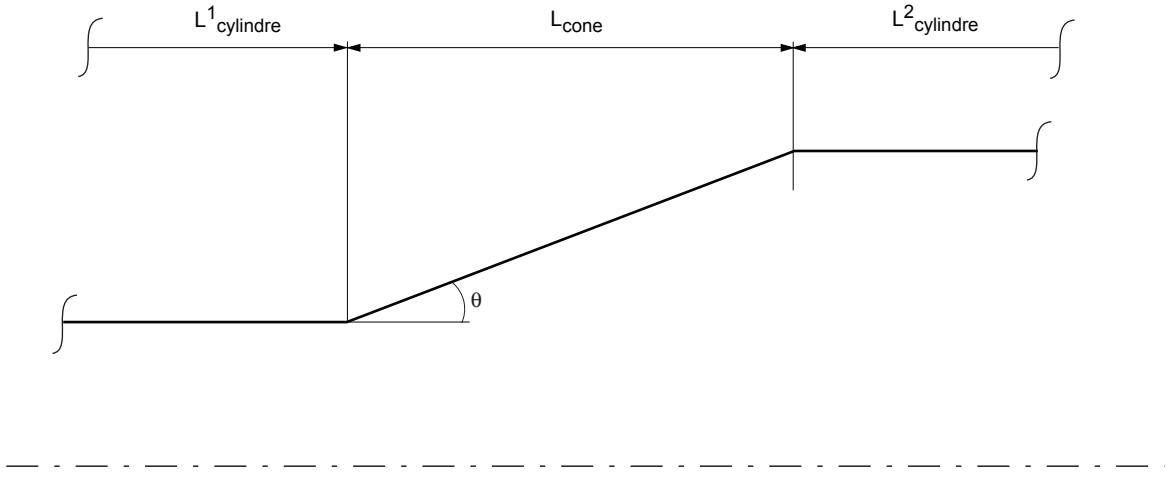
$$L_c = L^1_{Cylindre} + L_{Cone} + L^2_{Cylindre}$$

where $L^1_{Cylindre}$ and $L^2_{Cylindre}$ are to be defined in accordance with [1.3.2].

Figure 3 : Length between support for a vessel with conical parts



a : Length between support for conical part at end



b : Length between support for intermediate conical part

1.3.5 Length between support for a vessel with deep frames

Where a section of shell is fitted with deep frame, the general instability of this section is to be checked by direct calculation using computer assisted calculation. The calculation report is to be submitted to the Society for approval.

However in a preliminary design stage, the scantling of section of shell fitted with deep frame is to be checked with following formulae not considering deep frame as support. In this case the general instability critical pressure should not be less than 0,75 P_C. In a second step a direct calculation using computer assisted calculation is to be performed.

2 Cylindrical shells

2.1 Stress calculation

2.1.1 Stress in the shell plate

In cylindrical shell sustaining a pressure P, the stress in longitudinal and circumferential directions for several locations of the usual frame is defined by the following formulae, where:

- index x and φ refer respectively to longitudinal and circumferential directions
- index i and e refer respectively to the interior and exterior side of the shell plating.

At half span of the plating:

$$\sigma_{\varphi e} = -\frac{P(R_{HB}-a/2)}{a}\left[1-\left(1-\frac{\nu}{2}\right)\frac{Z}{(1+Z)(1+\alpha)}\left(\varphi-\sqrt{\frac{3\nu^2}{1-\nu^2}}\beta\right)\right]$$

$$\sigma_{\varphi i} = -\frac{P(R_{HB}-a/2)}{a}\left[1-\left(1-\frac{\nu}{2}\right)\frac{Z}{(1+Z)(1+\alpha)}\left(\varphi+\sqrt{\frac{3\nu^2}{1-\nu^2}}\beta\right)\right]$$

$$\sigma_{xe} = -\frac{P(R_{HB}-a/2)}{a}\left[\frac{1}{2}+\left(1-\frac{\nu}{2}\right)\frac{Z}{(1+Z)(1+\alpha)}\sqrt{\frac{3}{1-\nu^2}}\beta\right]$$

$$\sigma_{xi} = -\frac{P(R_{HB}-a/2)}{a}\left[\frac{1}{2}-\left(1-\frac{\nu}{2}\right)\frac{Z}{(1+Z)(1+\alpha)}\sqrt{\frac{3}{1-\nu^2}}\beta\right]$$

In way of the stiffener:

$$\sigma_{\varphi e} = -\frac{P(R_{HB}-a/2)}{a}\left[1-\left(1-\frac{\nu}{2}\right)\frac{Z}{(1+Z)(1+\alpha)}\left(1+\sqrt{\frac{3\nu^2}{1-\nu^2}}\gamma\right)\right]$$

$$\sigma_{\varphi i} = -\frac{P(R_{HB}-a/2)}{a}\left[1-\left(1-\frac{\nu}{2}\right)\frac{Z}{(1+Z)(1+\alpha)}\left(1-\sqrt{\frac{3\nu^2}{1-\nu^2}}\gamma\right)\right]$$

$$\sigma_{xe} = -\frac{P(R_{HB}-a/2)}{a}\left[\frac{1}{2}-\left(1-\frac{\nu}{2}\right)\frac{Z}{(1+Z)(1+\alpha)}\sqrt{\frac{3}{1-\nu^2}}\gamma\right]$$

$$\sigma_{xi} = -\frac{P(R_{HB}-a/2)}{a}\left[\frac{1}{2}+\left(1-\frac{\nu}{2}\right)\frac{Z}{(1+Z)(1+\alpha)}\sqrt{\frac{3}{1-\nu^2}}\gamma\right]$$

with:

$$\alpha = \frac{\sqrt{K_1K_2}}{\sqrt[4]{3(1-\nu^2)}}\frac{(\cosh(U)-\cos(V))}{(\sqrt{K_1}\sinh(U)+\sqrt{K_2}\sin(V))}\frac{\sqrt{a(R_{HB}-a/2)}}{E_a(1+Z)}$$

$$\beta = \frac{\sqrt{K_2}\cosh(U/2)\sin(V/2)-\sqrt{K_1}\sinh(U/2)\cos(V/2)}{\sqrt{K_1}\cosh(U/2)\sinh(U/2)+\sqrt{K_2}\cos(V/2)\sin(V/2)}$$

$$\gamma = \frac{\sqrt{K_1}\sinh(U)-\sqrt{K_2}\sin(V)}{\sqrt{K_1}\sinh(U)+\sqrt{K_2}\sin(V)}$$

$$\varphi = \frac{\sqrt{K_2}\cosh(U/2)\sin(V/2)+\sqrt{K_1}\sinh(U/2)\cos(V/2)}{\sqrt{K_1}\cosh(U/2)\sinh(U/2)+\sqrt{K_2}\cos(V/2)\sin(V/2)}$$

$$V = X\sqrt{K_1}$$

$$U = X\sqrt{K_2}$$

$$X = \sqrt[4]{\frac{\sqrt{3(1-\nu^2)}}{(R_{HB}-a/2)a}}L_1$$

$$L_1 = M-2E_a$$

$$K_1 = 1+\frac{R_{HB}-a/2}{a}\lambda\sqrt{3(1-\nu^2)}$$

$$K_2 = 1-\frac{R_{HB}-a/2}{a}\lambda\sqrt{3(1-\nu^2)}$$

$$\lambda = \frac{P(R_{HB}-a/2)}{2Ea}$$

$$Z = \frac{S}{ab} = \frac{S}{2E_aa}$$

2.1.2 Von Mises stress

The control of the stress level in the plating with the safety factor defined in Ch 2, Sec 1, [3.7.1] is to be performed on the Von Mises stress evaluated from stress in longitudinal and circumferential directions, as follows:

$$\sigma_{VM} = \sqrt{\sigma_x^2+\sigma_\varphi^2-\sigma_x\sigma_\varphi}$$

2.1.3 Stress in the stiffeners

In the stiffener face plate, the compressive stress can be evaluated by the following formula, where intermediate variables are defined in [2.1.1]:

$$\sigma_S = -\frac{P(R_{HB}-a/2)}{a}\left(1-\frac{Z}{(1+Z)(1+\alpha)}\right)\left(1-\frac{\nu}{2}\right)$$

As the face plate of stiffener is only subjected to circumferential compressive stress, the control of stress level can be done directly on the stress value given by above formula.

2.2 Buckling

2.2.1 General instability

For each section of a submarine between two supports, the general instability critical pressure is to be calculated by the following formula with the associated length between support L_c defined as prescribed in [1.3]:

$$p_{GI} = \frac{Ea}{R_m}\cdot\frac{1}{\left[n^2-1+\frac{1}{2}\left(\frac{\pi R_m}{L_c}\right)^2\right]\left[1+n^2\left(\frac{L_c}{\pi R_m}\right)^2\right]^2}+\frac{(n^2-1)}{R_g^2\,R_{int}M}EI_C$$

The general instability critical buckling pressure given by the above formula relies on the number of buckling waves or harmonic number, n. As a general rule, n is to be taken between 2 and 20.

In the above formula, I_c is the frame moment of inertia to be calculated considering an effective width of associated plating L_e given by the formula below and R_g is the radius taken at the centre of gravity of the stiffener considered with the associated plate of width L_e.

$$L_e = 1,556\frac{\sqrt{R_m a}}{\sqrt{\sqrt{\left[1+\frac{n^4}{2}\left(\frac{a}{R_m}\right)^2\right]}+\frac{n^2}{\sqrt{3}}\frac{a}{R_m}}}N$$

$$N = \frac{\cosh(\beta)-\cos(\beta)}{\sinh(\beta)+\sin(\beta)}$$

$$\beta = \sqrt[4]{3(1-\nu^2)}\frac{M-E_a}{\sqrt{R_m a}}$$

2.2.2 General instability considering out-of-roundness

Formula in [2.2.1] is applicable only for an ideal cylinder vessel with no shape deviation. The general instability critical buckling pressure p_{GI}, taking account of a given out-of-roundness ξ is the smallest positive root of the following polynomial equation:

$$\frac{|\sigma_s(p_c)|}{p_c}x_n^2-\left(\frac{|\sigma_s(p_c)|}{p_c}p_n+\frac{Ed\xi(n^2-1)}{R_m}+R_{p0,2}\right)x_n+R_{p0,2}p_{GI}=0$$

where:

x_n : Unknown of the equation

$\sigma_s(p_c)$: Compressive stress in the stiffener face plate for the nominal collapse diving pressure p_c, to be calculated according to [2.1.3]

d : Length between the outer side of the face plate of the stiffeners and the gravity centre of the stiffeners calculated with the effective width of associated plating L_e defined in [2.2.1]

p_{GI} : General instability critical pressure, as defined in [2.2.1].

At a design stage, here above equation is to be solved considering a default out-of-roundness level ξ taken equal to the maximum acceptable out-of-roundness.

2.2.3 General instability for an unstiffened cylinder

For an unstiffened cylinder, the general instability critical buckling pressure P_{GI} can be evaluated by the following Von Mises formula:

$$P_{GI} = \frac{Ea}{R_{HB}\left(n^2+\frac{\eta^2}{2}-1\right)}\left[\frac{\eta^4}{(n^2+\eta^2)^2}+\frac{a^2(n^2-1+\eta^2)^2}{12(1-\nu^2)R_{HB}^2}\right]$$

where:

$$\eta = \frac{\pi R_{HB}}{L_c}$$

2.2.4 Wave buckling - Formulae with out-of-straightness

As a general rule, the critical wave buckling pressure p_{WI} is to be calculated by the KSRI formulae given here below.

KRSI formulae take into account the shell out-of-straightness. At a design stage, those formulae are to be applied with a default out-of-straightness η_f taken equal to the maximum acceptable out-of-straightness:

$$\eta_f = \frac{M}{200}$$

However KRSI formulae are applicable only if $\sigma > 1$. Where this criterion is not verified, the critical wave buckling pressure is to be calculated by the Von Mises formula given in [2.2.5].

$$p'_{WI} = \eta p_{WI}$$

$$p_{WI} = \frac{E}{k_2^0(n^2-1)+\frac{\alpha^2}{2}}\left[\frac{a}{R_m}\frac{\alpha^4}{(n^2+\alpha^2)^2}+\frac{a^3}{12(1-\nu^2)R_m^3}(n^2-1+\alpha^2)^2\right]$$

$$\alpha = \frac{\pi R_m}{M}$$

$$u = \frac{1}{2}\sqrt[4]{3(1-\nu^2)}\frac{M}{\sqrt{R_m a}}$$

$$k_2^0 = 1-\frac{(2-\nu)}{1+\bar{\beta}_0 F_1(u)}\frac{u_1\cosh(u_1)\sin(u_2)+u_2\sinh(u_1)\cos(u_2)}{u_2\sinh(2u_1)+u_1\sin(2u_2)}$$

$$\bar{\beta}_0 = \frac{Ma}{S}\left(1-\frac{z_0}{R_m}\right)$$

$$F_1(u) = \sqrt{1-\gamma^2}\frac{\cosh(2u_1)-\cos(2u_2)}{u_2\sinh(2u_1)+u_1\sin(2u_2)}$$

$$\gamma = \frac{1}{2u}$$

$$u_1 = u\sqrt{1-\gamma}$$

$$u_2 = u\sqrt{1+\gamma}$$

$$\eta = \frac{f_1 f_2}{f_3}\cdot\frac{1}{1+\bar{a}\bar{f}_0^{\bar{n}}}$$

$$\bar{f}_0 = \frac{\eta_f}{a}$$

$$f_1 = 1-(0,04u-0,01)\frac{R_m}{100a}$$

$$f_2 = 0,828+0,148(u-1,5)^2+0,025(\beta-2)$$

$$\beta = \frac{Ma}{S}$$

$$f_3 = 1+0,835(\bar{\sigma}-1)^{1,11}$$

$$\bar{a} = 0,542+0,959\bar{\sigma}-0,201\bar{\sigma}^2$$

$$\bar{n} = 0,108+0,569\bar{\sigma}-0,091\bar{\sigma}^2$$

$$\bar{\sigma} = \frac{p_{WI}R_m k_2^0}{1,15aR_{p0,2}}$$

2.2.5 Wave buckling - Von Mises formula

The Von Mises formula defined here below is to be applied to assess the critical wave buckling pressure in case the KRSI formulae are not applicable.

In such a case, the critical wave buckling pressure to be compared with the nominal collapsing pressure is half the pressure given by the following formula:

$$p_{WI,VM} = \frac{Ea}{R_m\left(n^2 - 1 + \frac{\lambda^2}{2}\right)}\left[\frac{1}{\left(1 + \frac{n^2}{\lambda^2}\right)^2} + \frac{a^2(n^2 - 1 + \lambda^2)^2}{12R_m^2(1 - \nu^2)}\right]$$

with: $\lambda = \frac{\pi R_m}{M}$

2.2.6 Frame instability

Frame instability is due to one of the two phenomena:

- buckling of stiffener web
- tripping of stiffener face plate.

The buckling of stiffener web is considered as not possible if the ratio of the web height to the web thickness complies with the following criterion:

$$\frac{H_C - E_S}{E_a} \leq \sqrt{\frac{1,28E\pi^2}{12(1-\nu^2)R_{p0,2}}}$$

The tripping of stiffener face plate is considered as not possible if the stiffener complies with the following criterion:

$$\frac{EI_z}{R_{p0,2}R_{int}ZA_S} > 0,5$$

where:

I_z : Inertia of stiffener without associated plate, in mm^4, evaluated as follows:

$$I_z = \frac{E_s L_s^3 + (H_c - E_s)E_a^3}{12}$$

Z : Distance, in mm, between the neutral fibre of the stiffener without associated plate and the point where the web of the stiffener and the plating are connected.

3 Conical shell

3.1 Application

3.1.1 For conical shell located either at one end of the vessel or in the middle of the vessel, the formulae given in Article [2] can be used to check the scantling of plates and stiffeners, provided input parameters such as R, M, L_c, etc, are adequately adjusted.

How to adjust these parameters for conical shell is defined in [3.2].

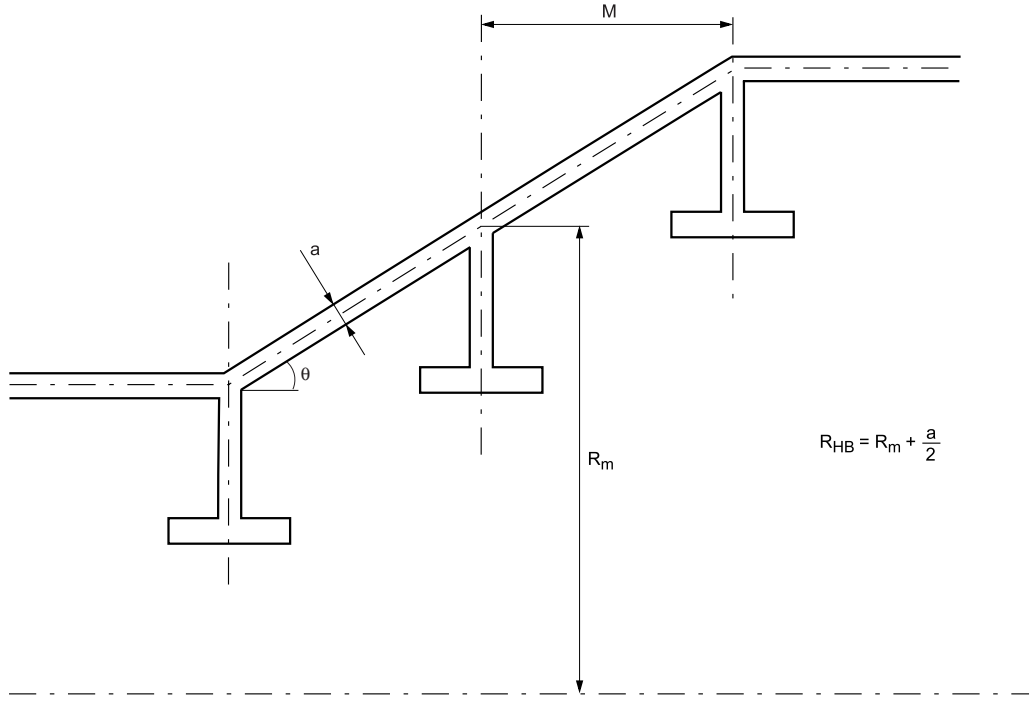
3.2 Calculation

3.2.1 General instability

For conical section or section containing a conical part, the general instability is to be checked by direct calculation using computer assisted calculation. The calculation report is to be submitted to the Society for approval.

However in a preliminary design stage, the general instability can be checked with the formulae given in [2.2.1] or [2.2.2], considering a length between support as defined in [1.3] and the maximum diameter of the conical part. In a second step, a direct calculation using computer assisted calculation is to be performed.

Figure 4 : Frame parameter for a conical part



3.2.2 Stress level, wave instability and frame instability

In conical parts, the stress level, wave instability and frame instability are to be checked by direct calculation using computer assisted calculation. The calculation report is to be submitted to the Society for approval.

However, in a preliminary design stage, stress level, wave instability critical pressure and frame instability critical pressure can be evaluated with the formulae given in Article [2], provided the following parameters R_m , R_{HB} and M are taken as shown in Fig 4. In a second step, a direct calculation using computer assisted calculation is to be performed.

4 Dished ends

4.1 Application

4.1.1 The formulae given in [4.2] for stress and critical buckling pressure are applicable to convex dished ends and convex main bulkheads if submitted to compressive stress.

4.2 Calculation

4.2.1 Stress

The stress in a convex dished end or convex main bulkhead under compressive stress is given by the following formula, where R' is the maximum radius of curvature of the dished end or main bulkhead:

$$\sigma = \frac{PR'}{2a}$$

4.2.2 Buckling

The critical buckling pressure P_c of a convex dished end or convex main bulkhead is given by the following formula:

$$P_c = kE\left(\frac{a}{R'}\right)^2$$

where:

k : k = 0,293 if the shape deviation complies with Ch 2, Sec 1, [2.3.4].

For higher shape deviation, k is to be submitted by designer and duly justified.

In addition to the criteria defined in Pt B, Ch 2, Sec 1, it is to be controlled that the buckling may not take place in the yielding domain which is guaranteed if the convex dished end or convex main bulkhead comply with the following criterion:

$$\frac{a}{R'} \leq 4,55\frac{R_{p0,2}}{E}$$

5 Shape deviation measurement

5.1 Definition

5.1.1 Out-of-roundness

The out-of-roundness ξ used in the above formulae is defined as the maximum ratio of the distance between the theoretical and as-built neutral axes to the mean radius of the shell (see Fig 5):

$$\xi = \frac{\text{Max}\left(\left|R_m^{asbuilt} - R_m^{theoretical}\right|\right)}{R_m^{theoretical}}$$

The out-of-roundness is to comply with the criteria defined in Ch 2, Sec 1, [2.3.1].

5.1.2 Out-of-straightness

The out-of-straightness η_f used in the above formulae is defined as the maximum distance, in mm, between the theoretical and as-built neutral axes on a width of side shell between two stiffeners (see Fig 6).

The out-of-straightness is to comply with the criteria defined in Ch 2, Sec 1, [2.3.1].

5.1.3 Shape deviation of convex dished end

The shape deviation of convex dished end ζ used in the above formulae is defined as the maximum distance, in mm, between the theoretical and as-built neutral axes on the dished end (see Fig 7).

The shape deviation of convex dished end is to comply with the criteria defined in Ch 2, Sec 1, [2.3.1].

5.2 Measurement

5.2.1 Measurement procedure of shape deviation is to be submitted for approval and duly justified by the designer on the basis of yard experience feedback.

Figure 5 : Out-of-roundness ξ

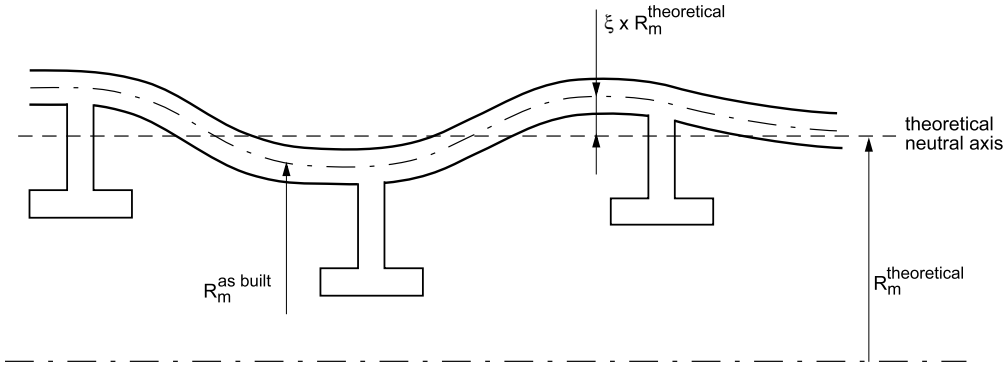


Figure 6 : Out-of-straightness η

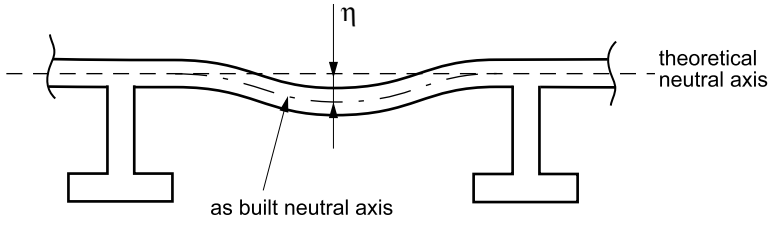
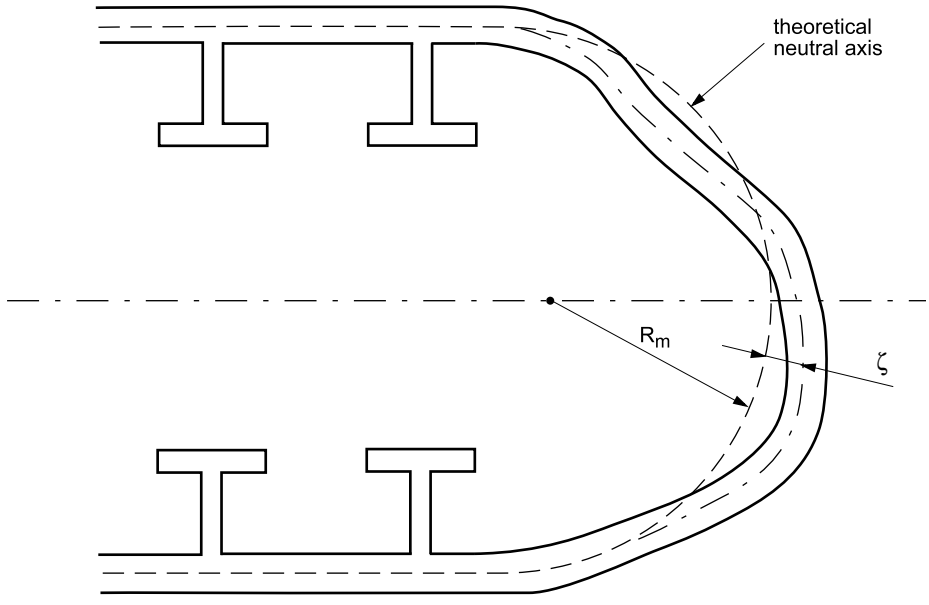


Figure 7 : Shape deviation of convex dished end ζ



Part C
Pressure Hull and Structures

Chapter 3
RESISTING STRUCTURES

SECTION 1 GENERAL

SECTION 2 TYPICAL RESISTING STRUCTURES

SECTION 1 GENERAL

1 Definition and classification principles

1.1 Application

1.1.1 The following requirements apply to resisting structures as defined in Ch 1, Sec 1, [2.3.2].

1.1.2 Requirements of this Section are general requirements applicable to all resisting structures. Additional specific requirements for some typical resisting structures are given in Ch 3, Sec 2.

1.2 Review principles

1.2.1 Resisting structures are to be designed in accordance with design principles defined in Article [2] and are to comply with the checking criteria defined in Article [3].

1.2.2 For each resisting structure, the designer is to submit to the Society a calculation report on which the design of resisting structures is based. Submitted documents are to clearly specify:

- main data of the resisting structures
- operational and environmental conditions of the resisting structures
- loading cases considered
- modes of collapse investigated
- results of calculation.

1.2.3 Whenever scantling calculations are computer assisted, input and output data and any other relevant information allowing to check the validity of calculation are to be submitted. For computer programs on which sufficient experience has not been gained, a reference file is to be submitted.

2 Design principles

2.1 Loads

2.1.1 As a general rule, resisting structures are to be designed in order to withstand the nominal diving pressure, P_N. However, resisting structures which are not permanently exposed to the diving pressure may be designed to withstand a given pressure lower than the nominal diving pressure. In this case, the design pressure is to be submitted by the designer and clearly specified in the calculation report.

2.1.2 In addition to [2.1.1], any other load deemed relevant in view of the operational and environmental conditions of the resisting structure is to be taken in account.

2.2 Resisting structures connected to pressure hull

2.2.1 For resisting structures connected directly to the pressure hull, care is to be taken to minimize stress concentration in way of the connection.

2.2.2 For resisting structures connected directly to the pressure hull, stress induced by the hull contraction is to be considered in addition of the loads defined in [2.1].

2.3 General design features

2.3.1 As a general rule, resisting structures are to be designed with an equivalent safety level as the pressure hull.

2.3.2 Any mode of collapse deemed relevant by the Society must be investigated. For typical resisting structures, modes of collapse to be investigated are defined in Ch 3, Sec 2.

3 Scantling calculation

3.1 Checking criteria

3.1.1 Stress in resisting structures shall not exceed $R_{p0,2} / \chi$, where χ is the safety factor of the pressure hull defined in Ch 2, Sec 1, [3.7.2].

3.1.2 In way of structural details, stress higher than $R_{p0,2} / \chi$ may be accepted by the Society provided that:

- area affected by stress above $R_{p0,2} / \chi$ is limited in size
- peak stress level remains lower than 0,8 times the yield stress

- a fatigue analysis of the detail is performed according to [3.1.3].

For computer assisted calculation (i.e. trough finite elements), stress over $R_{p0,2} / \chi$ can be accepted provided it is due to a local mesh singularity.

3.1.3 For fatigue analysis of resisting structure details, the design cycle number is to be taken as given in Pt C, chap 1, Sec 1, [3.7.6].

3.1.4 Where resisting structures are made of plate panels subjected to compressive stress, linear elastic buckling of such plate panels is to be investigated. A safety factor not lower than 2,0 is to be applied.

SECTION 2 TYPICAL RESISTING STRUCTURES

1 Weapon launching tube

1.1 Application

1.1.1 The following requirements apply to cylindrical weapon launching tube located outside of the pressure hull, and fixed at one end on the fore dished end of the pressure hull. Other arrangements will be considered by the Society on a case-by-case basis.

1.2 Design principles

1.2.1 Weapon launching tube are to be designed to withstand the nominal diving pressure with an equivalent safety level as the pressure hull.

1.2.2 If equipments are fixed on the weapon launching tube, weight of those equipments is to be taken in account for the design of the weapon launching tube.

1.2.3 Weapon launching tube can be considered as externally pressurized structure. Therefore, in addition to the general modes of collapse listed in Ch 3, Sec 1, buckling under nominal diving pressure is to be investigated.

1.2.4 Weapon launching tube can be generally considered as unstiffened cylinder under external pressure. In such case the critical buckling pressure can be evaluated with the formula given in Ch 2, App 1, [2.2.3].

1.2.5 Buckling pressures calculated for weapon launching tube are to comply with pressure hull criteria defined in Ch 2, Sec 1, [3.7].

2 Capacities

2.1 Internal capacities

2.1.1 Application

The following requirements apply to capacities located into the pressure hull and subjected to the diving pressure on their inner side.

2.1.2 Loads

Design of internal capacities is to be such as to support the three following load cases:

- hull contraction
- testing condition
- loads due to any operational condition likely to occur.

2.1.3 Calculation

Hull contraction is to be investigated considering the submarine submitted to the nominal diving pressure. Induced stress is to be lower than $R_{p0,2} / \chi$, where χ is the safety factor of the pressure hull defined in Ch 2, Sec 1, [3.7.2].

Stress under testing condition is to be calculated considering 1,2 P_T, where P_T is the test pressure of the capacity to be given by the designer and not lower than the value given in Ch 7, Sec 3, [3]. Induced stress is to be lower than $R_{p0,2}$.

Loads and associated checking criteria due to particular operating conditions are to be submitted by the designer and duly justified.

2.1.4 Collapse modes

As a general rule, scantling of internal capacities can be assessed by the sole evaluation by a sole yielding check. Nevertheless, if deemed necessary by the Society, collapse under buckling instability may possibly be investigated for internal capacities not free to expand.

2.2 External capacities

2.2.1 Application

The following requirements apply to capacities located outside of the pressure hull and subjected to the diving pressure on their outer side.

2.2.2 Loads

As a general rule, external capacities are to be designed to withstand the nominal diving pressure with a safety level equivalent to the pressure hull.

However, where operational or environmental conditions induce other non negligible loads, the latter have to be considered to design external capacities.

2.2.3 Collapse modes

Where subjected to the nominal diving pressure, external capacities are likely to collapse under one the following failure modes which must be investigated:

- yielding
- buckling instability
- fatigue failure.

2.2.4 Calculation

Stress levels and buckling pressures of internal capacities are to be checked by direct calculation using computer assisted calculation. The calculation report is to be submitted to the Society for approval.

However in a preliminary design stage, stress level and buckling pressure of internal capacities can be evaluated with formulas adapted to their geometry. For example stress levels and buckling pressures of stiffened cylindrical shell shaped capacities can be calculated with formulae given in Pt D, Ch 3, App 1.

In a second step, a direct calculation using computer assisted calculation is to be performed.

2.2.5 Stress and buckling pressures calculated for external capacities are to comply with pressure hull criteria defined in Ch 2, Sec 1, [3.7].

3 Collective rescue platform

3.1 Application

3.1.1 The following requirements apply to platform located on the pressure hull and dedicated for the berthing alongside of a rescue device.

3.2 Loads and applicable Rules

3.2.1 Design and scantling of the collective rescue platform are to be such as to fulfil the two following functions:

- supporting hull contraction
- providing reinforcements for associated hull penetration.

Scantling of collective rescue platform is to be assessed by direct calculation (i.e. by mean of computer assisted calculations) considering the pressure hull submitted to the nominal diving pressure.

The resulting stress level is to be lower than $R_{p0,2} / \chi$, where χ is the safety factor of the pressure hull defined in Ch 2, Sec 1, [3.7.2].

3.2.2 In addition, the collective rescue platform is to comply with all requirements of applicable standard for the berthing alongside of the rescue device.

Information on forecasted rescue device and reference to applicable rules are to be submitted to the Society.

Part C
Pressure Hull and Structures

Chapter 4
EXOSTRUCTURE

SECTION 1 GENERAL

SECTION 2 TYPICAL EXOSTRUCTURES

SECTION 1 GENERAL

1 Application and classification principles

1.1 Application

1.1.1 The following requirements apply to exostructure as defined in Ch 1, Sec 1, [2.3.3].

1.1.2 Requirements of this Section are general requirements applicable to all exostructures. Additional specific requirements for some typical exostructures are given in Ch 4, Sec 2.

1.2 Review principles

1.2.1 Exostructures are to be designed in accordance with the design principles defined in Article [2] and are to comply with the checking criteria defined in Article [3].

1.2.2 For exostructures or parts of exostructure which scantling cannot be determined by direct calculation of by three-dimensional beam model, the designer is to submit to the Society a calculation report on which the structure is based. Submitted documents are to clearly specify:

- main data of the exostructures
- input and output data of the calculation
- loading cases considered
- collapsing modes investigated.

2 Design principles

2.1 General design features

2.1.1 All exostructure parts and volumes are to be free flooding spaces and provided with adequate opening allowing a complete flooding, venting and inspection of those areas.

2.1.2 Size and number of external appendages of exostructures are to be limited to the minimum compatible with the submarine safe operation.

2.1.3 Openings in exostructures shell are to be reduced to the minimum compatible with the safe operation of submarine and are to be adequately reinforced.

2.2 Exostructure attached to pressure hull

2.2.1 For exostructures attached directly to the pressure hull, care is to be taken to minimize stress concentration in way of the connection.

2.2.2 For exostructures attached directly to the pressure hull, stress induced by the hull contraction is to be considered in addition of the loads defined in [2.3].

2.2.3 Exostructures attached directly to the pressure hull are to be designed to prevent any damage to the pressure hull in the event they are crushed.

2.3 Loads

2.3.1 Any load or combination of loads defined in Ch 1, Sec 3 likely to exert on exostructures is to be considered for the scantling of exostructures.

2.3.2 For equipments supported by exostructures, inertial forces induced by the submarine acceleration are to be considered by applying a factor 2 to the weight of the supported equipment.

3 Scantling calculation

3.1 Checking criteria

3.1.1 Stress in exostructures shall not exceed 2/3 $R_{p0,2}$ for all load case considered.

3.1.2 In way of structural details, stress higher than 2/3 $R_{p0,2}$ may be accepted by the Society provided that:

- area affected by stress above 2/3 $R_{p0,2}$ is limited in size
- peak stress level remains lower than 0,8 times the yield stress

- a fatigue analysis of the detail is performed according to [3.1.3].

For computer assisted calculation (i.e. trough finite elements), stress over $R_{p0,2} / \chi$ can be accepted provided it is due to a local mesh singularity.

3.1.3 For fatigue analysis of exostructure details, the design cycle number is to be taken as given in Pt C, chap 1, Sec 1, [3.7.6].

3.1.4 Where exostructures are made of plate panels subjected to compressive stress, linear elastic buckling of those plate panels is to be investigated. A safety factor not lower than 1,2 is generally to be applied. For structures whose buckling collapse may lead to additional failure of surrounding structure, a safety factor of 3,0 is to be applied.

SECTION 2 TYPICAL EXOSTRUCTURES

1 Typical exostructures

1.1 Bridge fin

1.1.1 The bridge fin is to be designed to accommodate and support mast, access trunk and the outer navigation bridge.

1.1.2 As a general rule, the bridge fin is only submitted to green seas loads and weight or reaction of equipment connected to it.

1.1.3 If trimming fin are fitted on the bridge fin, the latter is to be adequately reinforced in way of the connection with trimming fin in order to support induced efforts.

Those efforts are to be calculated as specified in Ch 6, Sec 1, [2].

1.2 Fore end

1.2.1 The submarine fore end is generally designed to provide a hull geometrical continuity and to accommodate and support antenna, anchoring line and any other equipment located in the fore end.

1.2.2 Connection of the fore end with pressure hull structure is to be designed to reduce the risk of damage to the pressure hull in the case of front collision.

1.2.3 As a general rule, the fore end shell is to be designed considering only the following loads:

- wave and green seas loads
- water resistance.

Structure located into the fore end are to be designed considering the weight of supported equipment and associated inertial forces.

1.3 Aft end

1.3.1 Aft end is generally designed to provide a hull geometrical continuity and to support steering and trimming devices, shaft line and other equipment likely to be fitted in the aft end.

1.3.2 As a general rule, the aft end is to be designed considering the following loads:

- wave and green seas loads
- shaft bearing load
- efforts induced by trimming and steering devices.

1.4 Exposed deck

1.4.1 The submarine exposed deck is generally designed to provide a geometrical hull continuity and to accommodate equipment located immediately above the pressure hull.

1.4.2 As a general rule, the exposed deck is to be designed considering only the wave and green seas loads.

2 Typical exostructure equipment

2.1 Ballast

2.1.1 Ballast designed for normal blowing

Ballast designed for normal blowing are to be designed to withstand the blowing pressure for normal blowing and the hull contraction at accidental diving depth considered independently.

2.1.2 Ballast designed for emergency blowing

Ballast designed for emergency blowing are to be designed to withstand the combination of:

a) the blowing pressure for emergency blowing and the hull contraction at accidental diving depth

b) the blowing pressure for emergency blowing and the hull contraction at nominal diving depth.

Stress level under combination of emergency blowing and hull contraction is to be lower than:

- $R_{p0.2}$ for case a) above
- $R_{p0.2} / 1,2$ for case b) above.

2.2 Mooring, towing and anchoring equipment

2.2.1 Mooring, towing and anchoring points located on the exostructure are to be reinforced to support the duty pull load evaluated as specified in Pt F, Ch 1, Sec 5, [2.2] and Ch 6, Sec 2, [3.2] for the most severe conditions.

Part C
Pressure Hull and Structures

Chapter 5
NON-RESISTING STRUCTURES

SECTION 1 DECK AND SUSPENDED DECK

SECTION 2 SEATING

SECTION 3 OTHER NON-RESISTING STRUCTURES

SECTION 1 DECK AND SUSPENDED DECK

1 Application

1.1 Application

1.1.1 The following requirements apply to deck and suspended deck as defined in Ch 1, Sec 1, [2.5.7].

1.2 Scope of classification

1.2.1 Requirements here below concern only the structural resistance of deck and suspended deck in normal operation and normal condition. In particular, acoustic discretion and shock resistance are outside the scope of classification.

2 Loads and design principles

2.1 Loads

2.1.1 As a rule, the design pressures to be considered for the assessment of the scantling of deck and suspended deck are to be taken as uniform in each compartment of the cradle.

For one compartment, the design pressure is to be evaluated in view of the forecasted equipment to be fitted in the compartment.

2.1.2 The designer is to submit to the Society the designation of each compartment on the deck or suspended deck and the associated design pressure.

At a preliminary design stage, where the detail and weight of equipment in each compartment is not known, the scantling of deck and suspended deck can be assessed with the default design pressures defined in Ch 1, Sec 3, [2.3.1].

2.1.3 Motions of the submarine are to be taken into account by adding inertial pressures to the design pressures. Inertial pressures are to be evaluated considering a vertical acceleration equal to 2 g. Transversal and longitudinal accelerations can be disregarded.

2.2 Design principles

2.2.1 Deck and suspended deck are to be made of steel and are to comply with the applicable requirements defined in Ch 1, Sec 2.

2.2.2 Heavy concentrated loads to be supported by deck and suspended deck are to be fitted in way of supporting elements such as beam or pillar.

2.2.3 The suspended deck structure is to be designed in order not to create any stress concentration in way of their support.

3 Checking criteria

3.1 Principles

3.1.1 As a rule, scantling of deck and suspended deck can be assessed by a sole yielding evaluation.

However, where deemed necessary by the Society, linear elastic buckling of supporting elements under compression is to be investigated.

3.2 Safety factors

3.2.1 The combined Von Mises stress in deck and suspended deck shall not exceed $2/3\ R_{p0,2}$.

SECTION 2 SEATING

1 General principles

1.1 Application

1.1.1 The following requirements apply to seatings dedicated to support heavy equipment. Seatings can be located either on the pressure hull or on cradles.

1.2 Loads

1.2.1 As a rule, seatings are submitted to the sole weight of the equipment they are supporting.

In addition, motions of the submarine are to be taken into account by adding inertial loads. Inertial loads are to be evaluated considering a vertical acceleration equal to 2 g. Transversal and longitudinal acceleration can be disregarded.

1.2.2 For each seating, the designer is to submit to the Society the weight of the supported equipment.

For seatings of cradles, the weight of each cradle is to be determined from the steel weight of the cradle and the design pressures of each compartment.

1.2.3 For large equipment supported by several seatings, the weight of the equipment is to be considered as equally distributed on all the seatings.

However, in case where seatings are not equally spaced, and if deemed necessary by the Society, the actual weight supported by each seating is to be considered.

1.3 Design principles

1.3.1 Geometry and scantling of the seating and its surrounding structure are to be such as not to create any stress concentration.

1.3.2 The support area, defined as the surface where there is a contact between the seating and the supported equipment is to be as large as possible.

1.3.3 Seating located on the pressure hull are to be fitted in line with the of web of stiffeners. Seating located in way of pressure hull plating can be accepted for seatings not supporting heavy equipment and will be considered by the Society on a case-by-case basis.

1.3.4 Seatings located on the pressure hull are to be designed to support the contraction of the pressure hull. The interaction between seatings and the contraction of the pressure hull is to be investigated for the pressure hull submitted to the nominal diving pressure.

2 Scantling of seating

2.1 Yielding

2.1.1 As a rule, the scantling of seating can be assessed by a sole yielding evaluation.

2.1.2 The combined Von Mises stress in the seating shall not exceed $2/3\ R_{p0,2}$.

Stresses in way of the seating located on the pressure hull shall not exceed the following values:

- $2/3\ R_{p0,2}$ in the seating
- $R_{p0,2} / \chi$ in the part of the pressure hull connected with the seating.

2.2 Seating of engine

2.2.1 The scantlings of seatings of engines or other vibrating devices are to be adequate in relation to the weight, power and static and dynamic forces transmitted by the engines or the vibrating devices.

Such seatings are to be in accordance with the engines or vibrating devices manufacturer recommendations.

SECTION 3 OTHER NON-RESISTING STRUCTURES

1 General

1.1 Application

1.1.1 The following requirements apply to non-resisting structures other than cradles and seatings.

Particular requirements for tanks and secondary bulkheads are defined respectively in Articles [2] and [3].

Other non-resisting structures will be considered by the Society on a case-by-case basis.

1.2 Design principles

1.2.1 For the design of the other non-resisting structures, all the loads likely to be exerted on the non-resisting structures are to be taken into account.

For the non-resisting structures connected to the pressure hull, particular attention is to be given to the possible effect of the hull contraction.

1.2.2 Unless otherwise specified, the Von Mises stress in the non resisting structures shall not exceed:

- $2/3\ R_{p0,2}$ under design loads
- $R_{p0,2} / \chi$ under hull contraction, where χ is the pressure hull safety factor defined in Ch 2, Sec 1, [3.7.1].

The stress in non-resisting structures under hull contraction is to be evaluated considering the pressure hull submitted to the nominal diving pressure.

2 Tanks

2.1 Application

2.1.1 The following requirements apply to tanks within the pressure hull which do not belong to resisting structures.

2.2 Loads and scantling criteria

2.2.1 Tanks are to be designed to support the following load cases:

- design pressure of the piping system connected to the tank
- test pressure of the tank
- hull contraction if the tank is connected to the pressure hull.

2.2.2 For the above load cases, the maximum stress levels defined in [1.2.2] are applicable, except for the test condition.

Stress under testing condition is to be calculated considering the tank submitted to $1,2\ P_T$, where P_T is the test pressure of the capacity to be given by the designer and not taken lower than the value given in Ch 7, Sec 3, Tab 1. Induced stress is to be lower than $R_{p0,2}$.

3 Secondary bulkheads

3.1 Application

3.1.1 The following requirements apply to structural secondary bulkheads.

3.2 Design principles

3.2.1 Secondary bulkheads forming the boundary of a compartment where an over pressure is likely to occur are to be designed to support this over pressure.

The design over pressure is to be submitted by the designer and the stress induced in the secondary bulkhead shall not exceed $2/3\ R_{p0,2}$.

3.2.2 As a general rule, transverse secondary bulkheads attached to the pressure hull are to be fitted in line with the web of the stiffeners of the pressure hull.

Where a secondary bulkhead is not fitted in way of the web of the stiffeners of the pressure hull, particular attention is to be given to the linear elastic buckling of the bulkhead plate panel.

Part C

Pressure Hull and Structures

Chapter 6

HULL OUTFITTINGS

SECTION 1 STEERING AND TRIMMING DEVICES

SECTION 2 ANCHORING, MOORING AND TOWING ARRANGEMENT

SECTION 3 DOORS AND HATCH COVERS

SECTION 1 STEERING AND TRIMMING DEVICES

1 General

1.1 Application

1.1.1 The requirements of this Section apply to steering and trimming devices in cross or 'X' configuration and to fore trimming devices, as defined in [1.2]. Other configurations will be considered by the Society on a case-by-case basis.

In particular, the following requirements are applicable to the various components of the steering and trimming devices such as rudder blade, stock, bearing, trunk, solepiece and tiller.

1.2 Definitions

1.2.1 Cross configuration

Steering and trimming devices are said to be in cross configuration where made up by four rudders: two rudders with a vertical axis and two diving planes with an horizontal axis.

Generally, the rudders are actuated by groups of two.

1.2.2 'X' configuration

Steering and trimming devices are said to be in 'X' configuration where made up by four rudders having their axes oriented about 45° from the axes corresponding to rudders in cross configuration.

Generally, rudders of 'X' configuration are individually actuated.

1.2.3 Fore trimming devices

Fore trimming devices are diving planes located on the bridge fin or ahead of the bridge fin.

1.3 Materials

1.3.1 Rudders and diving planes are built either in steel or in composites.

1.3.2 Steel rudders and diving planes are generally made of a metallic structure filled with foam and covered by metallic external plating.

Composites rudders and diving planes are generally made of a metallic structure filled with foam and covered by composites external plating.

1.3.3 Materials are to comply with the applicable requirements of Ch 1, Sec 2.

1.4 Amplitude

1.4.1 The maximum time to move from the maximum angle on one side to the maximum angle on the other side is to be given by the designer, depending on the diving operation limits (see Pt A, Ch 1, App 2).

1.4.2 The Society may accept lower amplitude values if duly justified by the designer that the submarine manoeuvrability remains efficient in normal conditions and normal operational limits, as well as in emergency conditions.

1.5 Arrangement

1.5.1 Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure. The hull structure in way of the rudder supporting point is to be suitably reinforced.

1.5.2 Suitable arrangements are to be provided to prevent the rudder from moving along its axis direction.

2 Loads

2.1 Design load cases

2.1.1 The steering and trimming devices are to be designed to withstand the wave and green seas loads in surface condition and the steering and trimming hydrodynamic loads in submerged conditions. All the loads are to be considered in the most unfavourable way.

2.1.2 Hydrodynamic loads and the related centre of lifting force are to be calculated at the maximum speed and the maximum blade angle corresponding to the limiting devices.

2.1.3 For fore trimming devices used only at safety depth as defined in Ch 1, Sec 1, [2.2.5], hydrodynamic loads can be calculated at the maximum speed at safety depth and the maximum fore trimming device angle.

2.1.4 Diving depth is not considered for structural design of rudders and diving planes, if they are filled with foam. In such case, justification of filling foam performances at maximum depth is to be submitted by the designer.

2.2 Calculation of loads

2.2.1 The designer is to submit the calculation according to [2.1] of the loads exerting on the steering and trimming devices.

2.2.2 The submitted documents are to clearly specify:

- input data and methodology of calculation
- hydrodynamic resulting forces on the rudder blade
- centre of lifting and drag forces.

2.2.3 Loads in all steering and trimming device components (blade, stock, bearings, trunk, solepiece, tiller,... etc) are to be calculated by direct calculation according to rudder geometry or any recognized standard agreed by the Society.

3 Criteria

3.1 General

3.1.1 The maximum allowable stress for the various components of the steering and trimming devices is given in [3.2] to [3.5].

3.1.2 As an alternative, stress higher than the maximum allowable stress given here below can be accepted if deemed acceptable by the Society and provided that:

- a fatigue analysis of the detail is performed
- area affected by stress above $R_{p0,2} / \chi$ is limited in size
- peak stress level remains lower than 0,8 times the yield stress.

In such case, a calculation report on the fatigue analysis is to be submitted to the Society for approval.

3.2 Wave and green seas loads

3.2.1 The maximum stress level in structural members of rudders or diving planes under wave and green seas loads is not to exceed $R_{p0,2} / \chi$, where $\chi = 1,5$.

3.2.2 The maximum stress level in the rudder or diving plane stock under wave and green seas loads is not to exceed $R_{p0,2} / \chi$, where $\chi = 2,0$.

3.3 Steering and diving loads

3.3.1 The maximum stress level in the structural members of rudders or diving planes under steering and diving loads is not to exceed $R_{p0,2} / \chi$, where $\chi = 1,5$.

3.3.2 The maximum stress level in the rudder or diving plane stock under steering and diving loads is not to exceed $R_{p0,2} / \chi$, where $\chi = 1,1$.

3.4 Bearing pressure

3.4.1 The bearing pressure under wave loads, green seas loads, steering loads and diving loads in the various supporting bearings is not to exceed the maximum allowable pressure of the bearing material. The maximum allowable pressure of the bearing material is to be duly qualified and justified by the designer.

The maximum allowable pressure is generally not to exceed the values given in Tab 1. However, values greater than those specified in Tab 1 may be accepted by the Society on the basis of specific tests.

Table 1 : Allowable bearing pressure

Bearing material	$p_{F,ALL}$, in N/mm^2
White metal, oil lubricated	4,5
Synthetic material with hardness between 60 and 70 Shore D **(1)**	5,5
(1) Indentation hardness test at 23°C and with 50% moisture to be performed according to a recognized standard. Type of synthetic bearing materials is to be approved by the Society.	

3.5 Tiller

3.5.1 The maximum stress level in the tiller under wave and green sea loads and under steering and diving loads is not to exceed $R_{p0,2} / \chi$, where $\chi = 2,0$.

3.5.2 For stress level evaluated thought finite elements model, a stress level higher than $R_{p0,2} / \chi$ can be accepted provided that:

- area affected by stress above $R_{p0,2} / \chi$ is limited in size
- peak stress level remains lower than 0,8 times the yield stress.

3.5.3 For keyed tiller/stock connection, the boss of the tiller and the key are to comply with the following criteria:

- the depth of the boss is not to be less than d_s
- the radial thickness of the boss in way of the tiller is not to be less than 0,4 d_s
- the key is to be made of steel with a yield stress not less than that of the rudder stock and that of the tiller boss
- the width of the key is not to be less than 0,25 d_s
- the thickness of the key is not to be less than 0,10 d_s
- the ends of the keyways in the rudder stock and in the tiller are to be rounded,

where d_s is the rudder stock diameter in way of the tiller.

Other types of tiller/stock connection will be considered by the Society on a case-by-case basis.

SECTION 2 ANCHORING, MOORING AND TOWING ARRANGEMENT

1 General

1.1 Application

1.1.1 The following requirements apply to equipment fixed on the submarine structure for mooring, towing and anchoring operation.

1.1.2 Requirements for towing and mooring equipment are listed in Article [3] and are applicable on a single post basis (no more than one turn of one cable).

2 Anchoring

2.1 General

2.1.1 Submarines having the additional class notation **ANCHORING** are to be fitted with one anchoring line designed in accordance with Pt F, Ch 1, Sec 5.

2.1.2 For submarines fitted with one anchor but not having the additional class notation **ANCHORING**, the designer is to submit to the Society the design loads exerted by the various components of the anchoring line on the submarine structure. The designer is also to submit the calculation on which the design loads are based.

3 Mooring and towing

3.1 General

3.1.1 Submarines are to be fitted with shipboard fittings allowing mooring and towing operations.

3.1.2 Shipboard fittings means those pieces of equipment limited to the following: bollards and bitts, fairleads, stand rollers and chocks used for normal towing or mooring of the vessel.

3.2 Loads

3.2.1 The towing design load to be used for towing equipment is not to be less than 1,25 times the intended maximum towing load (e.g. static bollard pull).

3.2.2 The mooring design load to be used for mooring equipment is not to be less than 1,25 times the maximum breaking load of the mooring line.

3.2.3 The design loads are to be applied according to the towing and mooring arrangement drawing.

3.2.4 The safe working load of shipboard fitting is not to be greater than 0,8 times the design load and is to be marked on each shipboard fitting.

3.3 Calculation

3.3.1 Selection of shipboard fittings is to be made by the yard to support the design load and is to comply with recognized standards agreed by the Society.

Shipboard fittings not complying with recognized standards agreed by the Society will be considered on a case-by-case basis.

3.3.2 Submarine structure in way of connections with shipboard fittings is to be suitably reinforced. Allowable stress levels under design load as specified in [3.2] are as follows:

- $R_{p0,2}$ for normal stress
- $0,6\ R_{p0,2}$ for shear stress.

SECTION 3 DOORS AND HATCH COVERS

1 General

1.1 Application

1.1.1 The following requirements apply to structural doors and hatch covers included in structural elements of one of the following types: pressure hull, resisting structures, exostructures and non-resisting structures.

1.2 Design principles

1.2.1 Doors and hatch covers are generally to be operable from the both sides.

1.2.2 Weathertight and watertight doors and hatch covers are to be equipped with suitable sealing and closing devices exerting a sufficient pressure on sealing joints in all conditions and at all immersions up to the collapsing depth. Watertightness of sealing joint is to be demonstrated by a workshop test performed with testing pressure corresponding to the design condition.

1.2.3 Doors and hatch covers designed to allow entry into and exit from the submarine are to be provided with adequate coaming preventing water ingress.

2 Calculation

2.1 Loads

2.1.1 Doors and hatch covers are to be designed to withstand the same pressure as their surrounding structure.

2.2 Checking criteria

2.2.1 Doors and hatch covers are to be designed with a safety level equivalent to the one of their surrounding structure. In particular, safety factor applicable for the surrounding structure is applicable to the door or the hatch cover.

Part C
Pressure Hull and Structures

Chapter 7
CONSTRUCTION AND TESTING

SECTION 1 FORMING

SECTION 2 WELDING AND WELD CONNECTIONS

SECTION 3 TESTING

APPENDIX 1 APPROVAL OF STEEL WELDING PROCEDURES

SECTION 1 FORMING

1 Cold forming

1.1 General

1.1.1 Cold forming means forming at a temperature not exceeding 250°C, in general.

1.1.2 Usual cold forming processes are cold rolling or cold pressing of plates to cylindrical forms, cold bending of pipes and cold forming of plates into spherical shapes, etc.

1.1.3 The cold forming process is to be such as not to impair the material properties. The effect of work hardening is to be considered and suitable heat treatment is to be applied as far as necessary.

1.1.4 The cold forming of butt welded parts is subject to special consideration by the Society.

1.2 Cold forming procedure

1.2.1 The deformation is to be calculated using a formula adapted to the forming process and to the product and is to be submitted to the Society.

For values of deformation above the limit specified by the steel manufacturer if any or 5%, whichever is the less, a heat treatment is to be performed after cold forming.

The heat treatment may be omitted if strain ageing tests are performed with satisfactory results in accordance with [1.3].

1.2.2 For cold rolling of plates, the deformation A is to be calculated using the following formula, where R_i is the inner forming radius and t the plate thickness:

$$A = 100\frac{t}{2R_i + t}$$

The use of an other formula is subject to acceptance by the Society.

1.2.3 The cold bending of plates using a press for free bending is to be made using a punch with a sufficient radius in order to avoid excessive localized deformation in the outer side of the plate.

Welding in the bent area of plates intended for special category element is to be avoided. In the other cases, such a welding is subject to qualification tests on a representative sample.

1.3 Strain ageing tests

1.3.1 Where applicable, strain ageing tests are to be performed according to the following procedure:

a) A sample is cold formed under the same conditions as those used for fabrication or is permanently strained to the expected permanent elongation used in fabrication.

b) The sample is then subjected to an artificial ageing at 250°C for 1 hour.

c) One set of three Charpy V-notch test specimens is taken in the strained sample artificially aged. The notch is to be located in the plastically strained area, in the part of the cross-section with the highest strain. The longitudinal axis of the specimen is to be located in such a way to test in the same direction as required by the base material specification.

d) The impact testing temperature and the minimum average energy required are to be in accordance with the base material specification.

e) One cylindrical tensile test specimen is to be taken and tested in order to check the tensile properties in the strained zone.

If the test results do not satisfy the base material specification, a suitable heat treatment procedure is to be qualified by tests agreed with the Society.

2 Hot forming

2.1 General

2.1.1 Hot forming means forming at a temperature exceeding 250°C, in general.

2.1.2 The hot forming process is to be such as not to impair the material properties.

2.2 Hot forming procedure

2.2.1 The conditions of the hot forming of steel plates are to be described in a procedure prepared by the builder with sufficient details and submitted to the Society.

2.2.2 The hot forming is to be in accordance with any limitations specified by the steel manufacturer for the products involved. Particular attention is to be paid to products rolled using thermomechanical controlled process (TM or TMCP).

2.2.3 If forming temperature is greater than 500°C, a suitable heat treatment is to be carried out after forming.

2.2.4 The forming procedure, together with any eventual subsequent heat treatment, is to be subject to qualification test on sample reproducing all the conditions intended for production heat forming. The qualification tests are to include, as a minimum, a set of three Charpy V-notch impact tests and one cylindrical tensile test. The results are to be in accordance with the base material specification.

2.2.5 In each case, when hot forming is subsequent to heat treatment, the builder is to demonstrate to the Society that forming process and operating conditions are such as not to impair the material properties.

SECTION 2 WELDING AND WELD CONNECTIONS

1 General

1.1 Scope

1.1.1 The requirements of this Section apply for the preparation, execution and inspection of welded connections in pressure hull and structures.

1.1.2 The general requirements given in NR216 Materials and Welding, Ch 5, Sec 1, apply.

1.2 Documentation

1.2.1 The structural drawings to be submitted for approval according to Ch 1, Sec 1, Tab 2 are to contain the necessary data relevant to the fabrication by welding of the structures and items represented. The type of welded joints, dimensions and locations of the welds are to be detailed.

1.2.2 Fabrication specifications which detail fabrication and building conditions such as forming, welding, heat treatment and inspection, are to be submitted by the builder.

The welding documentation included in the fabrication specifications is to include the welding procedure specifications showing all welding parameters and their supporting qualification records.

1.2.3 The fabrication standard or quality standard adopted by the builder is to be submitted to the Society.

1.3 Traceability

1.3.1 A traceability system is to be established by the builder to ensure that correct material grades are used throughout the fabrication process with regards to the approved structural drawings.

2 Welding consumables, welding procedures and welders

2.1 Welding consumables

2.1.1 The grades of welding consumables selected are to satisfy the requirements for mechanical properties as specified for the qualification of welding procedures given in Ch 7, App 1.

As a general rule, the requirements for Charpy V properties of the weld metal, fusion line and heat affected zone are to be those specified in transverse direction for the base material to be welded. For the pressure hull steel grade, the builder may propose an alternative approach based upon documented evidences that the welding consumables specifications proposed to the Society have been established to take into account the fracture behaviour under dynamic loading. In that case, each type or brand of welding consumable is to be subject to a special procedure for type approval.

The welding consumables used are to be in accordance with the approved welding procedure specification.

2.1.2 Welding consumables used are to be type approved by the Society in accordance with the requirements of NR216 Materials and Welding, unless otherwise agreed.

The type approval procedure of welding consumables used to weld the pressure hull steel grade is to include tests agreed with the Society to take into account the fracture behaviour of typical welded assembly under dynamic loading similar to those used to assess the toughness of the pressure hull steel grade itself.

When non-approved welding consumables are used, the Society may require additional conditions for the qualification of welding procedures on case-by-case basis.

2.1.3 For welding of high strength quenched and tempered steel, welding consumables with hydrogen-controlled grade H5 (HHH) are to be used, as applicable.

2.2 Welding procedures

2.2.1 The welding procedures adopted for the construction are to be submitted to the Society for approval.

2.2.2 The requirements for welding procedure approval are detailed in Ch 7, App 1. Alternative procedures may be accepted by the Society, provided such procedures give reasonable equivalence to the requirements of these Rules.

2.2.3 Production tests may be required during the construction, at the discretion of the Society.

2.3 Welders

2.3.1 Welders for manual welding and for semi-automatic welding are to be tested and qualified by the Society in accordance with the requirements of NR476 Approval Testing of Welders. Alternative procedures may be accepted by the Society provided such procedures give reasonable equivalence to the requirements of these Rules.

2.3.2 The training of welders, control of their qualification and maintenance of their skills are the responsibility of the builder.

2.3.3 Welders engaged in fully mechanized or fully automatic processes are to be experienced and trained welders for the specific welding work concerned.

3 Types of connections and preparations

3.1 General

3.1.1 The type of connection 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.

3.2 Distance between welds

3.2.1 The minimum distances between welds are to be in accordance with a recognized standard accepted by the Society.

3.3 Butt weld assembly

3.3.1 The butt weld assemblies are to be with full penetration unless otherwise agreed on a case -by-case basis.

3.3.2 Products of different thicknesses may be butt welded without taper where the thickness difference is less than 3mm. The external profile of the weld bead is to have a maximum slope of 1/4.

In the other cases, the edge of the thicker product is to be tapered with a maximum slope of 1/4.

3.4 Partial and full penetration fillet welds

3.4.1 Partial or full penetration angle welds are required when assembling highly stressed elements, playing an important part in the structure and in which fatigue phenomena are likely to occur.

3.4.2 Partial and full penetration edge preparations are to be made in accordance with a recognized standard agreed by the Society.

3.4.3 For very thick assemblies subject to high restraint and essential to the structural safety of the unit or installation, a postweld heat treatment may be required.

3.4.4 For special category elements submitted to fatigue cycles, the surface condition of the weld, in particular its connection with plates, is to be taken care of and inspected. In certain cases, grinding of weld connection with plate or equivalent procedure increasing fatigue strength may be required.

3.5 Fillet welds

3.5.1 General

The value of the throat thickness of a double continuous line of welding is determined in terms of the thinnest plate (the thickness of which being noted e_{min}) of the assembly under consideration and in terms of minimum welding heat input necessary to obtain required hardness values.

3.5.2 Throat of fillet welding for the exostructure and the non-resisting structure

As a general rule, the throat thickness for double fillet welds on exostructures and non-resisting structures are not to be less than $0,35\ e_{min}$, without being less than 3 mm.

Besides complying with these maximum and minimum values, throat thickness is to be large enough to satisfy the strength purposes.

3.5.3 Throat of fillet welding for the pressure hull and the resisting structure

Fillet welding for steel assemblies of the pressure hull and of the resisting structure is to be made with a reinforced throat. The minimum throat is to be evaluated from yard standard and feed back experience and is not to be less than $0,5\ e_{min}$.

Besides complying with these minimum values, throat thickness is to be large enough to satisfy the strength purposes.

4 Fabrication by welding

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.

4.1.2 The welding consumables contaminated by moisture, rust, oil, grease or other deleterious element are to be discarded unless they have been restored to satisfactory condition.

The welding consumables are to be stored and handled in accordance with the manufacturer's recommendations and procedures giving details about conditions of storage and use.

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 Edge preparation

The edge preparation is to comply with the welding procedure specification. Edges are to have a smooth and uniform surface. Flame cutting is to be followed by grinding to bright metal.

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.

4.2.4 Tack welding

Tack welding is to be performed in accordance with a qualified welding procedure by qualified welders.

Tack welds may form part of the completed welds provided that the qualification of the welding procedure used has been made using test samples incorporating tack welds.

4.2.5 Assembling and gap

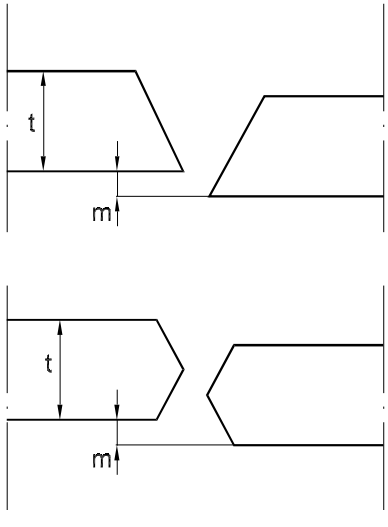
The setting appliances and system used for positioning are to ensure correct adjustment and appropriate gap of the parts to be welded, while leaving shrinkage as free as possible.

The gap before welding is to comply with the approved welding procedure specification.

4.2.6 Plate misalignment in butt connections

The misalignment m, measured as shown in Fig 1, between plates having the same gross thickness t, is to be less than 0,15 t, without being greater than 4 mm.

Figure 1 : Plate misalignment in butt connections



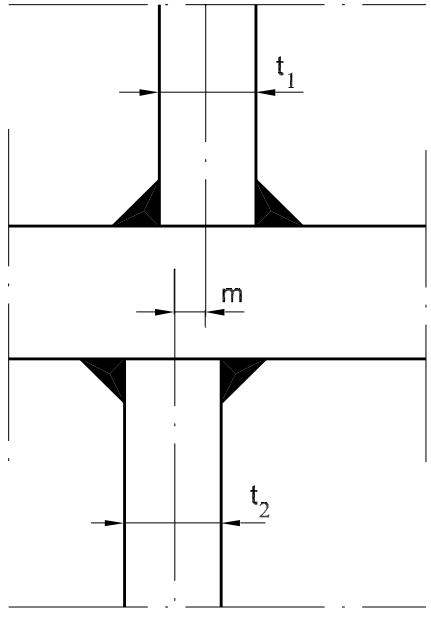
4.2.7 Misalignment in cruciform connections

The misalignment m in cruciform connections, measured on the median lines as shown in Fig 2, is to be less than the smaller of:

- t / 2, where t is the thickness of the thinner plate
- 5 mm.

The Society may require lower misalignment to be adopted for cruciform connections subjected to high stresses.

Figure 2 : Misalignment in cruciform connections



4.2.8 Preheating, interpass and post-heating

Preheating and post-heating is to be performed using electric heating elements or gas burners under controlled conditions.

Preheating and interpass temperatures as well as post-heating temperature and duration are to be in accordance with the approved welding procedure specification.

Methods are to be established and implemented for the control of temperatures.

4.2.9 Welding sequences

Welding sequences and direction of welding are to be determined so as to minimise deformations and prevent defects in the welded connection.

4.2.10 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.

4.2.11 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, are to be stress-relieved in a furnace, before final assembly. Concerned structures are agreed on a case-by-case basis.

4.2.12 Temporary attachments

Temporary attachments like lifting lugs, supports or other fabrication aids are to be welded in accordance with a suitable welding procedure. These attachments are to be removed by cutting followed by grinding.

4.3 Repairs

4.3.1 Repairs are to be performed in accordance with repair procedures agreed with the Society on a case-by-case basis.

4.3.2 Build-up by welding of gaps above the specified value and correction of weld deformations may be accepted by the Society upon special examination.

4.3.3 Imperfections and defects of the base material and welded connections found during the construction may be rectified by grinding, machining or welding. Removal of defects is to be verified by magnetic particle or liquid penetrant examination.

4.3.4 Repair by welding is to be performed in accordance with a qualified welding procedure.

5 Inspections and checks

5.1 General

5.1.1 Materials, workmanship, structures and welded connections are to be subjected, before fabrication, during fabrication and after completion, to inspections by the builder to check compliance with the applicable requirements, the approved drawings, approved welding procedures and the fabrication standard and testing specifications.

The Surveyors cannot be expected to act as substitutes to the builder's organization to be in place for these checks.

5.1.2 The builder is to make available to the Surveyor the documentation in place to control that the welders engaged in the fabrication works are identified with their respective qualifications.

The builder's organization is responsible for ensuring that welders and operators are employed under proper conditions and within the range of their respective qualifications.

5.2 General requirements for Non-Destructive Testing (NDT)

5.2.1 It is the builder's responsibility to assure that testing specifications and procedures are adhered to during the construction and the report is made available to the Society on the findings made by the NDT.

The Surveyor may require to witness some testings.

5.2.2 The testing method, equipment, calibration, conditions and reporting are to comply with recognized National or International Standards or other documents, to the satisfaction of the Society.

5.2.3 Sufficient details including acceptance level for indications are to be given in a written procedure for each NDT technique which is to be submitted to the Society for acceptance.

5.2.4 NDT operators are to be qualified according to a nationally recognized scheme with a grade equivalent to level II qualification of ISO 9712, SNT-TC-1A, EN 473 or ASNT Central Certification Program (ACCP). Operators qualified to level I may be engaged in the tests under the supervision of personnel qualified to level II or III.

Personnel responsible for the preparation and approval of NDT procedures are to be qualified to a grade equivalent to level III of ISO 9712, SNT-TC-1A, EN 473, ACCP or ASNT.

Personnel qualifications are to be verified by certification.

5.2.5 NDT is to be conducted after welds have cooled to ambient temperature and after post weld heat treatment, where applicable.

5.2.6 For steels with specified minimum yield stress of 420 N/mm^2 and above, NDT is not to be carried out before 48 hours after completion of welding.

5.2.7 NDT performed is to be properly reported and an identification system is to be adopted to identify the exact location of the lengths of weld examined.

5.3 NDT procedures

5.3.1 The NDT written procedures used by the builder are to be submitted to the Society and are to include the following details, as a minimum:

- standard used
- personnel qualification
- types of welds covered (any limitations on materials, dimensions, geometry of joint, welding process are to be detailed)
- NDT technique
- type of equipment
- sensitivity
- calibration technique and calibration references
- testing parameters
- identification system of area examined
- assessment of indications and acceptance levels
- reporting of results.

5.4 NDT categories

5.4.1 The non-destructive testing categories are defined in Tab 1.

The NDT category is to be defined by the designer for each structural item and is to be specified on the drawings.

Alternative categorization may be accepted by the Society, provided such categorization gives reasonable equivalence to these requirements.

Table 1 : NDT categories

Category	Structure item
NDT category A	Pressure hull Resisting structures Structural items likely to induce a loss of integrity of the submarine
NDT category B	Ballast Aft end Steering and trimming devices Regulating tanks Structural items not likely to induce a loss of integrity of the submarine but the collapse of which may affect the safety of the submarine
NDT category C	Other items

5.5 Extent of NDT

5.5.1 The extent of NDT is to be determined by the builder, taking into account the design of the submarine to be built and the construction technology used.

5.5.2 For each construction, the builder is to submit to the Society the necessary documents specifying the areas to be tested and the extent of testing with reference of the NDT techniques and procedures used.

5.5.3 The minimum extent of NDT to be made by the builder is given in Tab 2. The Society may consider requests for reductions of this extent based on documented evidences submitted by the builder.

5.5.4 The grinded area left after removal of a temporary attachment is to be examined using liquid penetrant or magnetic particle technique.

5.6 Visual examination

5.6.1 All the welds over their full length are to be subject to visual testing by personnel designated by the builder.

5.6.2 The welds are to be examined when clean and free from paint.

5.7 Liquid penetrant and magnetic particle examinations

5.7.1 The surface to be examined is to include the weld bead and sufficient width of base metal on each side of the weld.

5.8 Ultrasonic examination

5.8.1 Ultrasonic examination may be used for thicknesses equal to or greater than 10 mm, unless otherwise agreed on a case-by-case basis.

5.8.2 Angle beam technique is to be used to search for longitudinal and transverse weld discontinuities.

5.8.3 The scanning technique is to allow the testing of the entire volume of weld bead and sufficient width of base metal on each side of the weld.

Table 2 : Minimum extent of non-destructive testing

Structure item **(1)**	Type of weld	Visual **(3)**	Magnetic particle or liquid penetrant	Radiography **(1) (2)**	Ultrasonics **(1) (2)**
Welds between items of NDT categories A, A/B and A/C	Butt weld	100%	100%	100%	100%
	T weld full penetration	100%	100%	–	100%
	T weld partial penetration and Fillet weld	100%	100% **(6)**	–	–
Welds between items of NDT categories B and B/C	Butt weld	100%	20%	30% **(4) (5)**	30% **(4) (5)**
	T weld full penetration	100%	20%	–	30% **(4) (5)**
	T weld partial penetration and Fillet weld	100%	20%	–	–
Welds between items of NDT category C	Butt weld	100%	–	–	–
	T weld full penetration	100%	–	–	–
	T weld partial penetration and Fillet weld	100%	–	–	–

(1) All start/stop points in welds made using automatic welding processes are to be tested using radiography or ultrasonics.

(2) A partial replacement of radiography by ultrasonics is permitted, provided the required length is tested. Full replacement of radiography by ultrasonics is subject to the agreement of the Society.

(3) Where used, 100% means examination of all finished welds over their full length.

(4) The percentage X% means:

- X% of the welds of length less than 1 m are to be examined over their full length
- X% of the length of each weld of length equal to or above 1 m is to be examined at random location.

(5) RT may be replaced by UT and vice-versa.

(6) 20% as per **(2)** for welds between items category C and category A other than hull pressure shell.

5.9 Radiographic examination

5.9.1 The type of source is left at the builder's discretion.

5.9.2 The image quality is to be verified using an Image Quality Indicator (IQI) in accordance with ISO 2504 or equivalent. The minimum image quality is to be in accordance with Class A of ISO 17636 or equivalent.

5.10 Acceptance level of indications

5.10.1 Indications evaluated to be crack are not acceptable.

5.10.2 Indications evaluated to be lack of fusion or lack of penetration are not acceptable for NDT category A.

Indications evaluated to be lack of fusion are not acceptable for NDT category B.

5.10.3 Other types of indications are to be assessed in accordance with a recognized standard accepted by the Society.

5.11 Repairs of unacceptable indications

5.11.1 Indications not accepted are to be eliminated and repaired where necessary. The repaired length of the weld is to be re-examined using the NDT technique applied originally.

5.11.2 Unless the indication has been judged isolated without any doubt, additional areas of the same weld length are to be examined. In case of weld joints made by automatic process, additional NDT are to be extended to the full length of the same weld.

5.11.3 The extent of examination can be extended at the Surveyor's discretion when repetitive non-acceptable indications are found.

SECTION 3 TESTING

1 General

1.1 Application

1.1.1 The following requirements determine the testing conditions of the pressure hull and of other structural components of the submarine.

1.2 Principles

1.2.1 Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion so that any subsequent work will not impair the strength or the tightness of the tested structure.

1.2.2 For structural components which testing is not expressively defined in this Section, the Society may requires specific tests. In such case, testing conditions will be considered by the Society on a case-by-case basis and based on testing conditions for similar structural components.

2 Testing of the pressure hull

2.1 General

2.1.1 After construction and after major modification, the pressure hull is to be submitted to a hydrostatic proof test to validate its strength and to confirm design calculations.

2.1.2 The pressure hull proof test procedure is to comply with requirements defined in [2.2] and a document describing this procedure is to be submitted to the Society for approval prior to the test.

2.2 Testing conditions

2.2.1 The pressure hull is to be tested at the nominal diving pressure P_N. During the test, the submarine is to reach the nominal diving pressure in stages. The sequence of the different stages and the associated pressures of each stage is to be included in the document required in [2.1.2] and duly justified by the designer on the basis of experience feed back.

2.2.2 In order to confirm the design calculations, the pressure hull is to be equipped with stress gauges.

Stress gauges are to be located at the following locations of the pressure hull:

- at casual parts of the pressure resisting hull, uniformly spread along the pressure hull
- in way or pressure hull discontinuities
- at areas where a problem occured during construction.

The number and locations of stress gauges are to be included in the document required in [2.1.2] and duly justified by the designer on the basis of experience feed back.

2.2.3 At each stage of the proof test, the stress values obtained from stress gauges are to be available on board for analysis.

At each stage, the submarine is allowed to proceed to the following stage if the acceptance criteria are fulfilled. These criteria are to be included in the documentation required in [2.1.2] and duly justified by the designer on the basis of experience feed back.

The evaluation of compliance of the measured stress with acceptance criteria is the responsibility of the shipmaster or any other person appointed by the designer.

3 Testing of other structural components

3.1 Definition

3.1.1 Structural testing

Structural testing is a hydrostatic test carried out to demonstrate the tightness of the structure and the structural adequacy of the design.

Structural testing is to be carried out according to [3.2].

3.1.2 Leak testing

Leak testing is an air or other medium test carried out to demonstrate the tightness of the structure.

Leak testing is to be carried out according to [3.3].

3.2 Structural testing

3.2.1 Structural testing is to be performed at the test pressure of the tested structural component. The test pressure should be maintained for at least 30 minutes. No leaking nor permanent deformation should be observed during the test.

3.2.2 Structural testing may be carried out after the protective coating has been applied, provided that one of the two following conditions is satisfied:

- all the welds are completed and carefully inspected visually to the satisfaction of the Surveyor prior to the application of the protective coating
- leak testing is carried out prior to the application of the protective coating.

In the absence of leak testing, protective coating is to be applied after the structural testing of:

- all erection welds
- all manual fillet welds and manual penetration welds.

3.2.3 Where practical limitations prevail and a hydrostatic testing is not feasible, a hydropneumatic testing may be carried out instead of a hydrostatic testing.

3.3 Leak testing

3.3.1 Where leak testing is carried out, an air pressure of 0,15 bar is to be applied during the test. An efficient indicating liquid, such as soapy water, is to be applied on all welds to detect leaks.

3.3.2 A U-tube filled with water up to a height corresponding to the test pressure is to be fitted to avoid over pressure and to verify the test pressure.

3.4 Proof testings

3.4.1 The various structural components of the submarine are to be tested according to the type of testing and the test pressure defined in Tab 1, where:

P_d : Design pressure of the component

P_a : Accidental pressure of the component

P_N : Nominal diving pressure of the submarine, as defined in Ch 1, Sec 1, [2.2.1]

P_A : Accidental diving pressure of the submarine, as defined in Ch 1, Sec 1, [2.2.2]

Pc : Collapse diving pressure of the submarine defined in Ch 1, Sec 1, [2.2.4].

P_d and P_a are to be submitted by the designer and in accordance with the normal and emergency operating and environmental conditions of the component.

Table 1 : Testing requirements for structural components

Structural component	Type of test	Test pressure
Internal resisting capacity	structural test	1,5 P_N
External resisting capacity	structural test	P_A **(1)**
Weapon launching tube, trunks	structural test	Exterior test pressure: P_A **(1)** Interior test pressure: ≥ Pc
Hatch cover and hull penetration	structural test	≥ Pc
Ballast	structural test	0,6 bar **(2)**
Internal non-resisting capacity	structural test	max (1,5 P_d ; P_a)

(1) The structural test can be performed only at P_N during the pressure hull proof test if sufficient experience feed back has been gained on similar components.

(2) The ballast strutural test can be either a hydrostatic test or a hydropneumatic test.
In general, ballast structural testing need not be repeated for subsequent ships of a series of identical new submarines.

APPENDIX 1 APPROVAL OF STEEL WELDING PROCEDURES

1 General

1.1 Scope

1.1.1 General

The requirements relevant to materials not covered herein are agreed on a case-by-case basis following, as far as applicable, the criteria specified in this Appendix.

1.1.2 Other standards and specifications

Procedures considered equivalent by the Society may be accepted.

1.2 Welding procedure

1.2.1 Welding processes

For reference, the processes are listed with their relevant number according to ISO 4063.

Qualification tests are, as a rule, required for the automatic or semi-automatic processes indicated below:

- submerged arc welding with wire electrode: 121
- flux-cored wire metal arc welding without gas shield: 114
- metal arc inert gas welding (MIG welding): 131
- metal arc active gas welding (MAG welding): 135
- flux-cored wire metal arc welding with active gas shield: 136
- flux-cored wire metal arc welding with inert gas shield: 137
- tungsten inert gas arc welding (TIG welding): 141
- plasma arc welding: 15.

1.2.2 Manual metal arc welding

In the case of manual metal arc welding, where the joint is welded with approved covered electrodes and by certified welders, qualification tests are generally not required; the results of tests performed by the shipyard on joints welded under similar conditions may be required, to the Surveyor's satisfaction.

Qualification tests are required for manual welding of special or primary category elements.

Qualification tests may be required for one side manual metal arc welding on ceramic backing.

Qualification tests are required in the case of welding higher strength steels having minimum yield stress equal to or higher than 390 N/mm^2 and steels not approved or not complying with recognised standards.

1.2.3 Welding consumables

Consumables approved in accordance with the requirements of NR216 Materials and Welding are to be used within the limits of their approval.

When non-approved welding consumables are used, the requirements relevant to the qualification of the welding procedures are established on a case-by-case basis and in general tests on a deposited metal sample are required.

1.2.4 Preliminary welding procedure specification (pWPS)

A welding procedure specification is to be prepared by the manufacturer or shipyard which intends to perform the qualification tests. This document is also referred to as a preliminary welding procedure specification (pWPS) and is to be submitted to the Society for review prior to the tests.

This pWPS may be modified and amended during the procedure tests as deemed necessary however it shall define all relevant variables as mentioned in the welding procedure specification (refer to [1.2.5]).

In case that the test pieces welded according to the pWPS show unacceptable results, the pWPS is to be adjusted by the shipyard or manufacturer. The new pWPS is to be prepared and the test pieces welded in accordance with the new pWPS.

In general, the qualification tests is to reflect fabrication conditions in respect to welding equipment, inside or outside fabrication, weld preparation, preheating and any post-weld heat treatment. It is to the manufacturer's responsibility to establish and document whether a procedure is suitable for the particular application.

The test pieces are to be chosen so as to cover all the production welds in accordance with the approval range of parameters.

1.2.5 Approval of welding procedure specification (WPS)

The qualification tests when required, welding of test pieces according to the proposed pWPS and testing of test specimens, are to be witnessed by the Surveyor.

Upon satisfactory completion of the tests, the Society may approve the pWPS as a welding procedure specification.

In its final version, the welding procedure specification (WPS) is to include all the parameters characterising the welding process, in particular, as applicable:

a) type of welding process and equipment, as appropriate

b) type of joint, preparation and backing material, if any

c) base metal, thickness range, pipe diameter etc.

d) filler metal

e) welding position

f) minimum preheat, minimum and maximum interpass temperature

g) post-weld heat treatment, if applicable

h) shielding gas, as applicable

i) welding parameters

j) other information relevant to the welding techniques, as applicable.

The actual parameters used for welding the approval test pieces and the results of the inspections and tests carried out are to be recorded in the welding procedure qualification record (WPQR) also referred to as welding procedure approval record (WPAR).

The WPQR is generally prepared by the shipyard or welding shops and endorsed by the attending Surveyor.

1.2.6 Certificate of approval of the welding procedure

Upon satisfactory completion of the approval tests, a certificate of approval of the welding procedure is generally issued by the Society to the individual users, stating the conditions of the approval of the WPS such as thickness range, positions, steel grades and additional conditions for the application of the process, as deemed necessary, on the basis of the indications already given in the WPS.

1.2.7 Inspections

Inspections and control tests may be periodically and randomly required as deemed necessary by the Society and are to yield satisfactory results in order to maintain the validity of the approval.

The results of any suitable control performed during production may be accepted, to the Surveyor's satisfaction.

1.2.8 Responsibilities of the users

The qualification tests are intended to verify that a manufacturer is adequately qualified to perform welding operations using a particular procedure.

Irrespective of the inspections carried out by the Surveyor, the user is responsible for the use of the approved procedures, within the limits of the range qualified and the conditions stated at the time of the approval.

Compliance with the above is essential for the validity of the approval.

2 Welding procedure qualification tests

2.1 Butt joints in plates with full penetration

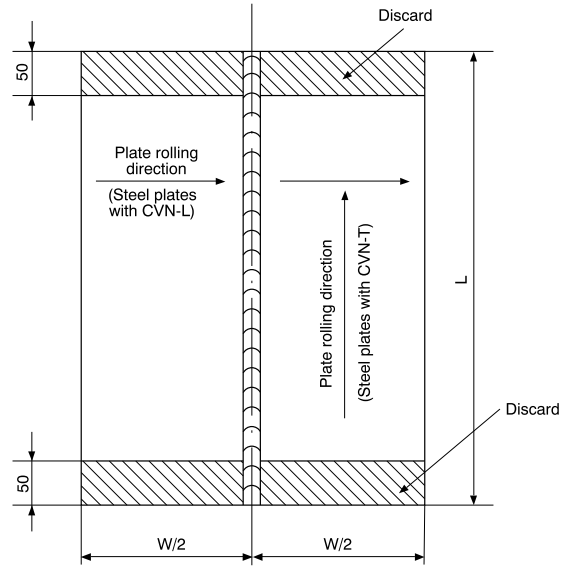
2.1.1 Assembly of test pieces

Preparation and welding are to be in accordance with the pWPS and under the general condition of production welding which it represents.

If tack welds and / or start and stop points are a condition of the weld process, they are to be fused into the joint and are to be included in the test pieces.

The test assembly is to be of a size sufficient to ensure a reasonable heat distribution and is to have the minimum following dimensions (see Fig 1):

Figure 1 : Test assembly for plate butt weld



a) manual or semiautomatic welding:

- length L = 6 t, min. 350 mm
- width W with W/2 = 3 t, min. 150 mm

b) automatic welding:

- length L = min.1000 mm
- width W with W/2 = 4 t, min. 200 mm.

In the case of steel plates impact tested in the longitudinal direction (CVN-L), the butt weld of the test piece is perpendicular to the rolling direction of the two plates.

In the case of steel plates impact tested in the transversal direction (CVN-T), the butt weld of the test piece is parallel to the rolling direction of the two plates.

2.1.2 Examinations and tests

Non-destructive examinations and destructive tests required according to Tab 1 are to be carried out, while the location of the test specimens is to be in accordance with Fig 2.

Figure 2 : Location of test specimens

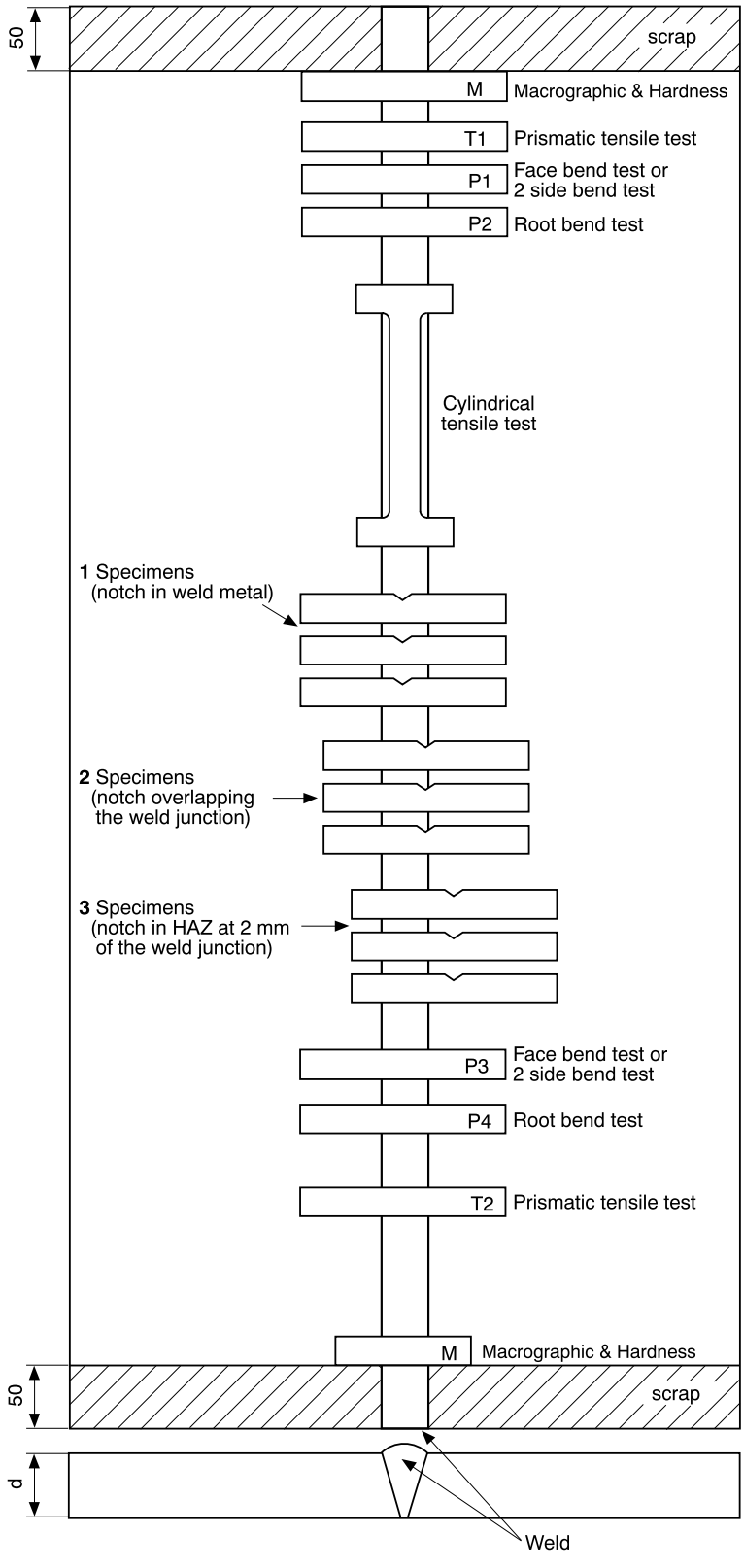


Table 1 : Examinations and tests for butt joints in plates

Type of examination or test	Extent of examination or test
Visual examination	100%
Surface crack detection **(1)**	100%
Radiographic or ultrasonic examination	100%
Transverse tensile test	2 specimens
Transverse bend tests **(2)**	2 root and 2 face specimens
Charpy V-notch impact tests **(3)**	3 sets
Macro examination	on 1 section
Hardness test **(4)**	on 1 section
Longitudinal tensile test **(5)**	1 specimen

(1) Dye penetrant according to ISO 3452 (or equivalent accepted standard) or magnetic particle testing; for non-magnetic materials, dye penetrant only.

(2) Dye penetrant according to ISO 3452 (or equivalent accepted standard) or magnetic particle testing; for non-magnetic materials, dye penetrant only.

(3) 3 sets each of 3 specimens as per [2.1.7].

(4) Only required for high strength steels with minimum specified yield strength equal to or greater than 355 N/mm^2.

(5) Required only when the use of non-approved filler metal has been accepted (see [1.2.3]).

2.1.3 Non-destructive examinations

Non-destructive examinations are to be carried out after any required or specified post-weld heat treatment and prior to the cutting of test specimens.

Imperfections detected by visual or non-destructive testing are to be assessed in accordance with ISO 5817 class B, except for the following imperfections for which the level C applies:

- excess weld metal or convexity
- excess throat thickness, and
- excess of penetration.

2.1.4 Transverse tensile tests

Specimens for transverse tensile tests are to be in accordance with NR216 Materials and Welding.

The tensile strength recorded for each specimen is to be not less than the minimum required for the parent metal; the location of the fracture is to be reported.

When butt welds are made between plates of different grades, the tensile strength to be obtained on the welded assembly is to be in accordance with the requirement of the grade having lower strength.

2.1.5 Tensile tests on cylindrical specimens

When required (see Tab 1), a round tensile specimen is to be cut along the weld axis to the dimension given in NR216 Materials and Welding, Ch 1, Sec 2, Fig 1, in the all weld metal.

Where the size of the deposited metal is too small, a 6 mm diameter specimen may be taken or a deposited weld metal test is to be carried out in accordance with the requirements of NR216 Materials and Welding, Ch 5, Sec 2.

The tensile properties recorded (yield stress R_{eH}, tensile strength R_m and elongation A_5) are to be not less than the minimum required for the approval of the appropriate grade of consumables.

When more than one welding process or type of consumable has been used to make the test weld, test specimens are to be removed from the area of the weld where each was used with the exception of those processes or consumables used to make the first weld run or root deposit.

2.1.6 Bend tests

Transverse root bend, face bend and side bend specimens are to be machined to the dimensions given in NR216 Materials and Welding, Ch 1, Sec 2, [3.1].

For dissimilar or heterogeneous butt-joints, one longitudinal bend test may be used instead of transverse bend tests.

The test specimens are to be bent on a mandrel having a diameter equal to 4 times the thickness of the specimen; the bending angle is to be 180°.

After testing, the test specimens are not to reveal any open defect, in any direction, greater than 3 mm. Defects appearing at the corners of the test specimen during testing are to be investigated case-by-case.

When butt welds are made between plates of different grades, face and root longitudinal bend test specimens may be used instead of the transverse bend test specimens.

2.1.7 Impact tests

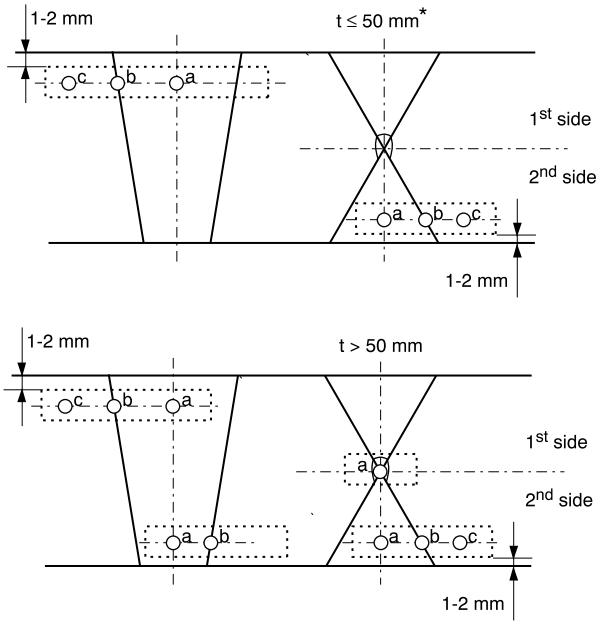
Dimensions and testing of Charpy V-notch impact test specimens are to be in accordance with NR216 Materials and Welding, Ch 1, Sec 2.

Charpy V-notch impact test specimens in accordance with NR216 Materials and Welding, Ch 1, Sec 2 are to be sampled from 1 to 2 mm below the surface of the parent material, transverse to the weld and on the side containing the last run.

The Charpy V-notch specimens are located in the butt-welded joint as indicated in Fig 3 and Fig 4, and the V-notch is to be cut perpendicular to the surface of the weld.

The requirements for test temperature and absorbed energy are to be those specified in transverse direction for the base material to be welded. For the pressure hull steel grade, the Builder may propose an alternative approach based upon documented evidences that the welding consumables specifications proposed to the Society have been established to take into account the fracture behaviour under dynamic loading. In that case each type or brand of welding consumable is to be subject to a special procedure for type approval.

Figure 3 : Location of V-notch for normal heat input ≤ 50 kJ/cm



a : Centre of weld "WM"

b : On fusion line "FL"

c : In HAZ, 2 mm from fusion line

* : For one side pass welding over 20 mm "WM" FL and HAZ, 2mm from fusion line to be added on root side.

When butt welds are made between different steel grades/types, the test specimens are to be taken from the side of the joint with steel of lower toughness level. Temperature and absorbed energy results are to be in accordance with the minimum value required for the steel of lower toughness level.

Where more than one welding process or consumable has been used to make the test weld, impact test specimens are to be removed from the respective areas where each was employed. This should not apply to the process or consumables used solely to make the first weld run or root deposit.

When cast or forged material with specified impact values is to be welded, test temperature and absorbed energy are to be in accordance with the requirements of the base material.

2.1.8 Macro examinations

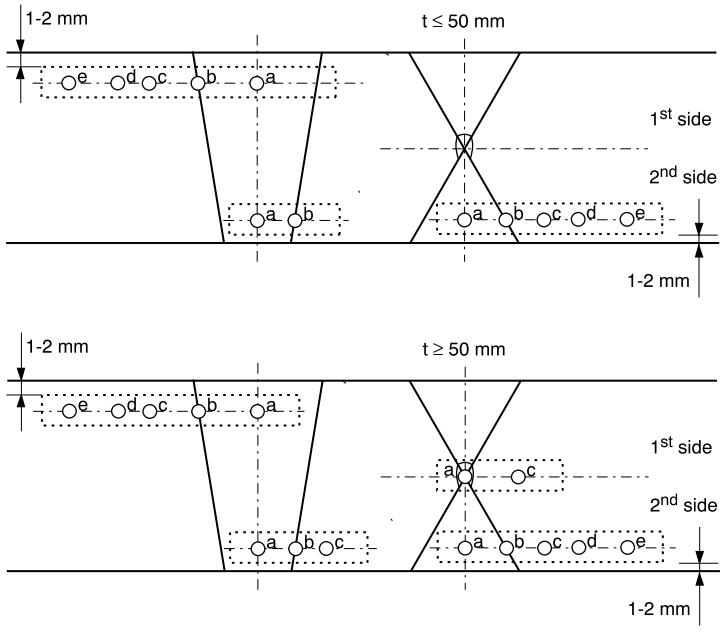
The test specimens are to be prepared and etched using suitable agent on one side to clearly reveal the weld metal, fusion line, the heat affected zone (HAZ) and about 10 mm of unaffected parent metal.

The examination shall reveal a regular weld profile, through fusion between adjacent layers of weld and base metal and the absence of defects such as cracks, lack of fusion etc.

2.1.9 Hardness tests

Hardness testing is required for steels with minimum specified yield strength equal to or greater than 355 N/mm^2. Unless otherwise agreed, the Vickers method HV10 is to be used.

Figure 4 : Location of V-notch for high heat input > 50 kJ/cm



a : Centre of weld "WM"

b : On fusion line "FL"

c : In HAZ, 2 mm from fusion line

d : In HAZ, 5 mm from fusion line

e : In HAZ, 10 mm from fusion line in case of heat input > 200 kJ/cm.

The indentations are to be made in the weld, heat affected zones, and the parent metals measuring and recording the hardness values. Two rows of indentations are to be carried out in accordance with Fig 5.

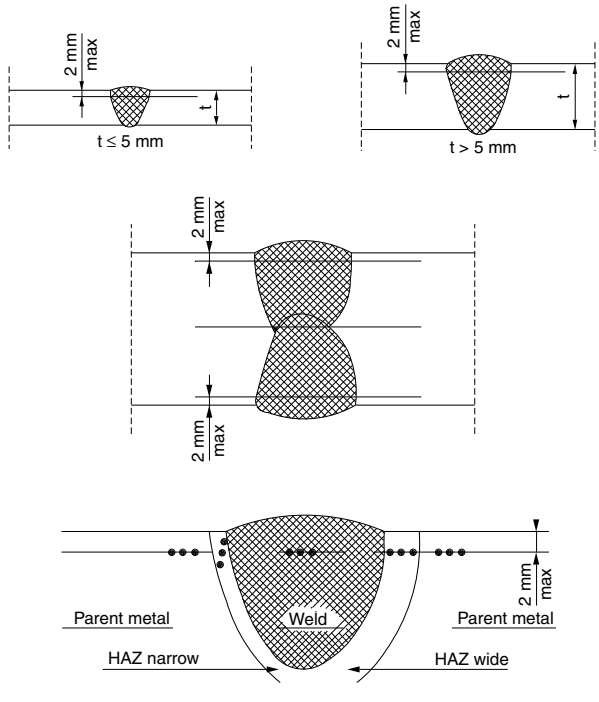
For each row of indentations, there is to be a minimum of 3 individual indentations in the weld, the heat affected zones (both sides) and the parent metals (both sides).

The distance between the indentations may vary from 0,5 mm to 2 mm, depending on the zone tested.

Typical example of hardness indentations are given in Fig 5.

The results of hardness tests are not to exceed 350 HV for steels with a specified minimum yield strength less than or equal to 420 N/mm^2.

Figure 5 : Examples of hardness indentations



2.2 T butt joints in plates

2.2.1 General

Where this type of joints is predominant in production, qualification tests are to be performed on T butt joint assembly in addition to the equivalent qualification on butt joint.

The same principle applies when changes occur in the geometry of the bevel which may significantly affect the penetration or fusion.

2.2.2 Assembly and welding

Preparation and welding are to be in accordance with the pWPS and under the general condition of production welding which it represents.

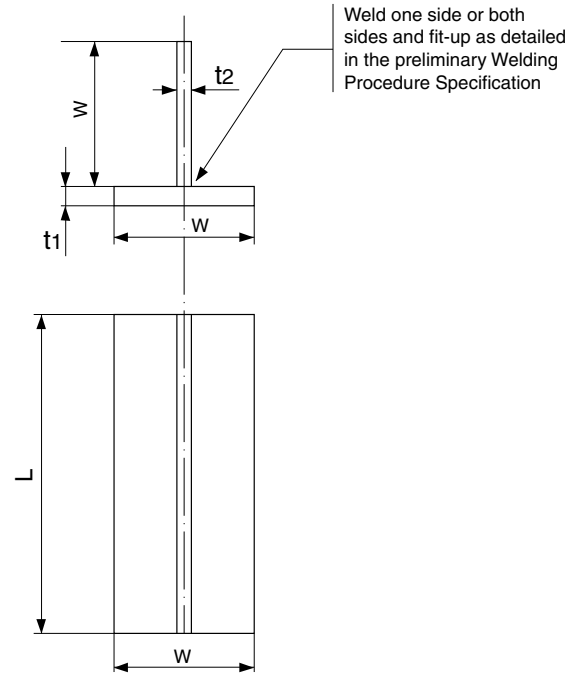
If tack welds are a condition of the weld process, they are to be fused into the joint and are to be included in the test pieces.

The test assembly is to be of a size sufficient to ensure a reasonable heat distribution and is to have the minimum following dimensions (reference may be made to Fig 6):

a) manual or semiautomatic welding:
   - length L = 6 t, min. 350 mm
   - width W = 3 t, min. 150 mm

b) automatic welding:
   - length L= min. 1000 mm
   - width W = 3 t, min. 150 mm.

Figure 6 : T butt joint in plates



2.2.3 Examinations and tests

Non-destructive examinations and destructive tests are required according to Tab 2; a discard of 50 mm from both edges is permitted.

2.2.4 Non-destructive examination

Reference is made to [2.1.3].

2.2.5 Tensile tests on cylindrical specimens

Reference is made to [2.1.5].

2.2.6 Macro examination

Reference is made to [2.1.8].

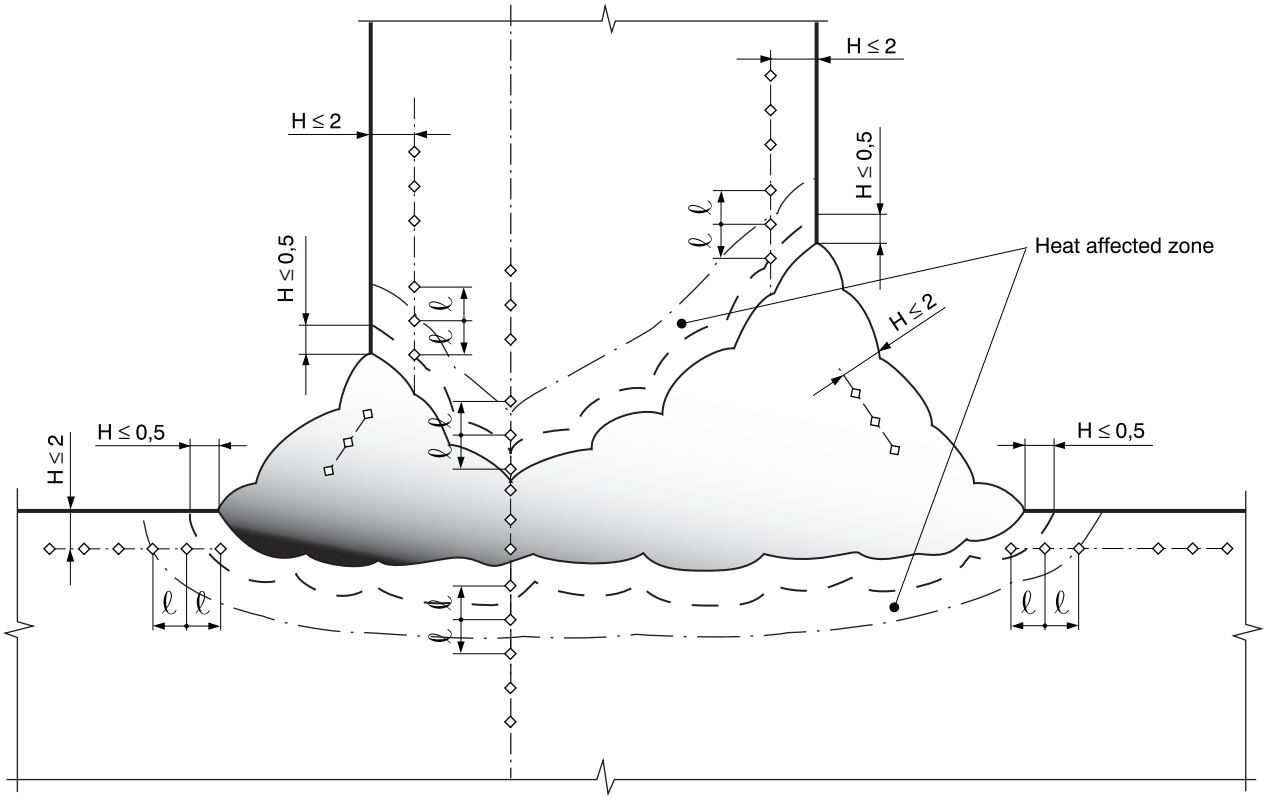
2.2.7 Hardness test

Hardness testing is required for steels with minimum specified yield strength equal to or greater than 355 N/mm^2. Unless otherwise agreed, the Vickers method HV10 is to be used.

The indentations are to be made in the weld, heat affected zones, and the parent metals measuring and recording the hardness values.

Rows of indentations are to be carried out in accordance with Fig 7.

Figure 7 : Macro and hardness indentations



H : Dimension in mm.

Table 2 : Examinations and tests for T butt joints in plates

Type of examination or test	Extent of examination or test
Visual examination	100%
Surface crack detection **(1)**	100%
Ultrasonic examination **(4)**	100%
Macro examination	on 1 section
Hardness test **(2)**	on 1 section
Longitudinal tensile test **(3)**	1 specimen

(1) Dye penetrant according to ISO 3452 (or equivalent accepted standard) or magnetic particle testing; for non-magnetic materials, dye penetrant only.

(2) Only required for high strength steels with minimum specified yield strength equal to or greater than 355 N/mm^2.

(3) Required for thickness above 50mm or when the use of non-approved filler metal has been accepted (see [1.2.3]).

(4) Applicable to full penetration weld or to verify the extent of penetration in partial penetration welds.

For each row of indentations, there is to be a minimum of 3 individual indentations in the weld, the heat affected zones (both sides) and the parent metals (both sides).

The results of hardness tests are not to exceed 350 HV for steels with a specified minimum yield strength less than or equal to 420 N/mm^2.

2.3 Fillet weld on plates

2.3.1 General

Where this type of joints is predominant in production, qualification tests are to be performed on a fillet weld assembly in addition to the equivalent qualification on butt joint.

2.3.2 Assembly and welding

Preparation and welding are to be in accordance with the pWPS and under the general condition of production welding which it represents.

If tack welds are a condition of the weld process, they are to be fused into the joint and are to be included in the test pieces.

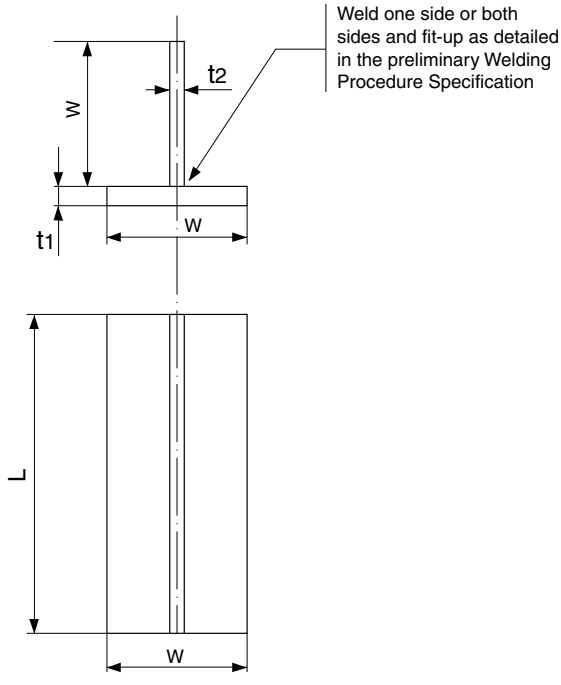
The test assembly is welded on one side only. For single pass manual and semi-automatic welding, a stop/restart is to be included in the test length and its position is to be clearly marked for subsequent examination.

The test assembly is to be of a size sufficient to ensure a reasonable heat distribution and is to have the minimum following dimensions (see Fig 8):

a) manual or semiautomatic welding:
   - length L = 6 t, min. 350 mm
   - width W = 3 t, min. 150 mm

b) automatic welding:
   - length L = min.1000 mm
   - width W = 3 t, min. 150 mm.

Figure 8 : Fillet weld on plates



2.3.3 Examinations and tests

Non-destructive examinations and destructive tests are required according to Tab 3. A discard of 50 mm from both edges is permitted.

Table 3 : Examinations and tests for fillet welds on plates

Type of examination or test	Extent of examination or test
Visual examination	100%
Surface crack detection **(1)**	100%
Macro examination **(2)**	2 sections
Hardness test **(3)**	on 1section
Fracture test	1 test

(1) Dye penetrant according to ISO 3452 (or equivalent accepted standard) or magnetic particle testing; for non-magnetic materials, dye penetrant only.

(2) One of the macro sections is to be taken at the position of the stop/restart; see [2.3.2].

(3) Only required for high strength steels having: $R_{eH} \geq 355$ N/mm^2

2.3.4 Visual examination and surface crack detection

Non-destructive examinations are to be carried out after any required or specified post-weld heat treatment and prior to the cutting of test specimens.

Imperfections detected are to be assessed in accordance with [2.1.3].

2.3.5 Macro examination

The test specimen is to be prepared and etched on one side to clearly reveal the weld metal, fusion line, root penetration, the heat affected zone and about 10mm of unaffected base material.

The examination is to reveal a regular weld profile, through fusion between adjacent layers of weld and base metal and the absence of defects such as cracks, lack of fusion etc.

The dimensions of leg size, throat and penetration are to be reported.

2.3.6 Fracture test

The fracture test is to be performed by folding the upright plate onto the through plate. Evaluation is to be concentrated on cracks, porosity and pores, inclusions, lack of fusion and incomplete penetration. Imperfections that are detected shall be assessed in accordance with ISO 5817 Class B.

2.3.7 Hardness test

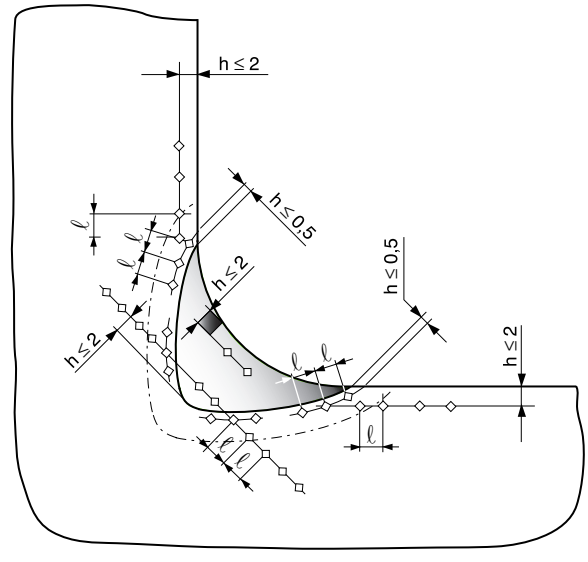
Hardness testing is required for steels with minimum specified yield strength equal to or greater than 355 N/mm^2. Unless otherwise agreed, the Vickers method HV10 is to be used.

The indentations are to be made in the weld, heat affected zones, and the parent metals measuring and recording the hardness values. Two rows of indentations are to be carried out in accordance with Fig 9.

For each row of indentations, there is to be a minimum of 3 individual indentations in the weld, the heat affected zones (both sides) and the parent metals (both sides).

The results of hardness tests are not to exceed 350 HV for steels with a specified minimum yield strength less than or equal to 420 N/mm^2.

Figure 9 : Macro and hardness indentations



2.4 Butt joint in pipes with full penetration

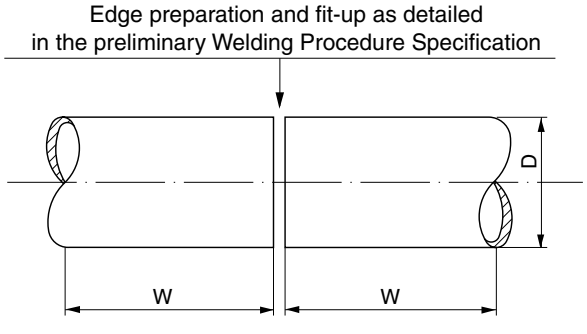
2.4.1 Assembly and welding

Preparation and welding are to be in accordance with the pWPS and under the general condition of production welding which it represents.

If tack welds are a condition of the weld process, they are to be fused into the joint and are to be included in the test pieces.

The test assembly is to be in accordance with Fig 10.

Figure 10 : Butt joint in pipes test assembly



W ≥ 150 mm; D : Outside diameter.

2.4.2 Examinations and tests

Non-destructive examinations and destructive tests required are given in Tab 1. The location of the test specimens is to be in accordance with Fig 11.

2.4.3 Non-destructive examinations

Reference is made to [2.1.3].

2.4.4 Transverse tensile tests

Reference is made to [2.1.4].

2.4.5 Tensile tests on cylindrical specimen

Reference is made to [2.1.5].

2.4.6 Bend tests

Reference is made to [2.1.6].

2.4.7 Impact tests

Reference is made to [2.1.7].

2.4.8 Macro examination

Reference is made to [2.1.8].

2.4.9 Hardness tests

Reference is made to [2.1.9].

2.5 Branch connection in pipes

2.5.1 General

Where this type of joints is predominant in production, qualification tests are to be performed on branch connection assembly in addition to the equivalent qualification on butt joint.

The same principle applies when changes occur in the geometry of the bevel may significantly affect the penetration or fusion.

2.5.2 Assembly and welding

Preparation and welding are to be in accordance with the pWPS and under the general condition of production welding which it represents.

If tack welds are a condition of the weld process, they are to be fused into the joint and are to be included in the test pieces.

The test assembly is to be in accordance with Fig 12.

2.5.3 Examinations and tests

Non-destructive examinations and destructive tests are required according to Tab 4. The location of the test specimens is to be in accordance with Fig 13.

2.5.4 Visual examination and surface crack detection

Reference is made to [2.1.3].

2.5.5 Macro examination

Reference is made to [2.1.8].

Figure 11 : Location of the test specimens

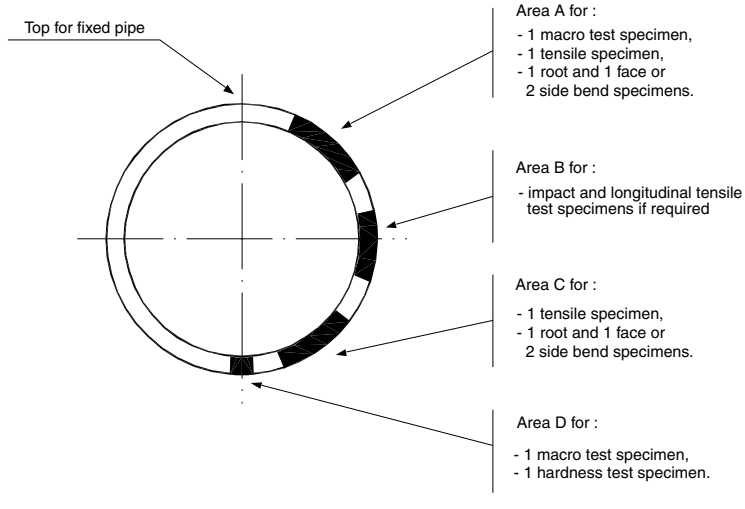


Figure 12 : Test assembly for branch connection in pipes

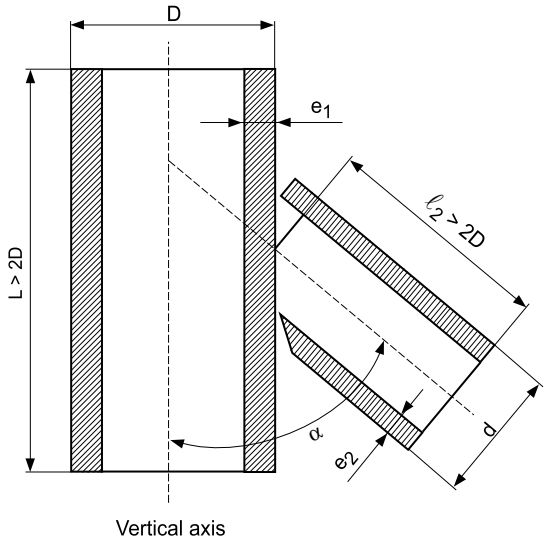


Table 4 : Examinations and tests for branch connection in pipes

Type of examination or test	Extent of examination or test
Visual examination	100%
Surface crack detection **(1)**	100%
Ultrasonic examination **(4)**	100%
Macro examination	on 1 section
Hardness test **(2)**	on 1 section
Longitudinal tensile test **(3)**	1 specimen

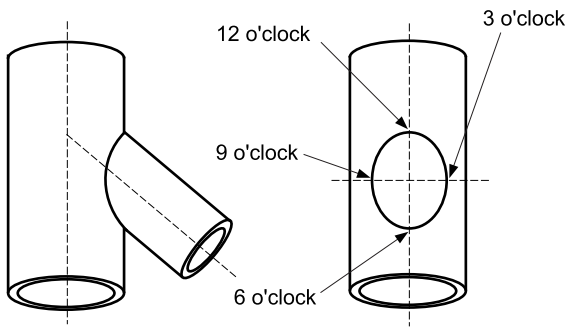
(1) Dye penetrant according to ISO 3452 (or equivalent accepted standard) or magnetic particle testing; for non-magnetic materials, dye penetrant only.

(2) Only required for high strength steels with minimum specified yield strength equal to or greater than 355 N/mm^2.

(3) Required for thickness above 50 mm or when the use of non-approved filler metal has been accepted (see [1.2.3]).

(4) Applicable to full penetration weld or to verify the extent of penetration in partial penetration welds

Figure 13 : Location of test specimen for branch connection in pipes



Area 6 o'clock for macrographic examination and hardness tests

Areas 3 or 9 o'clock for macrographic examination.

2.5.6 Hardness test

Hardness testing is required for steels with minimum specified yield strength equal to or greater than 355 N/mm^2. Unless otherwise agreed, the Vickers method HV10 is to be used.

The indentations are to be made in the weld, heat affected zones, and the parent metals measuring and recording the hardness values.

Rows of indentations are to be carried out in accordance with Fig 7.

For each row of indentations, there is to be a minimum of 3 individual indentations in the weld, the heat affected zones (both sides) and the parent metals (both sides).

The results of hardness tests are not to exceed 350 HV for steels with a specified minimum yield strength less than or equal to 420 N/mm^2.

2.6 Re-testing

2.6.1 If the test piece fails to comply with any of the requirements for visual or non-destructive testing, one further test piece is to be welded and subjected to the same examination.

If this additional test piece does not comply with the relevant requirements, the pWPS is to be regarded as not capable of complying with the requirements without modification.

2.6.2 If any test specimens fails to comply with the relevant requirements for destructive testing due to weld imperfection only, two further test specimens shall be obtained for each one that failed. These specimens can be taken from the same test piece if there is sufficient material available or from a new test piece, and is to be subjected to the same test. If either of these additional test specimens does not comply with the relevant requirements, the pWPS is to be regarded as not capable of complying with the requirements without modification.

2.6.3 If a tensile test specimen fails to meet the requirements, the re-testing is to be in accordance with NR216 Materials and Welding, Ch 1, Sec 2, [2.3].

2.6.4 If there is a single hardness value above the maximum values allowed, additional hardness tests shall be carried out (on the reverse of the specimen or after sufficient grinding of the tested surface). None of the additional hardness values is to exceed the maximum hardness values required.

2.6.5 The re-testing of Charpy V-notch impact test specimens are to be carried out in accordance with NR216 Materials and Welding, Ch 1, Sec 2, [4.4].

2.6.6 Where there is not sufficient material remaining in the test piece to provide the additional test specimens, a further assembly shall be welded using the same procedure to provide the additional specimens.

2.7 Range of approval

2.7.1 General

The approval of a WPS obtained by a yard or manufacturer is valid for welding in workshops under the same technical and quality management, to the Society's satisfaction.

The welding procedure is to be used within the range of the parameters indicated below; changes outside the range specified of one or more of these parameters require a new qualification test.

2.7.2 Parent metal

Where the equivalent carbon of the base material is more than 0,3% above that of the base material used for the qualification, the welding procedure is to be re-qualified.

For hull structural steel grades A to FH40 as defined in NR216 Materials and Welding, Ch 2, Sec 1, [2], the following applies:

a) for each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested

b) for each toughness grade, welding procedures are considered applicable to the same and two lower strength levels as that tested

c) for applying the above items a) and b) to high heat input processes above 50 kJ/cm, e.g. the two-run technique with either submerged arc or gas shielded metal arc welding, electroslag and electrogas welding, welding procedure is applicable that toughness grade tested and one strength level below.

Where steels used for construction are supplied from different delivery conditions from those tested, the Society may require additional tests.

For weldable C and C-Mn hull steel forgings as defined in NR216 Materials and Welding, Ch 2, Sec 3, [2], the following applies:

a) welding procedures are considered applicable to the same and lower strength level as that tested

b) qualification tests on quenched and tempered hull structural steel forgings do not qualify other delivery condition and vice-versa.

For weldable C and C-Mn hull steel castings as defined in NR216 Materials and Welding, Ch 2, Sec 4, [2], the following applies:

a) welding procedures are considered applicable to the same and lower strength level as that tested

b) qualification tests on quenched and tempered hull structural steel forgings do not qualify other delivery condition and vice-versa.

2.7.3 Thickness

The qualification of a WPS carried out on a welded assembly of thickness t is valid for the thickness range given in Tab 5.

Table 5 : Approved thickness range

Thickness t of test piece (mm) **(1)**	Range of approval	
	Single run or single run from both sides, Butt and T -joints	Multi-run welding, Butt, T-joint and fillet welds **(2)**
3 < t ≤ 12	0,7 t to 1,1 t	3 mm to 2 t **(2)**
12 < t ≤ 100	0,7 t to 1,1 t **(3)**	0,5 t to 2 t (max.150)

(1) For multi process procedures, the recorded thickness contribution of each process is to be used as a basis for the range of approval for the individual welding process.

(2) For fillet welds, the range of approval is to be applied to both parent materials.

(3) For high heat input process over 50 kJ/cm, the upper limit of range of approval is to be 1,0 t.

In addition to the requirements of Tab 5, the range of approval for fillet welds shall be as follows:

a) Single pass fillet welds: for throat thickness "a", the range of approval is "0,75 a" to "1,5 a"

b) Multipass fillet welds: for throat thickness "a" the range of approval is as for multipass butt welds (i.e. a = t).

For the vertical-down welding, the test piece thickness t is always taken as the upper limit of the range of application.

For unequal plate thickness of butt welds, the lesser thickness is the ruling dimension.

Notwithstanding the above, the approval of maximum base material thickness for any technique is restricted to the test assembly thickness if three of the hardness values in the heat affected zone are found to be within 25 HV of the maximum permitted, as stated in [2.1.9] and [2.3.7].

2.7.4 Pipe diameter

Qualification tests on an assembly of pipes of diameter D is valid for diameters in the range given in Tab 6.

Table 6 : Approved diameter range

Diameter of the test piece (mm)	Range of approval **(1)**
D ≤ 25	0,5 D to 2,0 D
D > 25	≥ 0,5 D (25 mm min.)

(1) Qualification for plates also covers pipes with outside diameter > 500 mm.

2.7.5 Welding position

Standard positions are given in Fig 14 for plates and pipes.

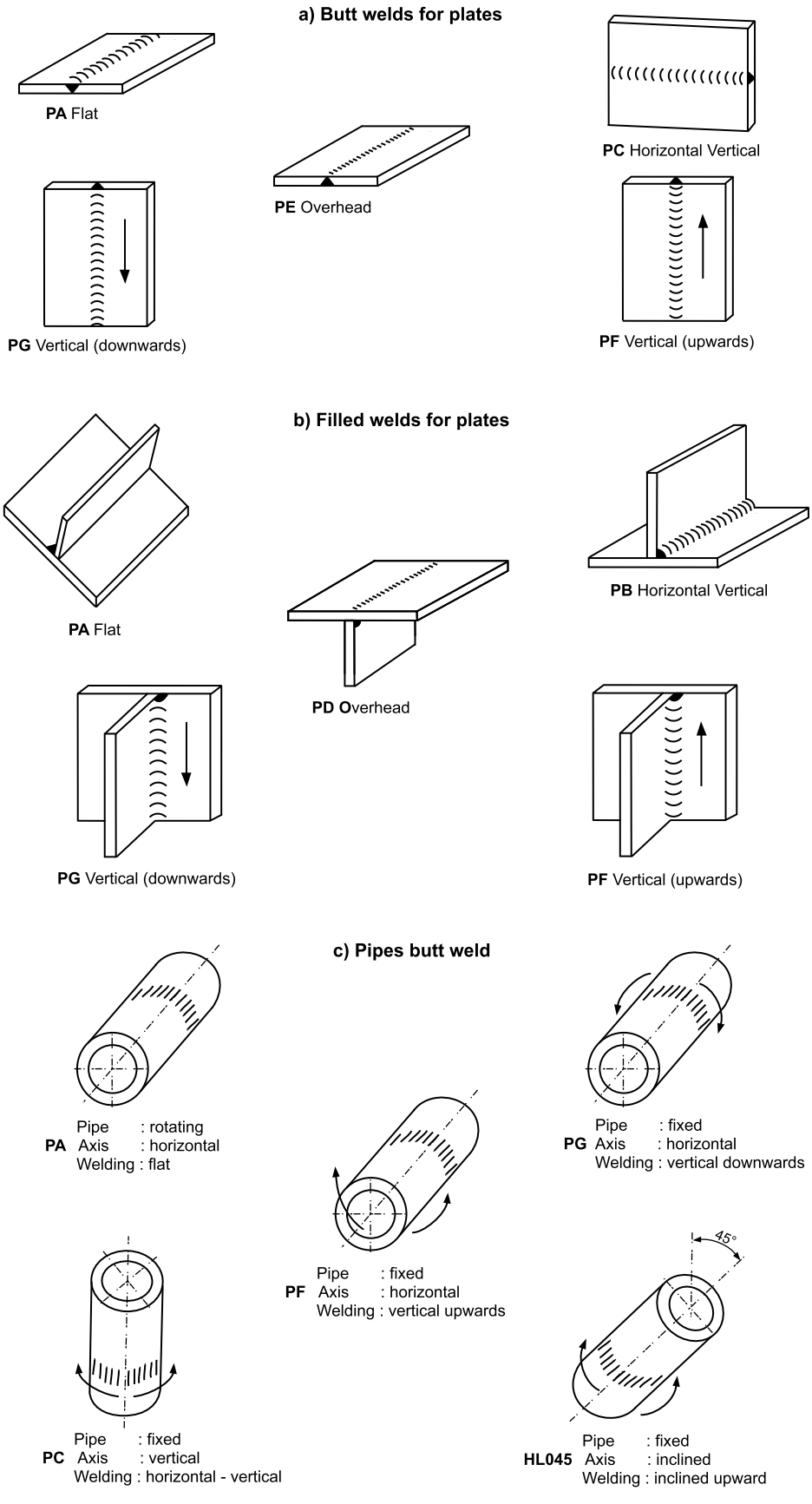
Approval for a test made in any position is restricted to that position.

To qualify all positions, test assemblies are to be welded for highest and lowest heat input position and all applicable tests are to be made on those assemblies.

For plates butt welds with full penetration, the highest heat input position is normally the vertical upwards position and the lowest heat input position is normally the horizontal-vertical position.

Vertical downwards techniques are to be qualified separately.

Figure 14 : Welding positions according to ISO Standard



2.7.6 Welding process

The approval is only valid for the welding process(es) used in the qualification tests. It is not permitted to change from a multi-run to a single run.

For multi-process procedures the welding procedure approval may be carried out with separate qualification tests for each welding process. It is also accepted to make the qualification test as a multi-process procedure test. The approval of such a test is only valid for the process sequence carried out during the multi-process procedure test.

For the manual metal arc welding process (111) and semi-automatic welding process with flux cored wire without shielding gas (114), the approval obtained is valid for the diameter of the electrode used in the welding procedure test plus or minus one electrode diameter size for each run, except for the root run of the one side welded assembly without backing strip, for which no size change is allowed.

For the gas metal arc welding processes (131, 135, 136), the approval obtained for face and/or back shielding gas is restricted to the type of gas (nominal composition) used during the procedure test. The approval is restricted to the wire system used in the approval test (e.g. single wire or multi-wire) and, in the case of automatic welding, to the relevant welding technique.

For the submerged arc processes (12), the approval obtained is restricted to the wire system used in the approval test (e.g. single wire or multi-wire) and relevant welding technique (T, M, U). Change in the flux trade mark requires new welding procedure approval tests.

2.7.7 Welding consumables

Except high heat input process (over 50 kJ/cm), welding consumables tested cover other approved welding consumables having the same grade mark including all suffixes specified in NR216 Materials and Welding, Ch 5, Sec 2, with that tested.

Change in the trade name of filler metal requires new welding procedure approval tests when Charpy V-notch impact tests are required at temperature strictly below –20°C.

2.7.8 Heat input

The upper limit of heat input approved is 25% greater than that used in welding the test piece or 50 kJ/cm whichever is smaller, except that the upper limit is 10% greater than that for high heat input processes over 50 kJ/cm.

The lower limit of heat input approved is 25% lower than that used in welding the test piece.

2.7.9 Preheat and interpass temperature

The minimum preheat temperature is not to be less than that used in the qualification test.

The minimum interpass temperature is not to be less than the specified preheat temperature.

The maximum interpass temperature is not to be higher than that used in the qualification test.

2.7.10 Post-weld heat treatment

The heat treatment used in the qualification test is to be maintained during manufacture. Holding time may be adjusted as a function of thickness.

2.7.11 Type of joint

The range of approval depending on type of welded joint for test assembly is given in NR426 Construction Survey of Steel Structures, Sec 4, Tab 7 to Sec 4, Tab 9.

New qualification tests may be required by the Surveyor when changes occur in the geometry of the bevel which may significantly affect the penetration or fusion.

3 Approval of stud welding

3.1 General

3.1.1 Stud welding to elements in special and first category is to be qualified by tests which shall include as a minimum macro-examination and hardness tests to check that there are no detrimental effects on the base material.

RULES FOR THE CLASSIFICATION OF NAVAL SUBMARINES

Part D
Systems

Chapters **1 2 3 4 5 6**

CHAPTER 1 GENERAL REQUIREMENTS

CHAPTER 2 PROPULSION

CHAPTER 3 MACHINERY AND STEERING

CHAPTER 4 POWER SUPPLY

CHAPTER 5 AUTOMATION

CHAPTER 6 COMMUNICATION AND NAVIGATING

September 2016

Part D
Systems

Chapter 1
GENERAL REQUIREMENTS

SECTION 1 GENERAL REQUIREMENTS

SECTION 1 GENERAL REQUIREMENTS

1 General

1.1 Application

1.1.1 Part D, Chapter 2 and Part D, Chapter 3 apply to the design, construction, installation, tests and trials of main propulsion and essential auxiliary machinery systems and associated equipment, boilers and pressure vessels, piping systems, and steering and manoeuvring systems installed on board classed submarines.

1.1.2 Part D, Chapter 4, Part D, Chapter 5 and Part D, Chapter 6 apply to the design, construction, installation and test and trials of equipment involved in power supply, automation, communication and navigating systems installed on board classed submarines.

1.2 Additional requirements

1.2.1 Additional requirements for systems are given in Part F for the assignment of additional class notations.

1.3 Documentation to be submitted

1.3.1 Before the actual construction is commenced, the Manufacturer, Designer or Shipbuilder is to submit to the Society the documents (plans, diagrams, specifications and calculations) requested in the relevant Sections of this Chapter.

The list of documents requested in each Section is to be intended as guidance for the complete set of information to be submitted, rather than an actual list of titles.

The Society reserves the right to request the submission of additional documents to those detailed in the Sections, in the case of non-conventional design or if it is deemed necessary for the evaluation of the system, equipment or component.

Plans are to include all the data necessary for their interpretation, verification and approval.

Unless otherwise stated in the other Sections of this Chapter or agreed with the Society, documents for approval are to be sent in triplicate if submitted by the Shipyard and in four copies if submitted by the equipment supplier. Documents requested for information are to be sent in duplicate.

In any case, the Society reserves the rights to require additional copies when deemed necessary.

Part D
Systems

Chapter 2
PROPULSION

SECTION 1 PROPELLERS

SECTION 2 MAIN PROPULSION SHAFTING

SECTION 1 PROPELLERS

1 General

1.1 Application

1.1.1 Propulsion propellers

The requirements of this Section apply to propellers of any size and type intended for propulsion. They include fixed propellers including those ducted in fixed nozzles.

1.1.2 Exclusions

The requirements of this Section do not apply to pump jet propellers.

1.2 Definitions

1.2.1 Solid propeller

A solid propeller is a propeller (including hub and blades) cast in one piece.

1.2.2 Built-up propeller

A built-up propeller is a propeller cast in more than one piece. In general, built up propellers have the blades cast separately and fixed to the hub by a system of bolts and studs.

1.2.3 Nozzle

A nozzle is a circular structural casing enclosing the propeller.

1.2.4 Ducted propeller

A ducted propeller is a propeller installed in a nozzle.

1.2.5 Geometry of propeller

For all geometrical definitions (see Fig 1):

a) Blade area and area ratio

A_P : Projected blade area, i.e. projection of the blade area in the direction of the propeller shaft

A_D : Developed blade area, i.e. area enclosed by the connection line between the end points of the cylindrical profile sections turned in the propeller plane

A_E : Expanded blade area, i.e. area enclosed by the connection line between the end points of the developed and additionally straightened sections

A_O : Disc area calculated by means of the propeller diameter

B : Developed area ratio with $B = A_D / A_O$.

b) Rake and rake angle

h : Rake is the horizontal distance between the line connecting the blade tip to the blade root and the vertical line crossing the propeller axis in the same point where the prolongation of the first line crosses it, taken in correspondence of the blade tip. Aft rakes are considered positive, fore rakes are considered negative

Rake angle is the angle at any point between the tangent to the generating line of the blade at that point and a vertical line passing at the same point. If the blade generating line is straight, there is only one rake angle; if it is curved there are an infinite number of rake angles.

c) Skew angle at tip of blade

ϑ : Skew angle at the tip of blade, i.e. the angle on the projected blade plane between a line starting at the centre of the propeller axis and tangent to the blade midchord line and a line also starting at the centre of the propeller axis and passing at the outer end of this midchord line as measured.

d) Skewed propellers

Skewed propellers are propellers whose blades have a skew angle other than 0.

e) Highly skewed propellers and very highly skewed propellers

- highly skewed propellers are propellers having blades with skew angle between 25° and 50°
- very highly skewed propellers are propellers having blades with skew angle exceeding 50°.

f) Leading and trailing edges

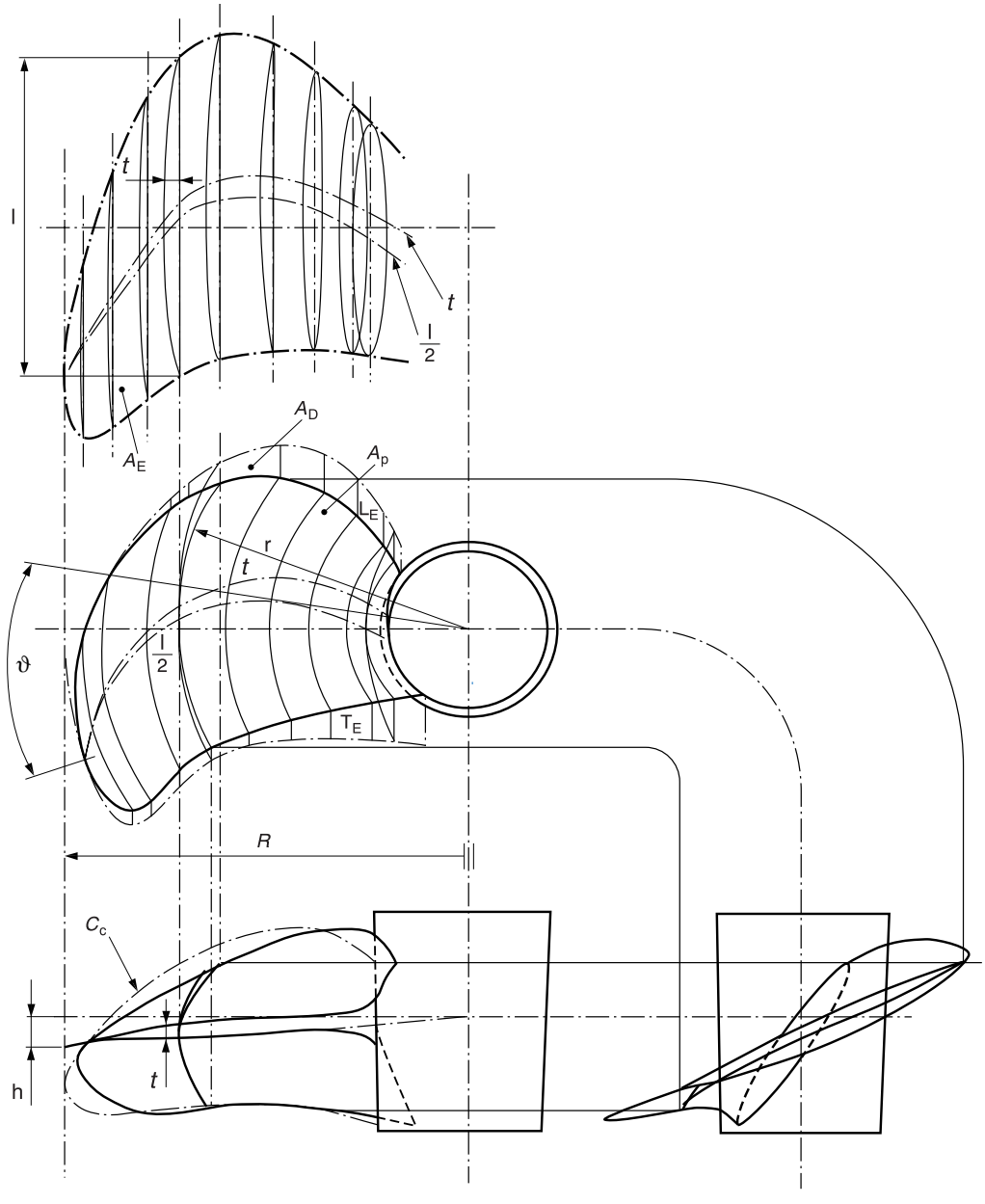
L_E : Leading edge of a propeller blade, i.e. the edge of the blade at side entering the water while the propeller rotates

T_E : Trailing edge of a propeller blade, i.e. the edge of the blade opposite to the leading edge.

1.2.6 Rake angle

Rake angle is the angle at any point between the tangent to the generating line of the blade at that point and a vertical line passing at the same point. If the blade generating line is straight, there is only one rake angle; if it is curved there are an infinite number of rake angles (see Fig 1).

Figure 1 : Description of propeller



1.2.7 Skew angle

Skew angle is the angle between a ray starting at the centre of the propeller axis and tangent to the blade midchord line and a ray also starting at the centre of the propeller axis and passing at the blade tip (see Fig 1).

1.2.8 Skewed propellers

Skewed propellers are propellers whose blades have a skew angle other than 0.

1.2.9 Highly skewed propellers and very highly skewed propellers

Highly skewed propellers are propellers having blades with skew angle exceeding 25°. Very highly skewed propellers are propellers having blades with skew angle exceeding 50°.

1.2.10 Leading edge

The leading edge of a propeller blade is the edge of the blade at side entering the water while the propeller rotates (see Fig 1).

1.2.11 Trailing edge

The trailing edge of a propeller blade is the edge of the blade opposite the leading edge (see Fig 1).

1.2.12 Blade developed area

Blade developed area is the area of the blade surface expanded in one plane.

1.2.13 Developed area ratio

Developed area ratio is the ratio of the total blade developed area to the area of the ring included between the propeller diameter and the hub diameter.

1.3 Documentation to be submitted

1.3.1 Solid propellers

The documents listed in Tab 1 are to be submitted for solid propellers intended for propulsion.

All listed plans are to be constructional plans complete with all dimensions and are to contain full indication of types of materials employed.

Table 1 : Documents to be submitted for solid propellers

No.	A/I (1)	ITEM
1	A	Sectional assembly
2	A	Blade and hub details
3	I	Rating (power, rpm, etc.)
4	A	Data and procedures for fitting propeller to the shaft
(1) A = to be submitted for approval in four copies I = to be submitted for information in duplicate.		

1.3.2 Built-up propellers

The documents listed in Tab 2, as applicable, are to be submitted for built-up propellers intended for propulsion.

Table 2 : Documents to be submitted for built-up propellers

No.	A/I (1)	ITEM
1	A/I	Same documents requested for solid propellers
2	A	Blade bolts and pre-tensioning procedures
(1) A = to be submitted for approval in four copies I = to be submitted for information in duplicate.		

1.3.3 Very highly skewed propellers and propellers of unusual design

For very highly skewed propellers and propellers of unusual design, in addition to the documents listed in Tab 1 and Tab 2, as applicable, a detailed hydrodynamic load and stress analysis is to be submitted (see [2.4.3]).

2 Design and construction

2.1 Materials

2.1.1 Normally used materials for propeller hubs and blades

a) Tab 3 indicates the minimum tensile strength R_m (in N/mm^2), the density δ (in kg/dm^3) and the material factor f of normally used materials.

b) Common bronze, special types of bronze and cast steel used for the construction of propeller hubs and blades are to have a minimum tensile strength of 400 N/mm^2.

c) Other materials are subject of special consideration by the Society following submission of full material specification.

Table 3 : Normally used materials for propeller blades and hub

Material	R_m	δ	f
Common bronze	400	8,3	7,6
Manganese bronze	440	8,3	7,6
Nickel-manganese bronze	440	8,3	7,9
Aluminium bronze	590	7,6	8,3
Steel	440	7,9	9,0

2.1.2 Materials for studs

In general, steel (preferably nickel-steel) is to be used for manufacturing the studs connecting steel blades to the hub of built-up or controllable pitch propellers, and high tensile brass or stainless steel is to be used for studs connecting bronze blades.

2.2 Solid propellers

2.2.1 Blade thickness

a) The maximum thickness $t_{0,25}$, in mm, of the solid propeller blade at the section at 0,25 radius from the propeller axis is not to be less than that obtained from the following formula:

$$t_{0,25} = 3,2\left[f \cdot \frac{1,5.10^6.\rho.M_T + 51.\delta.\left(\frac{D}{100}\right)^3.B.l.N^2.h}{l \cdot z \cdot R_m}\right]^{0,5}$$

where:

f : Material factor as indicated in Tab 3

$\rho = D / H$

H : Mean pitch of propeller, in m. When H is not known, the pitch at 0,7 radius from the propeller axis $H_{0,7}$ may be used instead of H

D : Propeller diameter, in m

M_T : Continuous transmitted torque, in kN.m; where not indicated, the value given by the following formula may be assumed for M_T:

$$M_T = 9,55 \cdot \left(\frac{P}{N}\right)$$

P : Maximum continuous power of propulsion machinery, in kW

N : Rotational speed of the propeller, in rev/min

δ : Density of blade material, in kg/dm^3, as indicated in Tab 3

B : Developed area ratio

h : Rake, in mm

l : Expanded width of blade section at 0,25 radius from propeller axis, in mm

z : Number of blades

R_m : Minimum tensile strength of blade material, in N/mm^2.

b) The maximum thickness $t_{0.6}$, in mm, of the solid propeller blade at the section at 0,6 radius from the propeller axis is not to be less than that obtained from the following formula:

$$t_{0,6} = 1,9\left[f\,\frac{1,5.10^6.\rho_{0,6}.M_T + 18,4.\delta.\left(\frac{D}{100}\right)^3.B.l.N^2.h}{l_{0,6}\cdot z\cdot R_m}\right]^{0,5}$$

where:

$\rho_{0,6} = D / H_{0.6}$

$H_{0.6}$: Pitch at 0,6 radius from the propeller axis, in m

$l_{0.6}$: Expanded width of blade section at 0,6 radius from propeller axis, in mm.

c) The radius at the blade root is to be at least 3/4 of the minimum thickness required in that position. As an alternative, constant stress fillets may also be considered. When measuring the thickness of the blade, the increased thickness due to the radius of the fillet at the root of the blade is not to be taken into account. If the propeller hub extends over 0,25 radius, the thickness calculated by the formula in a) is to be compared with the thickness obtained by linear interpolation of the actual blade thickness up to 0,25 radius.

d) As an alternative, a detailed hydrodynamic load and stress analysis carried out by the propeller designer may be considered by the Society. The hydrodynamic analysis is to be carried out according to recognized techniques (e.g. lifting line, lifting surface, panel methods). For stress analysis the blade is to be modelled as a cantilever subject to centrifugal and hydrodynamic forces; more complex blade models are also accepted. The safety factor resulting form such calculation is not to be less than 7,5 with respect to the minimum ultimate tensile strength of the propeller material R_m. Lower values, up to a minimum of 5 may be considered, when the load hypothesis for the calculation take in account margin for:

- full load end of life displacement
- sea state
- hull fouling
- doubts on ship resistance and global propulsion efficiency.

A fatigue strength analysis of the propeller is to be carried out. It should take in account the stress variation in the blade during rotation.

e) Maximum stress on blade during most severe transitory state of submarine propulsion system (for instance astern running in order to decrease speed in case of diving rudder dysfunction) must not overpass yield strength of the propeller material.

2.3 Built-up propellers

2.3.1 Blade thickness

a) The maximum thickness $t_{0.35}$, in mm, of the blade at the section at 0,35 radius from the propeller axis is not to be less than that obtained from the following formula:

$$t_{0,35} = 2,7\left[f\,\frac{1,5.10^6.\rho_{0,35}.M_T + 41.\delta\left(\frac{D}{100}\right)^3 B.l_{0.35}.N^2h}{l_{0.35}\cdot z\cdot R_m}\right]^{0,5}$$

where:

$\rho_{0,35} = D / H_{0.35}$

$H_{0.35}$: Pitch at 0,35 radius from the propeller axis, in m

$l_{0.35}$: Expanded width of blade section at 0,35 radius from propeller axis, in mm.

b) The maximum thickness $t_{0.6}$, in mm, of the solid propeller blade at the section at 0,6 radius from the propeller axis is not to be less than that obtained from the formula in [2.2.1] item b), using the value of $l_{0.35}$ in lieu of l.

c) The radius at the blade root is to be at least 3/4 of the minimum thickness required in that position. As an alternative, constant stress fillets may also be considered. When measuring the thickness of the blade, the increased thickness due to the radius of the fillet at the root of the blade is not to be taken into account.

d) As an alternative, a detailed hydrodynamic load and stress analysis carried out by the propeller designer may be considered by the Society. The hydrodynamic analysis is to be carried out according to recognized techniques (e.g. lifting line, lifting surface, panel methods). For stress analysis the blade is to be modelled as a cantilever subject to centrifugal and hydrodynamic forces; more complex blade models are also accepted. The safety factor resulting form such calculation is not to be less than 7,5 with respect to the minimum ultimate tensile strength of the propeller material R_m. Lower values, up to a minimum of 5 may be considered, when the load hypothesis for the calculation take in account margin for:

- full load end of life displacement
- sea state
- hull fouling
- doubts on ship resistance and global propulsion efficiency.

A fatigue strength analysis of the propeller is to be carried out. It should take in account the stress variation in the blade during rotation.

2.3.2 Flanges for connection of blades to hubs

a) The diameter D_F, in mm, of the flange for connection to the propeller hub is not to be less than that obtained from the following formula:

$D_F = D_C + 1,8\ d_{PR}$

where:

D_C : Stud pitch circle diameter, in mm

d_{PR} : Diameter of studs.

b) The thickness of the flange is not to be less than 1/10 of the diameter D_F.

c) In case blade flanges are not from the circular type, some direct calculation is to be submitted to Society.

2.3.3 Connecting studs

a) The diameter d_{PR}, in mm, at the bottom of the thread of the studs is not to be less than obtained from the following formula:

$$d_{PR} = \left(\frac{4{,}6.10^{7}.\rho_{0,7}.M_T + 0{,}88.\delta.\left(\frac{D}{10}\right)^{3}.B.l_{0.35}.N^{2}.h_1}{n_{PR} \cdot z \cdot D_C \cdot R_{m,PR}} \right)^{0,5}$$

where:

$h_1 = h + 1{,}125\ D_C$

n_{PR} : Total number of studs in each blade

$R_{m,PR}$: Minimum tensile strength of stud material, in N/mm^2.

b) The studs are to be tightened in a controlled manner such that the tension on the studs is approximately 60-70% of their yield strength.

c) The shank of studs may be designed with a minimum diameter equal to 0,9 times the root diameter of the thread.

d) The studs are to be properly secured against unintentional loosening.

2.4 Skewed propellers

2.4.1 Skewed propellers

The thickness of skewed propeller blades may be obtained by the formulae in [2.2] and [2.3.1], as applicable, provided the skew angle is less than 25°.

2.4.2 Highly skewed propellers

a) For solid and controllable pitch propellers having skew angles between 25° and 50°, the blade thickness, in mm, is not to be less than that obtained from the following formulae:

1) for solid propellers:

$$t_{S-0,25} = t_{0,25} \cdot (0{,}92 + 0{,}0032\vartheta)$$

2) for built-up and controllable pitch propellers:

$$t_{S-0,35} = t_{0,35} \cdot (0{,}9 + 0{,}004\vartheta)$$

3) for all propellers:

$$t_{S-0,6} = t_{0,6} \cdot (0{,}74 + 0{,}0129\vartheta - 0{,}0001\vartheta^2)$$

$$t_{S-0,9} = t_{0,6} \cdot (0{,}35 + 0{,}0015\vartheta)$$

where:

$t_{S-0,25}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,25 radius from the propeller axis

$t_{0,25}$: Maximum thickness, in mm, of normal shape propeller blade at the section at 0,25 radius from the propeller axis, obtained by the formula in [2.2.1]

$t_{S-0,35}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,35 radius from the propeller axis

$t_{0,35}$: Maximum thickness, in mm, of normal shape propeller blade at the section at 0,35 radius from the propeller axis, obtained by the formula in [2.3.1]

$t_{S-0,6}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,6 radius from the propeller axis

$t_{0,6}$: Maximum thickness, in mm, of normal shape propeller blade at the section at 0,6 radius from the propeller axis, obtained by the formula in [2.2.1]

$t_{S-0,9}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,9 radius from the propeller axis

ϑ : Skew angle.

b) As an alternative, a detailed hydrodynamic load and stress analysis carried out by the propeller designer may be considered by the Society. The hydrodynamic analysis is to be carried out according to recognized techniques (e.g. lifting line, lifting surface, panel methods). The stress analysis is to be carried out by a FEM method. The safety factor resulting form such calculation is not to be less than 8 with respect to the minimum ultimate tensile strength of the propeller material R_m.

Lower values, up to a minimum of 5 may be considered, when the load hypothesis for the calculation take in account margin for:

- full load end of life displacement
- sea state
- hull fouling
- doubts on ship resistance and global propulsion efficiency.

A fatigue strength analysis of the propeller is to be carried out. It should take in account the stress variation in the blade during rotation.

2.4.3 Very highly skewed propellers

For very highly skewed propellers, the blade thickness is to be obtained by a stress analysis according to a calculation criteria accepted by the Society. The safety factor to be used in this direct analysis is not to be less than 8 with respect to the ultimate tensile strength R_m of the propeller blade material.

2.5 Ducted propellers

2.5.1 The minimum blade thickness of propellers with wide tip blades running in nozzles is not to be less than the values obtained by the applicable formula in [2.2] or [2.3.1], increased by 10%.

2.6 Features

2.6.1 Blades and hubs

a) All parts of propellers are to be free of defects and are to be built and installed with clearances and tolerances in accordance with sound marine practice.

b) Particular care is to be taken with the surface finish of the blades with the specified class in ISO 484-1 and ISO 484-2.

c) In case of direct calculation the class to be specified is to take in account the safety factor resulting of the fatigue strength calculation.

3 Arrangement and installation

3.1 Fitting of propeller on the propeller shaft

3.1.1 General

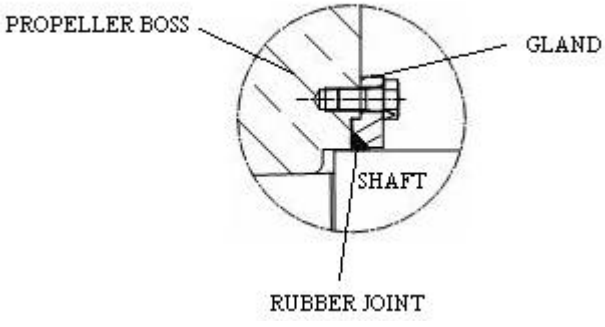
a) Screw propeller hubs are to be properly adjusted and fitted on the propeller shaft cone. The contacts shall be checked to be not less than 70% of the theoretical contact area. Non-contact bands extending circumferentially around the boss (excluding the center shanked part), or over the full length of the boss are not acceptable.

b) The forward end of the hole in the hub is to have the edge rounded to a radius of approximately 6 mm.

c) In order to prevent any entry of sea water under the liner and onto the end of the propeller shaft, the arrangement of Fig 2 is generally to be adopted for assembling the liner and propeller boss.

d) The external stuffing gland is to be provided with a seawater resistant rubber ring preferably without joints. The clearance between the liner and the internal air space of the boss is to be as small as possible. The internal air space is to be filled with an appropriate protective material which is insoluble in sea water and non-corrodible or fitted with a rubber ring.

Figure 2 : Example of sealing arrangement



e) All free spaces between the propeller shaft cone, propeller boss, nut and propeller cap are to be filled with a material which is insoluble in sea water and non-corrodible. Arrangements are to be made to allow any air present in these spaces to withdraw at the moment of filling. It is recommended that these spaces be tested under a pressure at least equal to that corresponding to the immersion of the propeller in order to check the tightness obtained after filling.

f) For propeller keys and key area, see Ch 2, Sec 2, [2.7.5].

3.1.2 Shrinkage of keyless propellers

In the case of keyless shrinking of propellers, the following requirements apply:

a) The meaning of the symbols used in the subparagraphs below is as follows:

A : 100% theoretical contact area between propeller boss and shaft, as read from plans and disregarding oil grooves, in mm^2

d_{PM} : Diameter of propeller shaft at the mid-point of the taper in the axial direction, in mm

d_H : Mean outer diameter of propeller hub at the axial position corresponding to d_{PM}, in mm

$K = d_H / d_{PM}$

F : Tangential force at interface, in N

M_T : Continuous torque transmitted, in N.m; where not indicated, M_T may be assumed as indicated in [2.2.1]

C :
- C = 1,0 for turbines, geared diesel engines, electrical drives and direct-drive reciprocating internal combustion engines with a hydraulic, electromagnetic or high elasticity coupling
- C = 1,2 for diesel engines having couplings other than those specified above.

The Society reserves the right to increase the value of C if the shrinkage needs to absorb an extremely high pulsating torque

T : Temperature of hub and propeller shaft material, in °C, assumed for calculation of pull-up length and push-up load

V : Ship speed at P power, in knots

S : Continuous thrust developed for free running ship, in N

s_F : Safety factor against friction slip at 35°C

θ : Half taper of propeller shaft (for instance: for taper = 1/15, θ =1/30)

μ : Coefficient of friction between mating surfaces

p_{35} : Surface pressure between mating surfaces, in N/mm^2, at 35°C

p_T : Surface pressure, in N/mm^2, between mating surfaces at temperature T

p_0 : Surface pressure between mating surfaces, in N/mm^2, at 0°C

p_{MAX} : Maximum permissible surface pressure, in N/mm^2, at 0°C

d_{35} : Push-up length, in mm, at 35°C

d_T : Push-up length, in mm, at temperature T

d_{MAX} : Maximum permissible pull-up length, in mm, at 0°C

W_T : Push-up load, in N, at temperature T

σ_{ID} : Equivalent uni-axial stress in the boss according to the von Mises-Hencky criterion, in N/mm^2

α_P : Coefficient of linear expansion of shaft material, in mm/(mm°C)

α_M : Coefficient of linear expansion of boss material, in mm/(mm°C)

E_P : Value of the modulus of elasticity of shaft material, in N/mm^2

E_M : Value of the modulus of elasticity of boss material, in N/mm^2

ν_P : Poisson's ratio for shaft material

ν_M : Poisson's ratio for boss material

$R_{S,MIN}$: Value of the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p\,0,2}$), of propeller boss material, in N/mm^2.

For other symbols not defined above, see [2.2].

b) The manufacturer is to submit together with the required constructional plans specifications containing all elements necessary for verifying the shrinkage. Tests and checks deemed necessary for verifying the characteristics and integrity of the propeller material are also to be specified.

c) Moreover, the manufacturer is to submit an instruction handbook, in which all operations and any precautions necessary for assembling and disassembling the propeller, as well as the values of all relevant parameters, are to be specified. A copy, endorsed by the Society, is to be kept on board each ship where the propeller is installed.

d) The formulae and other provisions below do not apply to propellers where a sleeve is introduced between shaft and boss or in the case of hollow propeller shafts. In such cases, a direct shrinkage calculation is to be submitted to the Society.

e) The taper of the propeller shaft cone is not to exceed 1/15.

f) Prior to final pull-up, the contact area between the mating surfaces is to be checked and is not to be less than 70% of the theoretical contact area (100%). Non-contact bands extending circumferentially around the boss or over the full length of the boss are not acceptable.

g) After final push-up, the propeller is to be secured by a nut on the propeller shaft. The nut is to be secured to the shaft.

h) The safety factor s_F against friction slip at 35°C is not to be less than 2,8, under the combined action of torque and propeller thrust, based on the maximum continuous power P for which classification is requested at the corresponding speed of rotation N of the propeller, plus pulsating torque due to torsionals. Equivalent methods of calculation may be considered.

i) For the oil injection method, the coefficient of friction μ is to be 0,13 in the case of bosses made of bronze, brass or steel. For other methods, the coefficient of friction will be considered in each case by the Society.

j) The maximum equivalent uni-axial stress in the boss at 0°C, based on the von Mises-Hencky criterion, is not to exceed 70% of the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p0,2}$), of the propeller material, based on the test piece value. For cast iron, the value of the above stress is not to exceed 30% of the nominal tensile strength.

k) For the formulae given below, the material properties indicated in the following items are to be assumed:

- Modulus of elasticity, in N/mm^2:

  Cast and forged steel: $E = 206000$

  Cast iron: $E = 98000$

  Type Cu1 and Cu2 brass: $E = 108000$

  Type Cu3 and Cu4 brass: $E = 118000$

- Poisson's ratio:

  Cast and forged steel: $\nu = 0,29$

  All copper based alloys: $\nu = 0,33$

- Coefficient of linear expansion in mm/(mm°C):

  Cast and forged steel and cast iron: $\alpha = 12,0 \cdot 10^{-6}$

  All copper based alloys: $\alpha = 17,5 \cdot 10^{-6}$

l) For shrinkage calculation the formulae in the following items, which are valid for the ahead condition, are to be applied. They will also provide a sufficient margin of safety in the astern condition.

- Minimum required surface pressure at 35°C:

$$p_{35} = \frac{s_F S}{AB} \cdot \left[- s_F \theta + \left(\mu^2 + B \cdot \frac{F^2}{S^2} \right)^{0,5} \right]$$

  where:

  $B = \mu^2 - s_F^2\,\theta^2$

- Corresponding minimum pull-up length at 35°C:

$$d_{35} = \frac{p_{35} d_{PM}}{2\theta} \cdot \left[\frac{1}{E_M} \cdot \left(\frac{K^2+1}{K^2-1} + \nu_M \right) + \frac{1-\nu_P}{E_P} \right]$$

- Minimum pull-up length at temperature T (T<35°C):

$$d_T = d_{35} + \frac{d_{PM}}{2\theta} \cdot (\alpha_M - \alpha_P) \cdot (35 - T)$$

- Corresponding minimum surface pressure at temperature T:

$$p_T = p_{35} \cdot \frac{d_T}{d_{35}}$$

- Minimum push-up load temperature T:

$$W_T = A p_T \cdot (\mu + \theta)$$

- Maximum permissible surface pressure at 0°C:

$$p_{MAX} = \frac{0,7 R_{S,MIN} \cdot (K^2 - 1)}{(3K^4 + 1)^{0,5}}$$

- Corresponding maximum permissible pull-up length at 0°C:

$$d_{MAX} = d_{35} \cdot \frac{p_{MAX}}{p_{35}}$$

- Tangential force at interface:

$$F = \frac{2000 C M_T}{d_{PM}}$$

- Continuous thrust developed for free running ship; if the actual value is not given, the value, in N, calculated by one of the following formulae may be considered:

$$S = 1760 \cdot \frac{P}{V}$$

$$S = 57{,}3 \cdot 10^3 \cdot \frac{P}{H \cdot N}$$

3.1.3 Circulating currents

Means are to be provided to prevent circulating electric currents from developing between the propeller and the hull.

4 Testing and certification

4.1 Material tests

4.1.1 Solid propellers

Material used for the construction of solid propellers is to be tested in accordance with the requirements of NR216 Materials and Welding in the presence of the Surveyor.

4.1.2 Built-up propellers

In addition to the requirement in [4.1.1], materials for studs and for all other parts of the mechanism transmitting torque are to be tested in the presence of the Surveyor.

4.2 Testing and inspection

4.2.1 Inspection of finished propeller

Finished propellers are to be inspected at the manufacturer's plant by the Surveyor. At least the following checks are to be carried out:

- visual examination of the entire surface of the propeller blades
- conformity to approved plans of blade profile
- liquid penetrant examination of suspected and critical parts of the propeller blade, to the satisfaction of the Surveyor.

Repair of defective casting is not allowed without the previous agreement of the owner; where agreed, it is to be carried out according to the requirements of NR216 Materials and Welding, Ch 4, Sec 2, [1.10].

4.2.2 Balancing

Finished propellers are to be statically balanced as required by the relevant class according to ISO 484. For built-up propellers, the required static balancing of the complete propeller may be replaced by an individual check of blade weight and gravity centre position.

4.3 Certification

4.3.1 Certification of propellers

Propellers having the characteristics indicated in [1.1.1] are to be individually tested and certified by the Society.

4.3.2 Mass produced propellers

Mass produced propellers may be accepted within the framework of the type approval program of the Society.

SECTION 2 MAIN PROPULSION SHAFTING

1 General

1.1 Application

1.1.1 This Section applies to shafts, couplings, clutches and other shafting components transmitting power for main propulsion.

For shafting components in engines see Ch 3, Sec 2.

For propellers, see Ch 2, Sec 1.

For vibrations, see Article [4].

1.2 Documentation to be submitted

1.2.1 The Manufacturer is to submit to the Society the documents listed in Tab 1 for approval.

Plans of power transmitting parts and shaft liners listed in Tab 1 are to include the relevant material specifications.

2 Design and construction

2.1 Materials

2.1.1 General

The use of other materials or steels having values of tensile strength exceeding the limits given in [2.1.2], [2.1.3] and [2.1.4] will be considered by the Society in each case.

2.1.2 Shaft materials

In general, shafts are to be of forged steel having tensile strength R_m between 400 and 800 N/mm^2.

2.1.3 Couplings, flexible couplings, hydraulic couplings

Non-solid forged couplings and stiff parts of elastic couplings subjected to torque are to be of forged or cast steel, or nodular cast iron.

Rotating parts of hydraulic couplings may be of grey cast iron, provided that the peripheral speed does not exceed 40 m/s.

Table 1 : Documentation to be submitted

No.	Document (drawings, calculations, etc.)
1	Shafting arrangement **(1)**
2	Thrust shaft
3	Intermediate shafts
4	Propeller shaft
5	Shaft liners, relevant manufacture and welding procedures, if any
6	Couplings and coupling bolts
7	Flexible couplings **(2)**
8	Aft bearings
9	Details of sealing glands
10	Shaft alignment calculation, see also [3.3]

(1) This drawing is to show the entire shafting, from the main engine coupling flange to the propeller. The location of the thrust block, and the location and number of shafting bearings (type of material and length) are also to be shown.

(2) The Manufacturer of the elastic coupling is also to submit the following data:

- allowable mean transmitted torque (static) for continuous operation
- maximum allowable shock torque
- maximum allowable speed of rotation
- maximum allowable values for radial, axial and angular misalignment.

In addition, when the torsional vibration calculation of main propulsion system is required, the following data are also to be submitted:

- allowable alternating torque amplitude and power loss for continuous operation, as a function of frequency and/or mean transmitted torque
- static and dynamic stiffness, as a function of frequency and/or mean transmitted torque
- moments of inertia of the primary and secondary halves of the coupling
- damping coefficient or damping capability
- properties of rubber components
- for steel springs of couplings: chemical composition and mechanical properties of steel employed.

2.1.4 Coupling bolts

Coupling bolts are to be of forged, rolled or drawn steel.

In general, the value of the tensile strength of the bolt material R_{mB} is to comply with the following requirements:

- $R_m \leq R_{mB} \leq 1,7\ R_m$
- $R_{mB} \leq 1000$ N/mm^2.

2.1.5 Shaft liners

Liners are to be of metallic corrosion resistant material complying with the applicable requirements of NR216 Materials and Welding and with the approved specification, if any; in the case of liners fabricated in welded lengths, the material is to be recognized as suitable for welding.

In general, they are to be manufactured from castings.

For small shafts, the use of liners manufactured from pipes instead of castings may be considered.

Where shafts are protected against contact with seawater not by metal liners but by other protective coatings, the coating procedure is to be approved by the Society.

2.2 Shafts - Scantling

2.2.1 General

For the check of the scantling, the methods given in [2.2.2] and [2.2.3] apply for intermediate shafts and propeller shafts, respectively. As an alternative, the direct stress calculation method as per [2.2.4] may be applied.

The scantling of the propulsion shafting is to be done for the power determined as per [2.2.4]. Whenever some trials are scheduled over maximum continuous power, fatigue strength is to be verified for evaluated cumulated duration of trials at this power.

2.2.2 Intermediate and thrust shafts

The minimum diameter of intermediate and thrust shafts is not to be less than the value d, in mm, given by the following formula:

$$d = F \cdot k \cdot \left[\frac{P}{n \cdot (1 - Q^4)} \cdot \frac{560}{R_m + 160} \right]^{1/3}$$

where:

Q :
- in the case of solid shafts: Q = 0
- in the case of hollow shafts: Q = ratio of the hole diameter to the outer shaft diameter in the section concerned.

  where $Q \leq 0,3$: Q = 0 is to be taken.

  Hollow shafts whose longitudinal axis does not coincide with the longitudinal hole axis will be specially considered by the Society in each case

F :
- F = 95 for main propulsion systems powered by diesel engines fitted with slip type coupling, by turbines or by electric motors
- F = 100 for main propulsion systems powered by diesel engines fitted with other type of couplings

k : Factor whose value is given in Tab 2 depending upon the different design features of the shafts.

For shaft design features other than those given in Tab 2, the value of k will be specially considered by the Society in each case

n : Speed of rotation of the shaft, in r.p.m., corresponding to power P

P : Maximum continuous power of the propulsion machinery for which the classification is requested, in kW

R_m : Value of the minimum tensile strength of the shaft material, in N/mm^2. Whenever the use of a steel having R_m in excess of 800 N/mm^2 is allowed in accordance with [2.1], the value of R_m to be introduced in the above formula will be subject to special consideration by the Society, but in general it is not to be taken higher than 800 N/mm^2. In cases of stainless steels and in other particular cases, at the discretion of the Society, the value of R_m to be introduced in the above formula will be specially considered.

The scantlings of intermediate shafts inside tubes or sterntubes will be subject to special consideration by the Society. Where intermediate shafts inside sterntubes are water lubricated, the requirements of [2.4.2] are to be applied.

Table 2 : Values of factor k

For intermediate shafts with					For thrust shafts external to engines	
integral coupling flange	shrink fit coupling	keyways	radial bores, transverse holes	longitudinal slots	on both sides of thrust collar	in way of axial bearing, where a roller bearing is used as a thrust bearing
1,00 **(1)**	1,00	1,10 **(2)**	1,10 **(3)**	1,20 **(4)**	1,10	1,10

(1) Value applicable in the case of fillet radii in accordance with the provisions of [2.7.1].

(2) After a distance of not less than 0,2 d from the end of the keyway, the shaft diameter may be reduced to the diameter calculated using k = 1,0. Fillet radii in the transverse section of the bottom of the keyway are to be not less than 0,0125 d, d being the diameter as calculated above using k = 1,0.

(3) Value applicable in the case of diameter of bore not exceeding 0,3 d, d being as defined in **(2)**.

(4) Value normally applicable in the case of slot having length not exceeding 1,4 d and width not exceeding 0,2 d, d being as defined in **(2)**, however to be justified on a case by case basis by the Manufacturers.

2.2.3 Propeller shafts

The minimum diameter of the propeller shaft is not to be less than the value d_P, in mm, given by the following formula:

$$d_P = 100 \cdot k_P \cdot \left[\frac{P}{n \cdot (1 - Q^4)} \cdot \frac{560}{R_m + 160} \right]^{1/3}$$

where:

k_p : Factor whose value, depending on the different constructional features of shafts, is given below.

The other symbols have the same meaning as in [2.2.2].

For the calculation of d_P, the value of R_m to be introduced in the above formula is generally to be taken not higher than 600 N/mm^2.

In cases of stainless steels and in other particular cases, at the discretion of the Society, the value of R_m to be introduced in the above formula will be specially considered. In general, the diameter of the part of the propeller shaft located forward of the forward sterntube seal may be gradually reduced to the diameter of the intermediate shaft.

The values of factor k_P to be introduced in the above formula are to be taken as follows:

- k_P = 1,26 for propeller shafts where:
  - the propeller is keyed on to the shaft taper in compliance with the requirements of [2.7.5]
- k_P = 1,22 for propeller shafts where:
  - the propeller is keyless fitted on to the shaft taper by a shrinkage method in compliance with Ch 2, Sec 1, [3.1.2], or the propeller boss is attached to an integral propeller shaft flange in compliance with [2.7.1]
  - aft bearings are water lubricated, sealing glands are approved by the Society and propeller shaft is fitted with continuous liner.

The above values of k_P apply to the portion of propeller shaft between the forward edge of the aftermost shaft bearing and the forward face of the propeller boss or the forward face of the integral propeller shaft flange for the connection to the propeller boss. In no case is the length of this portion of propeller shaft to be less than 2,5 times the rule diameter d_P obtained with the above formula.

The determination of factor k_P for shaft design features other than those given above will be specially considered by the Society in each case.

2.2.4 Direct stress calculation method

Shaft dimensions may be approved on the basis of documentation concerning fatigue considerations, or other methods accepted by the Society.

2.3 Liners

2.3.1 General

Metal liners or other protective coatings approved by the Society are required where propeller shafts are not made of corrosion-resistant material.

Metal liners are generally to be continuous; however, discontinuous liners, i.e. liners consisting of two or more separate lengths, may be accepted by the Society on a case by case basis, provided that:

- they are fitted in way of all supports
- the shaft portion between liners, likely to come into contact with sea water, is protected with a coating of suitable material with characteristics, fitting method and thickness approved by the Society.

2.3.2 Scantling

The thickness of metal liners fitted on propeller shafts or on intermediate shafts inside sterntubes shall in general not be less than the value t, in mm, given by the following formula:

$$t = \frac{d + 230}{32}$$

where:

d : Actual diameter of the shaft, in mm.

Whenever it is not possible to apply this rule, some justification about corrosion evolution and stress calculation shall be submitted to Society.

The shrinkage induced equivalent stress in the liner is not to exceed 70% of liner yield strength. A calculation in this respect is to be submitted.

2.4 Aft bearings

2.4.1 Water lubricated aft bearings of synthetic materials

a) Where the bearing is constructed of synthetic materials which are approved by the Society for use as water lubricated sternbush bearings, such as rubber or plastics, the length of the bearing is to be not less than 4 times the rule diameter of the shaft in way of the bearing.

b) For a bearing design substantiated by experimental data to the satisfaction of the Society, consideration may be given to a bearing length less than 4 times, but in no case less than 2 times, the rule diameter of the shaft in way of the bearing.

2.4.2 Water circulation system

For water lubricated bearings, means are to be provided to ensure efficient water circulation. When means for forced water circulation are to be provided, pumps are to be duplicated, unless absence of forced water circulation on an unlimited duration at a speed enabling manoeuvrability control on submarine is demonstrated and tested.

The water grooves on the bearings are to be of ample section such as to ensure efficient water circulation and be scarcely affected by wear-down, particularly for bearings of the plastic type.

Water circulation system is to comply with requirements of sea water pipings bearing immersion pressure (see Ch 3, Sec 5, [6]).

2.5 Thrust bearing

2.5.1 Performance expected

Thrust bearing shall be able to withstand loadings, taking into account:

- immersion pressure
- forward and aft thrust including transient efforts.

Calculation shall be submitted to Society in order to check behaviour of thrust bearings elements and elements connecting thrust bearing to hull.

2.5.2 Lubrication

Lubrication piping shall fulfil requirements mentioned in Ch 3, Sec 5, [17].

2.5.3 Refrigeration

Sea water shall not be used to cool thrust bearing oil directly unless design of cooler eliminating risk of leakage of sea water to oil system is adopted.

2.6 Sealing glands

2.6.1 Performance expected

Shaft line must be fitted with sealing glands able to maintain sufficient watertightness in the whole range of:

- shaft rotational speed, and
- immersion.

Value of leakage flow above which sealing gland is considered as damaged shall be mentioned.

2.6.2 Number of sealing glands

Shaft line must be fitted with at least two sealing glands. Whenever speed range of use of one of these sealing glands is more narrow than the others, use limitations shall be submitted to Society, including functional leakage expected if relevant.

If one of the sealing glands is designed for immersion depths smaller than nominal immersion pressure, it shouldn't be used during normal operations.

Design shall enable in case of failure of in-use sealing gland to operate in less than 15 minutes another one. Instructions for such operation shall be visible close to sealing glands operating organs.

2.6.3 Refrigeration

Sealing glands shall be fitted with refrigerating systems complying with requirements of Ch 3, Sec 5, especially for piping systems likely to withstand immersion pressure.

An alarm signal shall be sent to control room in case of flow under acceptable limit

In case of failure of refrigerating system, limitation of use of submarine if any shall be notified and submitted to Society.

2.7 Couplings

2.7.1 Flange couplings

a) Flange couplings of intermediate and thrust shafts and the flange of the forward coupling of the propeller shaft are to have a thickness not less than 0,2 times the rule diameter of the solid intermediate shaft and not less than the coupling bolt diameter calculated for a tensile strength equal to that of the corresponding shaft.

The fillet radius at the base of solid forged flanges is to be not less than 0,08 times the actual shaft diameter.

The fillet may be formed of multi-radii in such a way that the stress concentration factor will not be greater than that for a circular fillet with radius 0,08 times the actual shaft diameter.

Fillets are to have a smooth finish and are not to be recessed in way of nuts and bolt heads.

b) Where the propeller is connected to an integral propeller shaft flange, the thickness of the flange is to be not less than 0,25 times the rule diameter of the aft part of the propeller shaft. The fillet radius at the base of the flange is to be not less than 0,125 times the actual diameter.

The strength of coupling bolts of the propeller boss to the flange is to be equivalent to that of the aft part of the propeller shaft.

c) For couplings of intermediate and thrust shafts and for the forward coupling of the propeller shaft having all fitted coupling bolts, the coupling bolt diameter in way of the joining faces of flanges is not to be less than the value d_B, in mm, given by the following formula:

$$d_B = 0,65 \cdot \left[\frac{d^3 \cdot (R_m + 160)}{n_B \cdot D_C \cdot R_{mB}}\right]^{0,5}$$

where:

d : Rule diameter of solid intermediate shaft, in mm

n_B : Number of fitted coupling bolts

D_C : Pitch circle diameter of coupling bolts, in mm

R_m : Minimum tensile strength of intermediate shaft material taken for calculation of d, in N/mm^2

R_{mB} : Minimum tensile strength of coupling bolt material, in N/mm^2. Where, in compliance with [2.1.1], the use of a steel having R_{mB} in excess of the limits specified in [2.1.4] is allowed for coupling bolts, the value of R_{mB} to be introduced in the formula is not exceed the above limits.

d) Flange couplings with non-fitted coupling bolts may be accepted on the basis of the calculation of bolt tightening, bolt stress due to tightening, and assembly instructions.

To this end, the torque based on friction between the mating surfaces of flanges is not to be less than 2,8 times the transmitted torque, assuming a friction coefficient for steel on steel of 0,18. In addition, the bolt stress due to tightening in way of the minimum cross-section is not to exceed 0,8 times the minimum yield strength (R_{eH}), or 0,2 proof stress ($R_{p\,0,2}$), of the bolt material.

Transmitted torque has the following meanings:

- For main propulsion systems powered by diesel engines fitted with slip type or high elasticity couplings, by turbines or by electric motors: the mean transmitted torque corresponding to the maximum continuous power P and the relevant speed of rotation n, as defined under [2.2.2].
- For main propulsion systems powered by diesel engines fitted with couplings other than those mentioned in (a): the mean torque above increased by 20% or by the torque due to torsional vibrations, whichever is the greater.

The value 2,8 above may be reduced to 2,5 in the following cases:

- for ships having two or more main propulsion shafts
- when the transmitted torque is obtained, for the whole functioning rotational speed range, as the sum of the nominal torque and the alternate torque due to the torsional vibrations, calculated as required in Article [4].

2.7.2 Shrunk couplings

Non-integral couplings which are shrunk on the shaft by means of the oil pressure injection method or by other means may be accepted on the basis of the calculation of shrinking and induced stresses, and assembly instructions.

To this end, the force due to friction between the mating surfaces is not to be less than 2,8 times the total force due to the transmitted torque and thrust (thrust is to be increased by an amount equal to the maximum submergence pressure multiplied by the area of the propeller shaft).

The value 2,8 above may be reduced to 2,5 in the cases specified under item e) of [2.7.1].

The values of 0,14 and 0,18 will be taken for the friction coefficient in the case of shrinking under oil pressure and dry shrink fitting, respectively. Some higher friction coefficients may be taken into account: testing evidence and application procedure are to be submitted to Society.

In addition, the equivalent stress due to shrinkage determined by means of the Von Mises-Hencky criterion in the points of maximum stress of the coupling is not to exceed 0,8 times the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p0,2}$), of the material of the part concerned.

The transmitted torque is that defined in item e) of [2.7.1].

For the determination of the thrust, see Ch 2, Sec 1, [3.1.2].

2.7.3 Other couplings

Types of couplings other than those mentioned in [2.7.1] and [2.7.2] will be specially considered by the Society.

2.7.4 Flexible couplings

a) The scantlings of stiff parts of flexible couplings subjected to torque are to be in compliance with the requirements of Article [2].

b) For flexible components, the limits specified by the Manufacturer relevant to static and dynamic torque, speed of rotation and dissipated power are not to be exceeded.

c) Where all the engine power is transmitted through one flexible component only (ships with one propulsion engine and one shafting only), the flexible coupling is to be fitted with a torsional limit device or other suitable means to lock the coupling should the flexible component break.

In stiff transmission conditions with the above locking device, a sufficiently wide speed range is to be provided, free from excessive torsional vibrations, such as to enable safe navigation and steering of the ship. As an alternative, a spare flexible element is to be provided on board.

2.7.5 Propeller shaft keys and keyways

a) Keyways on the propeller shaft cone are to have well rounded corners, with the forward end faired and preferably spooned, so as to minimize notch effects and stress concentrations.

Design of keyways is to be in compliance with Fig 1. Alternative design shall be approved by the Society.

Different scantlings may be accepted, provided that at least the same reduction in stress concentration is ensured.

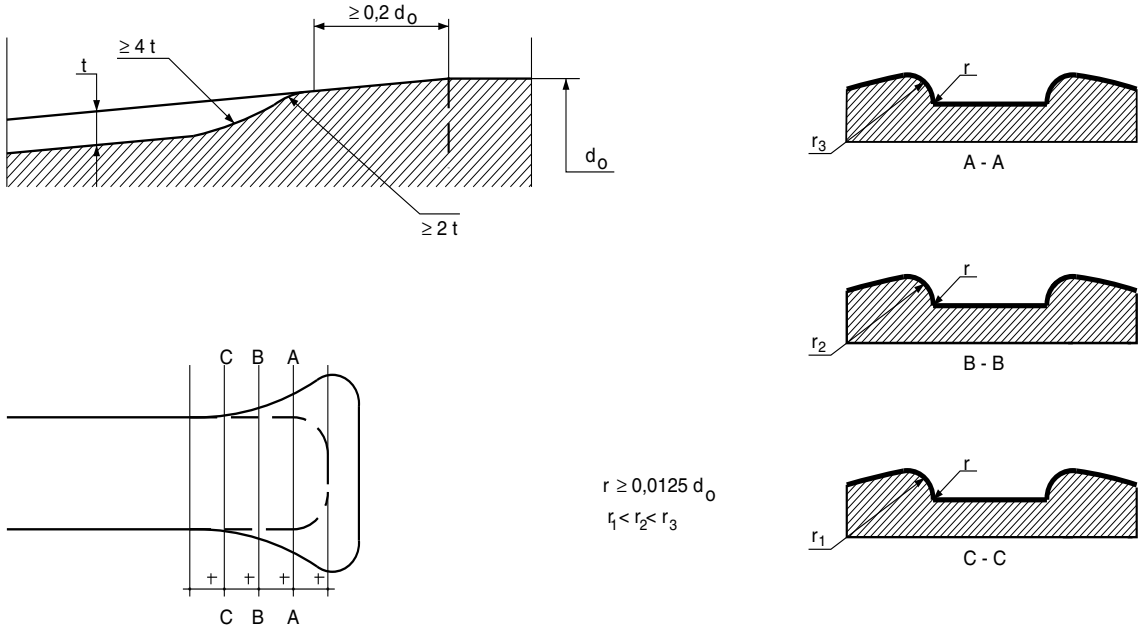
The fillet radius at the bottom of the keyway is to be not less than 1,25% of the actual propeller shaft diameter at the large end of the cone.

The edges of the key are to be rounded.

The distance from the large end of the propeller shaft cone to the forward end of the key is to be not less than 20% of the actual propeller shaft diameter in way of the large end of the cone.

Key securing screws are not to be located within the first one-third of the cone length from its large end; the edges of the holes are to be carefully faired.

Figure 1 : Details of forward end of propeller shaft keyway



b) The sectional area of the key subject to shear stress is to be not less than the value A, in mm², given by the following formula:

$$A = 0,4 \cdot \frac{d^3}{d_{PM}}$$

where:

d : Rule diameter, in mm, of the intermediate shaft calculated in compliance with the requirements of [2.2.2], assuming:

R_m = 400 N/mm²

d_{PM} : Actual diameter of propeller shaft at mid-length of the key, in mm.

2.8 Monitoring

2.8.1 General

In addition to those given in this item, the requirements of Part C, Chapter 2 apply.

2.8.2 Indicators

The local indicators for main propulsion shafting to be installed on ships of 500 gross tonnage and upwards without automation notations are given in Tab 3.

The indicators listed in Tab 3 are to be fitted at a normally attended position.

Table 3 : Shafting and clutches of propulsion machinery

Symbol convention H = High, HH = High high, G = Group alarm L = Low, LL = Low low, I = Individual alarm X = Function is required, R = Remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Temperature of each shaft thrust bearing (non applicable for ball or roller bearings)	H	R					
Clutches lubricating oil temperature	H	R					
Clutches oil tank level	L	R					
Refrigeration of aft bearing flow	L	R					
Refrigeration of sealing gland flow	L	R					

3 Arrangement and installation

3.1 General

3.1.1 The installation is to be carried out according to the instructions of the component Manufacturer or approved documents, when required.

3.1.2 The installation of sterntubes and/or associated non-shrunk bearings is subject to approval of procedures and materials used.

3.1.3 The joints between liner parts are not to be located in way of supports and sealing glands.

Metal liners are to be shrunk on to the shafts by pre-heating or forced on by hydraulic pressure with adequate interference; dowels, screws or other means of securing the liners to the shafts are not acceptable.

3.2 Protection of propeller shaft against corrosion

3.2.1 The propeller shaft surface between the propeller and the sterntube, and in way of propeller nut, is to be suitably protected in order to prevent any entry of sea water, unless the shaft is made of austenitic stainless steel.

3.3 Shaft alignment

3.3.1 In the case of propulsion shafting with turbines, direct coupled engines or bearings with offsets from a reference line, the relevant shaft alignment calculation is to be submitted for approval.

The Society may also require the above calculation in the case of special arrangements.

The alignment of the propulsion machinery and shafting and the spacing and location of the bearings are to be such as to ensure that the loads are compatible with the material used and the limits prescribed by the Manufacturer.

The calculation is to take into account thermal, static and dynamic effects; the results are to include the reaction forces of bearings, bending moments, shear stresses and other parameters (such as gap and sag of each flanged coupling or jacking loads) and instructions for the alignment procedure.

The alignment is to be checked on board by the Shipyard by a suitable measurement method.

3.4 Propeller shaft arrangement against sea water penetration

3.4.1 Hollow propeller shafts shall be closed at their extremities by plugs, plates or others. It shall be demonstrated, by calculations, that each part (aft and forward) is able to resist to twice the nominal immersion pressure applied as follows:

- Aft part of the propeller shaft: external pressure
- Forward part of the propeller shaft: internal pressure.

Maximum stress shall not overpass half the value of minimum yield stress of material.

4 Shaft vibrations

4.1 General

4.1.1 Application

The requirements of this Article apply to the shafting of the following installations

- propulsion systems with prime movers developing 220 kW or more
- other systems with internal combustion engines developing 110 kW or more and driving auxiliary machinery intended for essential services.

4.1.2 Exemption

The requirements of this Article may be waived in cases where satisfactory service operation of similar installations is demonstrated

4.2 Design of systems in respect of vibrations

4.2.1 Principle

a) General

- Special consideration shall be given by Manufacturers to the design, construction and installation of propulsion machinery systems so that any mode of their vibrations shall not cause undue stresses in these systems in the normal operating ranges.
- Calculations are to be carried out for the configurations of the system likely to have influence on the torsional vibrations.
- Where deemed necessary by the Manufacturer, axial and/or bending vibrations are to be investigated.

b) Vibration level

Systems are to have torsional, bending and axial vibrations both in continuous and in transient running acceptable to the Manufacturers, and in accordance with the requirements of this Section.

Where vibrations are found to exceed the limits stated in this Section, the builder of the plant is to propose corrective actions, such as:

- operating restrictions, provided that the owner is informed, or
- modification of the plant.

c) Condition of components

Systems are to be designed considering the following conditions, as deemed necessary by the Manufacturer:

- engine: cylinder malfunction
- flexible coupling: possible variation of the stiffness or damping characteristics due to heating or ageing
- vibration damper: possible variation of the damping coefficient.

4.2.2 Modifications of existing plants

Where substantial modifications of existing plants, such as:

- change of the running speed or power of the engine,
- replacement of an important component of the system (propeller, flexible coupling, damper) by one of different characteristics, or
- connection of a new component,

are carried out, new vibration analysis is to be submitted for approval.

4.3 Torsional vibrations

4.3.1 Documentation to be submitted

a) Calculations

Torsional vibration calculations are to be submitted for the various configurations of the plants, showing:

- the equivalent dynamic system used for the modelling of the plant, with indication of:
  - inertia and stiffness values for all the components of the system
  - diameter and material properties of the shafts
- the natural frequencies
- the values of the vibratory torques or stresses in the components of the system for the most significant critical speeds and their analysis in respect of the Rules and other acceptance criteria
- the possible restrictions of operation of the plant.

b) Particulars to be submitted

The following particulars are to be submitted with the torsional vibration calculations:

- for turbines, multi-engine installations or installations with power take-off systems:
  - description of the operating configurations
  - load sharing law between the various components for each configuration
- for installations with controllable pitch propellers, the power/rotational speed values resulting from the combinator operation
- for prime movers, the service speed range and the minimum speed at no load
- for internal combustion engines:
  - manufacturer and type
  - nominal output and rotational speed
  - mean indicated pressure
  - number of cylinders
  - "V" angle
  - firing angles
  - bore and stroke
  - excitation data, such as the polynomial law of harmonic components of excitations
  - nominal alternating torsional stress considered for crankpin and journal

Note 1: The nominal alternating torsional stress is part of the basic data to be considered for the assessment of the crankshaft. It is defined in Ch 3, App 2.

- for turbines:
  - nominal output and rotational speed
  - power/speed curve and range of operation
  - number of stages, and load sharing between the stages
  - main excitation orders for each rotating disc
  - structural damping of shafts
  - external damping on discs (due to the fluid)
- for reduction or step-up gears, the speed ratio for each step
- for flexible couplings, the data required in [2.1.3]
- for torsional vibration dampers:
  - the manufacturer and type
  - the permissible heat dissipation
  - the damping coefficient
  - the inertial and stiffness properties, as applicable
- for propellers:
  - the number of blades
  - the excitation and damping data, if available
- for electric motors, generators and pumps, the drawing of the rotating parts, with their mass moment of inertia and main dimensions.

4.3.2 Definition, symbols and units

a) Definitions

- Torsional vibration stresses referred to in this Article are the stresses resulting from the alternating torque corresponding to the synthesis of the harmonic orders concerned
- The misfiring condition of an engine is the malfunction of one cylinder due to the absence of fuel injection (which results in a pure compression or expansion in the cylinder).

b) Symbols, units

The main symbols used in this Article are defined as follows:

τ : Torsional vibration stress, as defined in [4.3.2], a) in N/mm^2

τ_1 : Permissible stress due to torsional vibrations for continuous operation, in N/mm^2

τ_2 : Permissible stress due to torsional vibrations for transient running, in N/mm^2

R_m : Tensile strength of the shaft material, in N/mm^2

C_R : Material factor, equal to:

$$\frac{R + 160}{18}$$

d : Minimum diameter of the shaft, in mm

C_D : Size factor of the shaft, equal to:

$$C_D = 0,35 + 0,93\ d^{-0,2}$$

Table 4 : Values of factor C_k

Intermediate shafts				Thrust shafts external to engines		Propeller shafts
with integral coupling flanges	with shrink-fit couplings	with keyways	splined shafts	on both sides of thrust collar	in way of axial bearing where a roller bearing is used as a thrust bearing	for which **(1)** k = 1,22 or k = 1,26
1,00	1,00	0,60	0,80	0,85	0,85	0,55

(1) k is defined in [2.2.1]

Note 1: Higher values of C_k factors based on direct calculations may also be considered.

Note 2: The determination of factor C_k for shafts other than those given in this Table is to be given special consideration by the Society.

N : Speed of the shaft for which the check is carried out, in rev/min.

N_n : Nominal speed of the shaft, in rev/min.

N_c : Critical speed, in rev/min.

λ : Speed ratio, equal to N / N_n

C_λ : Speed ratio factor, equal to:

- for $\lambda < 0,9$: $C_\lambda = 3 - 2\,\lambda^2$
- for $0,9 \leq \lambda \leq 1,05$: $C_\lambda = 1,38$

C_k : Factor depending on the shaft design features given in Tab 4.

4.3.3 Calculation principles

a) Method

- Torsional vibration calculations are to be carried out using a recognized method.
- Where the calculation method does not include harmonic synthesis, attention is to be paid to the possible superimposition of two or more harmonic orders of different vibration modes which may be present in some restricted ranges.

b) Scope of calculation

- Torsional vibration calculations are to be carried out considering:
  - normal firing of all cylinders, and
  - misfiring of one cylinder.
- Where the torsional dynamic stiffness of the coupling depends on the transmitted torque, two calculations are to be carried out:
  - one at full load
  - one at the minimum load expected in service.
- For installations with controllable pitch propellers, two calculations are to be carried out:
  - one for full pitch condition
  - one for zero pitch condition.
- The calculations are to take into account other possible sources of excitation, as deemed necessary by the Manufacturer. Electrical sources of excitations, such as static frequency converters, are to be detailed. The same applies to transient conditions such as engine start up, reversing, clutching in, as necessary.
- The natural frequencies are to be considered up to a value corresponding to 15 times the maximum service speed. Therefore, the excitations are to include harmonic orders up to the fifteenth.

c) Criteria for acceptance of the torsional vibration loads under normal firing conditions

- Torsional vibration stresses in the various shafts are not to exceed the limits defined in [4.3.4]. Higher limits calculated by an alternative method may be considered, subject to special examination by the Society in case of special manufacturing processes.

  Auxiliary machinery is to be capable of running continuously without restrictions at least within the range between 0,95 N_n and 1,1 N_n. Transient running may be considered only in restricted speed ranges for speed ratios $\lambda \leq 0,95$.
- Torsional vibration levels in other components are to comply with the provisions of [4.3.5].
- Propulsion systems are to be capable of running continuously without restrictions, and therefore are to respect the limits given in a) and b) in the whole operating speed range.

d) Criteria for acceptance of the torsional vibration loads under misfiring conditions

- The provisions of [4.3.3] related to normal firing conditions also apply to misfiring conditions.
- Where calculations show that the limits imposed for certain components may be exceeded under misfiring conditions, a suitable device is to be fitted to indicate the occurrence of such conditions.

4.3.4 Permissible limits for torsional vibration stresses in crankshaft, propulsion shafting and other transmission shafting

a) General

- The limits provided below apply to steel shafts. For shafts made of other material, the permissible limits for torsional vibration stresses will be determined by the Society after examination of the results of fatigue tests carried out on the material concerned.
- These limits apply to the torsional vibration stresses as defined in [4.3.2]. They relate to the shaft minimum section, without taking account of the possible stress concentrations.

b) Crankshaft

- Where the crankshaft has been designed in accordance with Ch 3, App 2, the torsional vibration stresses in any point of the crankshaft are not exceed the following limits:
  - $\tau_1 = \tau_N$ for continuous running
  - $\tau_2 = 1,7\ \tau_N$ for transient running,

  where τ_N is the nominal alternating torsional stress on which the crankshaft scantling is based (see Note 1).
- Where the crankshaft has not been designed in accordance with Ch 3, App 2, the torsional vibration stresses in any point of the crankshaft are not to exceed the following limits:
  - $\tau_1 = 0,55 \cdot C_R \cdot C_D \cdot C_\lambda$ for continuous running
  - $\tau_2 = 2,30\ \tau_1$ for transient running.

c) Intermediate shafts, thrusts shafts and propeller shafts

The torsional vibration stresses in any intermediate, thrust and propeller shafts are not to exceed the following limit:

- $\tau_1 = C_R \cdot C_k \cdot C_D \cdot C_\lambda$

In case the propulsion shafting has been designed according to a direct stress calculation method, the limits for torsional vibration stresses will be considered on case by case basis.

Note 1: For intermediate, thrust and propeller shafts, the material factor C_R is not to be taken as greater than 42,2.

d) Transmission shafting for generating sets and other auxiliary machinery

The torsional vibration stresses in the transmission shafting for generating sets and other auxiliary machinery, such as pumps or compressors, are not to exceed the following limits:

- $\tau_1 = 0,90 \cdot C_R \cdot C_D$ for continuous running
- $\tau_2 = 5,40\ \tau_1$ for transient running.

e) Restricted speed ranges

- Where the torsional vibration stresses exceed the limit τ_1 for continuous running, restricted speed ranges are to be imposed which are to be passed through rapidly.
- The limits of the restricted speed range related to a critical speed N_c are to be calculated in accordance with the following formula:

$$\frac{16 \cdot N_c}{18 - \lambda} \leq N \leq \frac{(18 - \lambda) \cdot N_c}{16}$$

- Where the resonance curve of a critical speed is obtained from torsional vibration measurements, the restricted speed range may be established considering the speeds for which the stress limit for continuous running τ_1 is exceeded.
- Where restricted speed ranges are imposed, they are to be crossed out on the tachometers and an instruction plate is to be fitted at the control stations indicating that:
  - the continuous operation of the engine within the considered speed range is not permitted
  - this speed range is to be passed through rapidly.
- When restricted speed ranges are imposed, the accuracy of the tachometers is to be checked in such ranges as well as in their vicinity.

4.3.5 Permissible vibration levels in components other than shafts

a) Gears

- The torsional vibration torque in any gear step is not to exceed 30% of the torque corresponding to the approved rating throughout the service speed range.
- Gear hammering induced by torsional vibration torque reversal is not permitted throughout the service speed range.

b) Generators

- In the case of alternating current generators, the torsional vibration amplitude at the rotor is not to exceed ± 2,5 electrical degrees at service rotational speed under full load working conditions.
- Vibratory inertia torques due to torsional vibrations and imposed on the rotating parts of the generator are not to exceed the values M_A, in N.m, calculated by the following formulae, as appropriate:
  - for $0,95 \leq \lambda \leq 1,1$: $M_A = \pm 2,5\ M_T$
  - for $\lambda \leq 0,95$: $M_A = \pm 6,0\ M_T$

  where:

  M_T : Mean torque transmitted by the engine under full load running conditions, in N·m

  Note 1: In the case of two or more generators driven by the same engine, the portion of M_T transmitted to each generator is to be considered.

  λ : Speed ratio defined in [4.3.2].

c) Flexible couplings

- Flexible couplings are to be capable of withstanding the mean transmitted torque and the torsional vibration torque throughout the service speed range, without exceeding the limits for continuous operation imposed by the manufacturer (permissible vibratory torque and power loss).

  Where such limits are exceeded under misfiring conditions, appropriate restrictions of power or speed are to be established.
- Flexible couplings fitted in generating sets are also to be capable of withstanding the torques and twist angles arising from transient critical and short-circuit currents. Start up conditions are also to be checked.

d) Dampers

- Torsional vibration dampers are to be such that the permissible power loss recommended by the manufacturer is not exceeded throughout the service speed range.
- Dampers for which a failure may lead to a significant vibration overload of the installation will be the subject of special consideration.

4.3.6 Torsional vibration measurements

a) General

- The Society may require torsional vibration measurements to be carried out under its attendance in the following cases:
  - where the calculations indicate the possibility of dangerous critical speeds in the operating speed range
  - where doubts arise as to the actual stress amplitudes or critical speed location, or
  - where restricted speed ranges need to be verified.
- Where measurements are required, a comprehensive report including the analysis of the results is to be submitted to the Society.

b) Method of measurement

When measurements are required, the method of measurement is to be submitted to the Society for approval. The type of measuring equipment and the location of the measurement points are to be specified.

4.4 Bending vibrations

4.4.1 General

The provisions of this Article apply to the bending vibrations of propulsion systems having a transmitted power in excess of 1000 KW:

- having a l / D ratio exceeding the following value:

$$10\left(\ln\frac{2}{D}\right) + D^2$$

where:

l : Span between the aft bearings of the propeller shaft, in m

D : Diameter of the propeller shaft, in m,

or

- fitted with bearings located outboard the hull (brackets), or
- fitted with cardan shafts.

4.4.2 Documentation to be submitted

a) Calculations

Bending vibration calculations are to show:

- the equivalent dynamic system used for the modelling of the plant, with indication of the mass of the shafts, propeller and other rotating components, and the lateral stiffness of the bearings, including that of the oil film and that of the seating
- the natural bending frequencies
- the values of the vibratory amplitudes and bending moments in the shafting for the most significant critical speeds
- the possible restrictions of operation of the plant.

b) Particulars to be submitted

The following particulars are to be submitted with the bending vibration calculations:

1) Shafting arrangement with indication of:
   - the diameter and length of the shafts
   - the position of the bearings
   - the mounting characteristics of the cardan shafts
2) detailed drawings of the bearings and their seating
3) details of the bearing lubrication, including the oil viscosity
4) for the propeller:
   - the diametral and polar moments of inertia of the propeller in air and water
   - excitations (bending moments and bending forces).

4.4.3 Calculation principles

a) Scope of calculation

1) Bending vibration calculations are to take into account:
   - the stiffness of the bearings and their seatings and, where applicable, that of the lubricating oil film
   - the excitations due to the propeller and cardan shafts.
2) Where data having a significant influence on the vibration levels cannot be determined with a sufficient degree of accuracy, parametric studies are to be carried out.

b) Criteria for acceptance of the bending vibration levels

The first shafting vibration mode is not to be excited by the first propeller blade excitation order, in the speed range between 80% and 110% of nominal speed.

Furthermore vibration induced stresses should not exceed 1,5 times the one indicated in [4.3.4] in the whole speed range.

In case the shafting is checked by means of direct calculation the allowable stresses will be established on a case-by-case.

4.4.4 Bending vibration measurements

a) General

1) The Society may require bending vibration measurements in the following cases:
   - where the calculations indicate the possibility of dangerous critical speeds in or near the operating speed range
   - where the accuracy of some data is not deemed sufficient
   - where restricted speed ranges need to be verified.
2) Where measurements are required, a comprehensive report including the analysis of the results is to be submitted to the Society.

b) Method of measurement

When measurements are required, the method of measurement is to be submitted to the Society for approval. The type of measuring equipment and the location of the measurement points are to be specified.

4.5 Axial vibrations

4.5.1 General

The provisions of this Article apply to the axial vibrations of propulsion systems fitted with:

- an internal combustion engine having a power exceeding 2000 kW and a running speed of less than 200 RPM, or
- a shaft line where the power transmitted exceeds 375 kW and the L / D ratio exceeds 50,

where:

L : Total length of the shaft line between the propeller and the thrust bearing

D : Minimum diameter of the shaft line.

4.5.2 Documentation to be submitted

a) Calculations

Axial vibration calculations are to show:

- the equivalent dynamic system used for the modelling of the plant, with indication of the masses and axial stiffnesses for all the components of the system
- the natural frequencies
- the axial vibration amplitude in way of the sterntube sealing gland for the most significant critical speeds
- for engines directly connected to the shaftline, the axial vibration amplitude at the free end of the crankshaft for the most significant critical speeds
- the possible restrictions of operation of the plant.

b) Particulars to be submitted

The following particulars are to be submitted with the axial vibration calculations:

- detailed drawing of the thrust bearing and its supporting structure with indication of their flexibility
- for the propeller:
  - the thrust
  - the excitations (axial forces)
  - the damping characteristics
- for the engine:
  - the axial excitations

  the permissible axial amplitude at the free end of the crankshaft
- the characteristics of the axial vibration of damper or detuner.

4.5.3 Calculation principles

a) Scope of the calculations

1) Axial vibration calculations are to take into account:
   - the flexibility of the thrust bearing and its supporting structure
   - the excitations due to the engine and to the propeller.
2) Where data having a significant influence on the vibration levels cannot be determined with a sufficient degree of accuracy (e.g. the flexibility of the thrust bearing and its supporting structure), parametric studies are to be carried out.
3) Where the plant includes an axial vibration damper or detuner, a calculation is to be carried out assuming a malfunction of the damper or detuner.

b) Criteria for acceptance of the axial vibration levels

1) The axial vibration force acting on the thrust bearing is not to exceed 30% of the nominal thrust.
2) The axial vibration amplitude is not to exceed:
   - at the free end of the crankshaft, the limit recommended by the engine manufacturer
   - in way of the sterntube sealing gland, the limit recommended by the sealing gland manufacturer, if any.
3) Where the calculations show that in the continuous operation speed range the above limits may be exceeded in the event of malfunction of the axial vibration damper or detuner, a suitable device is to be fitted to indicate the occurrence of such conditions.

Note 1: When detuners or dampers of satisfactorily proven design are used, this requirement may be waived.

4.5.4 Axial vibration measurements

a) General

1) The Society may require axial vibration measurements in the following cases:
   - where the calculations indicate the possibility of dangerous critical speeds in the operating speed range
   - where the accuracy of some data is not deemed sufficient, or
   - where restricted speed ranges need to be verified.
2) Where measurements are required, a comprehensive report including the analysis of the results is to be submitted to the Society.

b) Method of measurement

When measurements are required, the method of measurement is to be submitted to the Society for approval. The type of measuring equipment and the location of the measurement points are to be specified.

5 Material tests, workshop inspection and testing, certification

5.1 Material and non-destructive tests, workshop inspections and testing

5.1.1 Material tests

Shafting components are to be tested by the Manufacturer in accordance with Tab 5 and in compliance with the requirements of NR216 Materials and Welding.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 5 and are to be effected in positions agreed upon by the Surveyor, where Manufacturer's experience shows defects are most likely to occur.

Ultrasonic testing requires the Manufacturer's signed certificate.

5.1.2 Hydrostatic tests

a) Propeller shaft tests

Each hollow propeller shaft shall be submitted to hydrostatic tests according to the following conditions:

- the current and the forward parts of the shaft shall be internally oil tested to twice the nominal immersion pressure
- aft part of shaft shall be externally oil tested to twice the normal immersion pressure after assembly
- test tools will be fitted at the aft of the shaft
- the pressure shall be maintained during 30 minutes. No leak, no abnormal deflection of the parts must be detected.

b) Other tests

Propeller shaft liners, when machine-finished on the inside and with an overthickness not exceeding 3 mm on the outside, are to be hydrostatically tested to 0,2 N/mm^2.

5.2 Certification

5.2.1 Testing certification

Society's certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for material tests of components in items 1 to 5 of Tab 5.

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for hydrostatic tests of components indicated in [5.1.2] and for material and non-destructive tests of components in items of Tab 5 other than those for which Society's certificates (C) are required.

5.2.2 Sealing glands certification

Certification of sealing glands shall refer to Pt A, Ch 1, Sec 2, [3.3.1]

Table 5 : Material and non-destructive tests

Shafting component	Material tests (mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic
1) Coupling (separate from shafts)	all	if diameter ≥ 250 mm	if diameter ≥ 250 mm
2) Propeller shafts	all	if diameter ≥ 250 mm	if diameter ≥ 250 mm
3) Intermediate shafts	all	if diameter ≥ 250 mm	if diameter ≥ 250 mm
4) Thrust shafts	all	if diameter ≥ 250 mm	if diameter ≥ 250 mm
5) Cardan shafts (flanges, crosses, shafts, yokes)	all	if diameter ≥ 250 mm	if diameter ≥ 250 mm
6) Sterntubes	all	–	–
7) Sterntube bushes and other shaft bearings	all	–	–
8) Propeller shaft liners	all	all	all
9) Coupling bolts or studs	all	if diameter ≥ 40 mm	–
10) Flexible couplings (metallic parts only)	all	–	–
11) Thrust sliding-blocks (frame only)	all	–	–

Part D
Systems

Chapter 3
MACHINERY AND STEERING

SECTION 1	GENERAL REQUIREMENTS
SECTION 2	DIESEL ENGINES AND RELATED COMPRESSORS
SECTION 3	PRESSURE EQUIPMENT
SECTION 4	MASTS
SECTION 5	PIPING SYSTEMS
SECTION 6	REFRIGERATING INSTALLATIONS
SECTION 7	STEERING GEAR
APPENDIX 1	PLASTIC PIPES
APPENDIX 2	CHECK OF THE SCANTLINGS OF CRANKSHAFTS FOR DIESEL ENGINES
APPENDIX 3	REQUIREMENTS FOR DESIGN OF PRESSURE VESSELS

SECTION 1 GENERAL REQUIREMENTS

1 Design and construction

1.1 General

1.1.1 The machinery, boilers and other pressure vessels, associated piping systems and fittings are to be of a design and construction adequate for the service for which they are intended and shall be so installed and protected as to reduce to a minimum any danger to persons on board, due regard being paid to moving parts, hot surfaces and other hazards.

The design is to have regard to materials used in construction, the purpose for which the equipment is intended, the working conditions to which it will be subjected and the environmental conditions on board.

1.2 Materials, welding and testing

1.2.1 General

Materials, welding and testing procedures are to be in accordance with the requirements of NR216 Materials and Welding and those given in the other Sections of this Chapter. In addition, for machinery components fabricated by welding the requirements given in [1.2.2] apply.

1.2.2 Welded machinery components

Welding processes and welders are to be approved by the Society in accordance with NR216 Materials and Welding, Chapter 5.

References to welding procedures adopted are to be clearly indicated on the plans submitted for approval.

Joints transmitting loads are to be either:

- full penetration butt-joints welded on both sides, except when an equivalent procedure is approved, or
- full penetration T- or cruciform joints.

1.3 Vibrations

1.3.1 Special consideration is to be given to the design, construction and installation of propulsion machinery systems and auxiliary machinery so that any mode of their vibrations shall not cause undue stresses in this machinery in the normal operating ranges.

1.4 Operation in inclined position

1.4.1 Main propulsion machinery and all auxiliary machinery essential to the propulsion and the safety of the ship are, as fitted in the ship, be designed to operate when the ship is upright and when inclined at any angle of list either way and trim by bow or stern as stated in Pt B, Ch 1, Sec 3, [5].

Machinery with a horizontal rotation axis is generally to be fitted on board with such axis arranged alongships. If this is not possible, the Manufacturer is to be informed at the time the machinery is ordered.

1.5 Power of machinery

1.5.1 Unless otherwise stated in each Section of this Chapter, where scantlings of components are based on power, the values to be used are determined as follows:

- for main propulsion machinery, the power/rotational speed for which classification is requested. This power/rotational speed should take in account the most stress-inducing propulsion system configuration mode
- for auxiliary machinery, the power/rotational speed which is available in service.

1.6 Astern power

1.6.1 Sufficient power for going astern is to be provided to secure proper control of the ship in all normal circumstances.

Note 1: Attention is to be paid to maximum stopping distance and to minimum astern thrust, which may be imposed by the ship specification.

Running astern is not to lead to an overload of propulsion machinery.

During the sea trials, the ability of the main propulsion machinery to reverse the direction of thrust of the propeller is to be demonstrated and recorded.

1.7 Safety devices

1.7.1 Where risk from overspeeding of machinery exists, means are to be provided to ensure that the safe speed is not exceeded.

1.7.2 Where main or auxiliary machinery including pressure vessels or any parts of such machinery are subject to internal pressure and may be subject to dangerous overpressure, means shall be provided, where practicable, to protect against such excessive pressure.

1.7.3 Internal combustion machinery shall be provided with automatic shut-off arrangements in the case of failures, such as lubricating oil supply failure, which could lead rapidly to complete breakdown, serious damage or explosion.

The Society may permit provisions for overriding automatic shut-off devices.

See also the specific requirements given in the other Sections of this Chapter.

1.8 Fuels

1.8.1 Fuel oils employed for engines and boilers are, in general, to have a flash point (determined using the closed cup test) of not less than 60°C.

Whenever special precautions are taken to the Society's satisfaction, fuel oils having a flash point of less than 60°C but not less than 43°C may be used for engines, provided that, from previously effected checks, it is evident that the temperature of spaces where fuel oil is stored or employed will be at least 10°C below the fuel oil flash point at all times. Society may consider restricted enforcements of this last requirement as long as:

- circumstances when requirement is not fulfilled are clearly spotted
- risk of sparkling is eliminated during these periods.

Fuel oil having flash points of less than 43°C may be employed on board provided that it is stored outside pressure hull.

2 Arrangement and installation on board

2.1 General

2.1.1 Provision shall be made to facilitate cleaning, inspection and maintenance of main propulsion and auxiliary machinery, including boilers and pressure vessels.

Suitable demountable openings are to be foreseen in decks and bulkheads for the purpose of disembarking main machinery whose maintenance is intended to be carried out ashore.

Easy access to the various parts of the propulsion machinery is to be provided by means of metallic ladders and gratings fitted with strong and safe handrails.

Spaces containing main and auxiliary machinery are to be provided with adequate lighting and ventilation.

2.2 Floors

2.2.1 Floors in engine rooms are to be made of steel, divided into easily removable panels.

2.3 Bolting down

2.3.1 Bedplates of machinery are to be securely fixed to the supporting structures by means of foundation bolts which are to be distributed as evenly as practicable and of a sufficient number and size so as to ensure a perfect fit.

Where the bedplates bear directly on the inner bottom plating, the bolts are to be fitted with suitable gaskets so as to ensure a tight fit and are to be arranged with their heads within the double bottom.

Continuous contact between bedplates and foundations along the bolting line is to be achieved by means of chocks of suitable thickness, carefully arranged to ensure a complete contact.

The same requirements apply to thrust block and shaft line bearing foundations.

Particular care is to be taken to obtain a perfect levelling and general alignment between the propulsion engines and their shafting (see Ch 2, Sec 2).

2.3.2 Chocking resins are to be type approved.

2.4 Safety devices on moving parts

2.4.1 Suitable protective devices are to be provided in way of moving parts (flywheels, couplings, etc.) in order to avoid injuries to personnel.

2.5 Gauges

2.5.1 All gauges are to be grouped, as far as possible, near each manoeuvring position; in any event, they are to be clearly visible.

2.6 Ventilation in machinery spaces

2.6.1 Machinery spaces are to be sufficiently ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather condition, including heavy weather, a sufficient supply of air is maintained to the spaces for the safety of personnel and the operation of the machinery.

Special attention is to be paid both to air delivery and extraction and to air distribution in the various spaces.

The ventilation is to be so arranged as to prevent any accumulation of flammable gases or vapours.

Size and fittings of ducts are to be such as to satisfy the machinery flow, pressure and quality requirements for developing maximum continuous power.

2.7 Hot surfaces and fire protection

2.7.1 Surfaces of machinery with temperatures above 220°C, e.g. steam, thermal oil and exhaust gas lines, silencers, exhaust gas boilers and turbochargers, are to be effectively insulated with non-combustible material or equivalently protected to prevent the ignition of combustible materials coming into contact with them. Where the insulation used for this purpose is oil absorbent or may permit the penetration of oil, the insulation is to be encased in steel sheathing or equivalent material.

Fire protection, detection and extinction is to comply with the requirements of Part E, Chapter 1.

3 Tests and trials

3.1 Works tests

3.1.1 Equipment and its components are subjected to works tests which are detailed in the relevant Sections of this Chapter and are to be witnessed by the Surveyor.

In particular cases, where such tests cannot be performed in the workshop, the Society may allow them to be carried out on board, provided this is not judged to be in contrast either with the general characteristics of the machinery being tested or with particular features of the shipboard installation. In such cases, the Surveyor entrusted with the acceptance of machinery on board and the purchaser are to be informed in advance and the tests are to be carried out in accordance with the provisions of NR216 Materials and Welding relative to incomplete tests.

All boilers, all parts of machinery, all steam, hydraulic, pneumatic and other systems and their associated fittings which are under internal pressure shall be subjected to appropriate tests including a pressure test before being put into service for the first time as detailed in the other Sections of this Chapter.

3.2 Trials on board

3.2.1 Trials on board of machinery are detailed in Pt A, Ch 1, App 1.

SECTION 2 DIESEL ENGINES AND RELATED COMPRESSORS

1 General

1.1 Application

1.1.1 Diesel engines listed below are to be designed, constructed, installed, tested and certified in accordance with the requirements of this Section, under the supervision and to the satisfaction of the Society's Surveyors:

a) engines driving electric generators

b) other engines installed on board will be reviewed on case by case basis.

In addition to the requirements of this Section, those given in Ch 3, Sec 1 apply.

1.1.2 Engines with power output less than 800 kW

These engines may follow alternative design approval scheme as long as:

- They are designed an constructed according to sound marine practice
- Manufacturer's documentation regarding engine type characterisation, justification of crankshaft scantling and torsional vibration calculation including the whole generating set (diesel connected to alternator), work certificates regarding material are provided
- Double pipes are fitted on high pressure fuel lines
- An extensive type test is undertaken by Manufacturer or yard. Program of this type approval test shall be submitted and shall not ask less than type for mass produced engines (see [4.3]) and shall be approved by the Society
- Individual testing of engines is undertaken according to a program approved by the Society.

1.2 Documentation to be submitted

1.2.1 The Manufacturer is to submit to the Society the documents listed in Tab 1 for engine type approval.

Tab 1 are also to contain details of the lubricating oil sump in order to demonstrate compliance with Ch 3, Sec 1, [1.4].

Where changes are made to an engine type for which the documents listed in Tab 1 have already been examined or approved, the engine Manufacturer is to resubmit to the Society for consideration and approval only those documents concerning the engine parts which have undergone substantial changes.

If the engines are manufactured by a licensee, the licensee is to submit, for each engine type, a list of all the drawings specified in Tab 1, indicating for each drawing the relevant number and revision status from both licensor and licensee.

Where the licensee proposes design modifications to components, the associated documents are to be submitted by the licensee to the Society for approval or for information purposes. In the case of significant modifications, the licensee is to provide the Society with a statement confirming the licensor's acceptance of the changes. In all cases, the licensee is to provide the Surveyor entrusted to carry out the testing, with a complete set of the documents specified in Tab 1.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Document	Document details
1	I	Engine particulars as per the Society form "Particulars of diesel engines" or equivalent form	–
2	I	Engine transverse cross-section	Max inclination angles, oil surface lines, oil suction strum position
3	I	Engine longitudinal section	Max inclination angles, oil surface lines, oil suction strum position
4	I / A	Bedplate or crankcase, cast or welded. For welded bedplates or cranks, welding details and instructions	Design of welded joints, electrodes used, welding sequence, heat treatment, non-destructive examinations
5	A	Thrust bearing assembly **(2)**	–
6	I / A	Thrust bearing bedplate, cast or welded. For welded bedplates or cranks, welding details and instructions **(2)**	Design of welded joints, electrodes used, welding sequence, heat treatment, non-destructive examinations

No.	I/A **(1)**	Document	Document details
7	I / A	Frame/column, cast or welded with welding details and instructions **(3)**	Design of welded joints, electrodes used, welding sequence, heat treatment, non-destructive examinations
8	I	Tie rod	–
9	I	Cylinder cover, assembly	–
10	I	Cylinder jacket or engine block **(3) (4)**	–
11	I	Cylinder liner **(4)**	–
12	A	Crankshaft, details, for each cylinder number	–
13	A	Crankshaft, assembly, for each cylinder number	–
14	A	Thrust shaft or intermediate shaft (if integral with engine)	–
15	A	Coupling bolts	–
16	A	Counterweights (if not integral with crankshaft), with associated fastening bolts	Bolt fastening instructions
17	I	Connecting rod	–
18	I	Connecting rod, assembly **(4)**	Bolt fastening instructions
19	I	Crosshead, assembly **(4)**	–
20	I	Piston rod, assembly **(4)**	–
21	I	Piston, assembly	–
22	I	Camshaft drive, assembly	–
23	A	Material specifications of main parts of engine, with detailed information on: - non-destructive tests, and - pressure tests	Required for items 4, 7, 8, 9, 10, 11, 12, 15, 18, 21, including acceptable defects and repair procedures Required for items 4, 7, 9, 10, 11, 21 and for injection pumps and exhaust manifold
24	A	Arrangement of foundation bolts (for main engines only)	–
25	A	Schematic layout or other equivalent documents for starting air system on the engine **(5)**	–
26	A	Schematic layout or other equivalent documents for fuel oil system on the engine **(5)**	–
27	A	Schematic layout or other equivalent documents for lubricating oil system on the engine **(5)**	–
28	A	Schematic layout or other equivalent documents for cooling water system on the engine **(5)**	–
29	A	Schematic diagram of engine control and safety system on the engine **(5)**	List, specification and layout of sensors, automatic controls and other control and safety devices
30	I	Shielding and insulation of exhaust pipes, assembly	–
31	A	Shielding of high pressure fuel pipes, assembly	Recovery and leak detection devices
32	A	Crankcase explosion relief valves **(6)**	Volume of crankcase and other spaces (camshaft drive, scavenge, etc.)
33	I	Operation and service manuals	–

(1) A = to be submitted for approval, in four copies
mb ar to be submitted for information, in duplicate.
Where two indications I / A are given, the first refers to cast design and the second to welded design.

(2) To be submitted only if the thrust bearing is not integral with the engine and not integrated in the engine bedplate.

(3) Only for one cylinder.

(4) To be submitted only if sufficient details are not shown on the engine transverse and longitudinal cross-sections.

(5) Dimensions and materials of pipes, capacity and head of pumps and compressors and any additional functional information are to be included. The layout of the entire system is also required, if this is part of the goods to be supplied by the engine Manufacturer.

(6) Required only for engines with cylinder bore of 200 mm and above or crankcase gross volume of 0,6 m^3 and above.

1.3 Definitions

1.3.1 Engine type

In general, the type of an engine is defined by the following characteristics:

- the cylinder diameter
- the piston stroke
- the method of injection (direct or indirect injection)
- the kind of fuel (liquid, gaseous or dual-fuel)
- the working cycle (4-stroke, 2-stroke)
- the gas exchange (naturally aspirated or supercharged)
- the maximum continuous power per cylinder at the corresponding speed and/or brake mean effective pressure corresponding to the above-mentioned maximum continuous power
- the method of pressure charging (pulsating system or constant pressure system)
- the charging air cooling system (with or without intercooler, number of stages, etc.)
- cylinder arrangement (in-line or V-type).

1.3.2 Engine power

The maximum continuous power is the maximum power at ambient reference conditions (see [1.3.3]) which the engine is capable of delivering continuously, at nominal maximum speed, in the period of time between two consecutive overhauls.

Power, speed and the period of time between two consecutive overhauls are to be stated by the Manufacturer and agreed by the Society.

The rated power is the maximum power at ambient reference conditions (see [1.3.3]) which the engine is capable of delivering as set after works trials (fuel stop power) at the maximum speed allowed by the governor.

The rated power for engines driving electric generators is the nominal power, taken at the net of overload, at ambient reference conditions (see [1.3.3]), which the engine is capable of delivering as set after the works trials Pt A, Ch 1, App 1).

1.3.3 Ambient reference conditions

The power of engines as per [1.1.1] is to be referred to the following conditions, corresponding to snorkel situation:

Parameters to be taken into account are:

- air inlet pressure: 900 mbar before compressors
- exhaust gas pressure: 1600 mbar after turbo compressors if any
- relative humidity: 80%
- inlet air temperature: 45°C
- sea water temperature: 32°C.

It is understood that same power must be reachable on surface conditions:

- air inlet temperature: over 950 mbar
- exhaust gas pressure: 1100 mbar after turbo compressors if any
- relative humidity: 80%
- sea water temperature: 32°C.

In the case reachable power on surface is under the one developed on snorkel conditions, this power is to be known.

Other parameters proposed by designer may be considered by the Society.

In case of multi-engine installation, the different configurations of running together engines are to be considered, especially about air inlet and exhaust gas pressure.

1.3.4 Same type of engines

Two diesel engines are considered to be of the same type when they do not substantially differ in design and construction characteristics, such as those listed in the engine type definition as per [1.3.1], it being taken for granted that the documentation concerning the essential engine components listed in [1.2] and associated materials employed has been submitted, examined and, where necessary, approved by the Society.

2 Design and construction

2.1 Materials and welding

2.1.1 Crankshaft materials

In general, crankshafts are to be of forged steel having a tensile strength not less than 400 N/mm^2 and not greater than 1000 N/mm^2.

The use of forged steels of higher tensile strength is subject to special consideration by the Society in each case.

The Society, at its discretion and subject to special conditions (such as restrictions in ship navigation), may accept crankshafts made of cast carbon steel, cast alloyed steel of appropriate quality and manufactured by a suitable procedure having a tensile strength as follows:

a) between 400 N/mm^2 and 560 /mm^2 for cast carbon steel

b) between 400 N/mm^2 and 700 N/mm^2 for cast alloyed steel.

2.1.2 Welded frames and foundations

Steels used in the fabrication of welded frames and bedplates are to comply with the requirements of NR216 Materials and Welding.

Welding is to be in accordance with the requirements of Ch 3, Sec 1, [1.2].

2.2 Crankshaft

2.2.1 Check of the scantling

The check of crankshaft strength is to be carried out in accordance with Ch 3, App 2.

2.3 Crankcase

2.3.1 Strength

The scantling of crankcases and crankcase doors is to be designed to be of sufficient strength, and the doors are to be securely fastened so that they will not be readily displaced by an explosion.

2.3.2 Ventilation and drainage

The ventilation of crankcases, or any other arrangement which may produce an inrush of air, is in principle prohibited.

Vent pipes, where provided, are to be as small as practicable. If provision is made for the forced extraction of gases from the crankcase (e.g. for detection of explosive mixtures), the vacuum in the crankcase is not to exceed: $2{,}5.10^{-4}$ MPa.

Where two or more engines are installed, their vent pipes and lubricating oil drain pipes are to be independent to avoid intercommunication between crankcases.

Lubricating oil drain pipes from the engine sump to the drain tank are to be submerged in the latter at their outlet ends.

2.3.3 Warning notice

A warning notice is to be fitted, preferably on a crankcase door on each side of the engine, or alternatively on the control stand.

This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling of the crankcase.

2.3.4 Crankcase explosion relief valves

a) Diesel engines of a cylinder diameter of 200 mm and above or a crankcase gross volume of 0,6 m^3 and above are to be provided with crankcase explosion relief valves in accordance with the following requirements.

b) Engines having a cylinder bore not exceeding 250 mm, are to have at least one valve near each end, but over eight crankthrows, an additional valve is to be fitted near the middle of the engine. Engines having a cylinder bore exceeding 250 mm, but not exceeding 300 mm, are to have at least one valve in way of each alternate crankthrow, with a minimum of two valves. Engines having a cylinder bore exceeding 300 mm are to have at least one valve in way of each main crankthrow.

c) Additional relief valves are to be fitted on separate spaces of the crankcase, such as gear or chain cases for camshaft or similar drives, when the gross volume of such spaces is 0,6 m^3 or above. Scavenge spaces in open connection to the cylinders are to be fitted with explosion relief valves.

d) The free area of each relief valve is not to be less than 45 cm^2.

e) The combined free area of the valves fitted on an engine is not to be less than 115 cm^2 per cubic metre of the crankcase gross volume.

Note 1: The total volume of the stationary parts within the crankcase may be discounted in estimating the crankcase gross volume (rotating and reciprocating components are to be included in the gross volume).

f) Crankcase explosion relief valves are to be provided with lightweight spring-loaded valve discs or other quick-acting and self closing devices to relieve a crankcase of pressure in the event of an internal explosion and to prevent any inrush of air thereafter.

g) The valve discs in crankcase explosion relief valves are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

h) Crankcase explosion relief valves are to be designed and constructed to open quickly and to be fully open at a pressure not greater than 0,02 MPa.

i) Crankcase explosion relief valves are to be provided with a flame arrester that permits flow for crankcase pressure relief and prevents passage of flame following a crankcase explosion.

j) Crankcase explosion relief valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine.

The purpose of type testing crankcase explosion valves is to:

- verify the effectiveness of the flame arrester
- verify that the valve closes after an explosion
- verify that the valve is gas/air tight after an explosion
- establish the level of overpressure protection provided by the valve.

Where crankcase relief valves are provided with arrangements for shielding emissions from the valve following an explosion, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

k) Crankcase explosion relief valves are to be provided with a copy of the manufacturer's installation and maintenance manual that is pertinent to the size and type of valve being supplied for installation on a particular engine.

The manual is to contain the following information:

- description of valve with details of function and design limits
- copy of type test certification
- installation instructions
- maintenance in service instructions to include testing and renewal of any sealing arrangements
- actions required after a crankcase explosion.

l) A copy of the installation and maintenance manual required in i) above is to be provided on board the unit.

m) Valves are to be provided with suitable markings that include the following information:

- name and address of manufacturer
- designation and size
- month/year of manufacture
- approved installation orientation.

2.4 Systems

2.4.1 General

In addition to the requirements of the present sub-article, those given in Ch 3, Sec 5 are to be satisfied.

Flexible hoses in the fuel and lubricating oil system are to be limited to the minimum and are to be type approved.

2.4.2 Fuel oil system

Relief valves discharging back to the suction of the pumps or other equivalent means are to be fitted on the delivery side of the pumps.

In fuel oil systems for propulsion machinery, filters are to be fitted and arranged so that an uninterrupted supply of filtered fuel oil is ensured during cleaning operations of the filter equipment, except when otherwise stated in Ch 3, Sec 5.

All external high pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are to be protected with a shielded piping system capable of containing fuel from a high pressure line failure.

A shielded pipe incorporates an outer pipe into which the high pressure fuel pipe is placed forming a permanent assembly.

The shielded piping system is to include a means for collection of leakages and arrangements are to be provided for an alarm to be given in the event of a fuel line failure.

If flexible hoses are used for shielding purposes, these are to be approved by the Society.

When in fuel oil return piping the pulsation of pressure with peak to peak values exceeds 2 MPa, shielding of this piping is also required as above.

2.4.3 Lubricating oil system

Efficient filters are to be fitted in the lubricating oil system when the oil is circulated under pressure.

In such lubricating oil systems for propulsion machinery, filters are to be arranged so that an uninterrupted supply of filtered lubricating oil is ensured during cleaning operations of the filter equipment, except when otherwise stated in Ch 3, Sec 5.

Relief valves discharging back to the suction of the pumps or other equivalent means are to be fitted on the delivery side of the pumps.

The relief valves may be omitted provided that the filters can withstand the maximum pressure that the pump may develop.

Where necessary, the lubricating oil is to be cooled by means of suitable coolers.

2.4.4 Charge air system

Requirements relevant to design, construction, arrangement, installation, tests and certification of exhaust gas turbochargers and motocompressors are given in Article [5].

2.5 Starting air system

2.5.1 The requirements given in Ch 3, Sec 5, [11.3] apply.

2.6 Control and monitoring

2.6.1 General

In addition to those of this sub-article, the general requirements given in Part D, Chapter 5 apply.

2.6.2 Alarm

The lubricating oil system of diesel engines with a power equal to or in excess of 37 kW is to be fitted with alarms to give audible and visual warning in the event of an appreciable reduction in pressure of the lubricating oil supply.

2.6.3 Governors of engines

Each engine, except engines for driving electric generators for which [2.6.4] applies, is to be fitted with a speed governor so adjusted that the engine does not exceed the rated speed by more than 15%.

2.6.4 Governors for engines driving electric generators

a) Auxiliary engines intended for driving electric generators are to be fitted with a speed governor which prevents any transient speed variations in excess of 10% of the rated speed when the rated power is suddenly thrown off or specific loads are suddenly thrown on. For engines driving generators delivering direct current or rectified alternative current, no stop of engine by overspeed protection should occur during transient, keeping a sufficient margin with overspeed protection limit.

b) At all loads between no load and rated power, the permanent speed variation is not to be more than 5% of the rated speed.

c) Application of the electrical load in more than 2 load steps can only be allowed if the conditions within the ship's mains permit the use of those auxiliary engines which can only be loaded in more than 2 load steps (see Fig 1 for guidance) and provided that this is already allowed for in the designing stage.

   This is to be verified in the form of system specifications to be approved and to be demonstrated at ship's trials. In this case, due consideration is to be given to the power required for the electrical equipment to be automatically switched on after blackout and to the sequence in which it is connected.

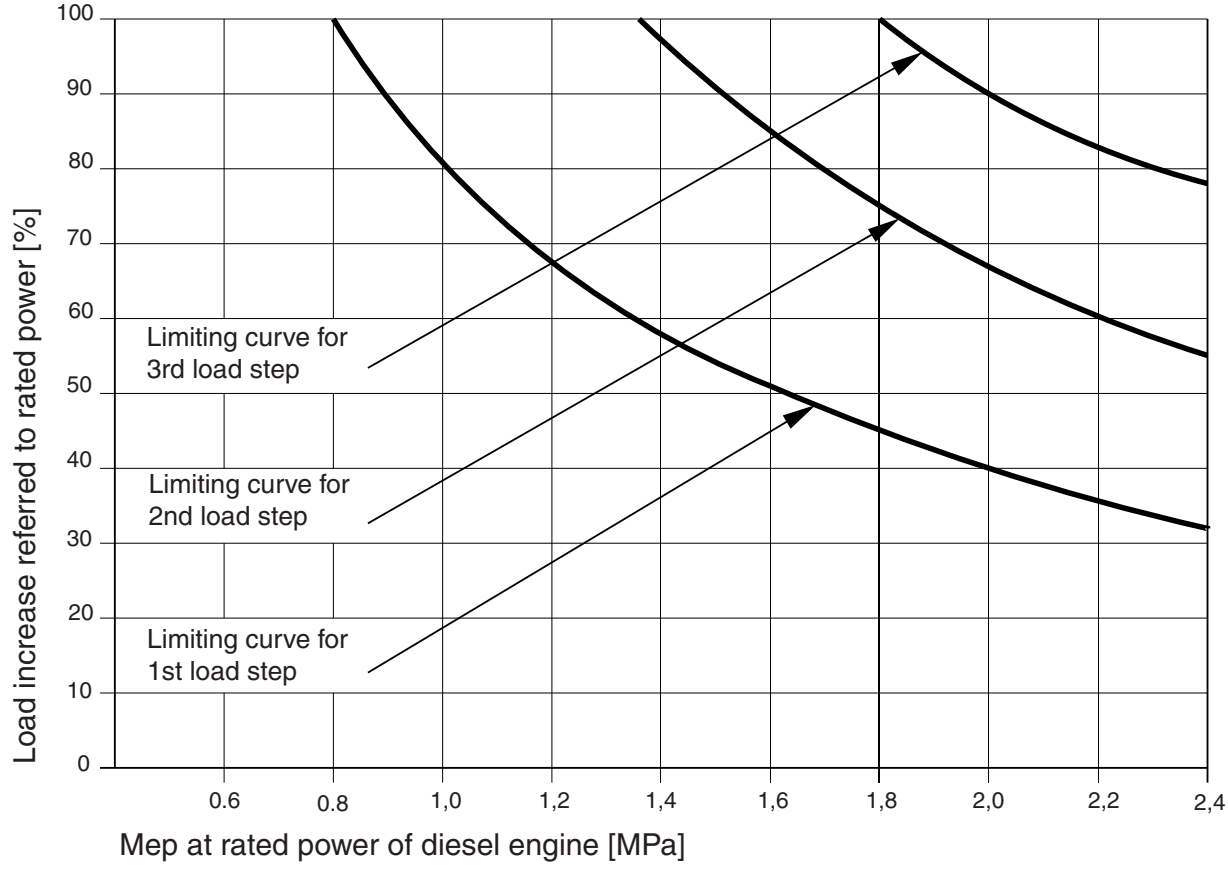
   This also applies to generators to be operated in parallel and where the power is to be transferred from one generator to another, in the event that any one generator is to be switched off.

d) When the rated power is suddenly thrown off, steady state conditions should be achieved in not more than 5 s.

e) Emergency generator sets must satisfy the governor conditions as per items a) and b) even when their total consumer load is applied suddenly.

f) For alternating current generating sets intended to operate in parallel, facilities are to be provided to adjust the governor sufficiently finely to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.

Figure 1 : Limiting curves for loading 4-stroke diesel engines step by step from no load to rated power as a function of the brake mean effective pressure



2.6.5 Manual emergency stop of engine

Emergency stop of engine should be possible by manual command. Location of this command should be located where engine is controlled.

2.6.6 Overspeed protective devices of engines driving electric generators

In addition to the speed governor, engines of rated power equal to or greater than 220 kW driving electric generators are to be fitted with a separate overspeed protective device, adjusted so as to prevent the rated speed from being exceeded by more than 15%.

This device is to automatically shut down the engine.

2.6.7 Use of electronic governors

a) Type approval

Electronic governors and their actuators are to be type approved by the Society.

b) Electronic governors for main propulsion engines

If an electronic governor is fitted to ensure continuous speed control or resumption of control after a fault, an additional separate governor is to be provided unless the engine has a manually operated fuel admission control system suitable for its control.

A fault in the governor system is not to lead to sudden major changes in propulsion power or direction of propeller rotation.

Alarms are to be fitted to indicate faults in the governor system.

The acceptance of electronic governors not in compliance with the above requirements will be considered by the Society on a case by case basis, when fitted on ships with two or more main propulsion engines.

c) Electronic governors for auxiliary engines driving electric generators

In the event of a fault in the electronic governor system the fuel admission is to be set to “zero”.

Alarms are to be fitted to indicate faults in the governor system.

The acceptance of electronic governors fitted on engines driving emergency generators will be considered by the Society on a case-by-case basis.

2.6.8 Summary tables

Diesel engines installed on ships without automation notations are to be equipped with monitoring equipment as detailed in Tab 2.

The alarms are to be visual and audible.

The indicators are to be fitted at a normally attended position (on the engine or at the local control station).

Table 2 : Monitoring of diesel engines used for auxiliary services

Symbol convention H = High, HH = High high, G = Group alarm L = Low, LL = Low low, I = Individual alarm X = Function is required, R = Remote	Monitoring		Automatic control				
			Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil viscosity or temperature before injection (for engine running on heavy fuel)		local					
Fuel oil pressure		local					
Fuel oil leakage from pressure pipes	H						
Lubricating oil pressure	L	local		X			
Exhaust gas temperature	H	local					
Pressure or flow of cooling water, if not connected to main system	L	local					
Temperature of cooling water or cooling air		local					
Engine speed		local					
	H			X			
Fault in the electronic governor system	X						
Pressure in diesel engine room	LL			X			

3 Arrangement and installation

3.1 Starting arrangements

3.1.1 Mechanical air starting

a) Air starting of engines is to be arranged in compliance with Ch 3, Sec 5, [11.4].

b) Any supply device involved specifically in engine starting is to be independent for each engine. Alternative arrangement may be submitted to Society in multi engine plants with more than two engines.

c) The main starting air arrangements for main propulsion or auxiliary diesel engines are to be adequately protected against the effects of backfiring and internal explosion in the starting air pipes. To this end, the following safety devices are to be fitted:

- An isolating non-return valve, or equivalent, at the starting air supply connection to each engine
- A bursting disc or flame arrester:
  - in way of the starting valve of each cylinder, for direct reversing engines having a main starting air manifold
  - at least at the supply inlet to the starting air manifold, for non-reversing engines.

  The bursting disc or flame arrester above may be omitted for engines having a bore not exceeding 230 mm.

Other protective devices will be specially considered by the Society.

The requirements of this item c) do not apply to engines started by pneumatic motors.

3.2 Turning gear

3.2.1 Each engine is to be provided with a turning gear; where deemed necessary, the turning gear is to be both hand and mechanically-operated.

The turning gear engagement is to inhibit starting operations when hand operated.

3.3 Fittings on decompression valves

3.3.1 Decompression valves must be able to be remotely opened and closed.

3.4 Trays

3.4.1 Trays fitted with means of drainage are to be provided in way of the lower part of the crankcase and, in general, in way of the parts of the engine, where oil is likely to spill in order to collect the fuel oil or lubricating oil dripping from the engine.

3.5 Exhaust gas system

3.5.1 In addition to the requirements given in Ch 3, Sec 5, [15], the exhaust system is to be efficiently cooled or insulated in such a way that the surface temperature does not exceed 220°C.

4 Type tests, material tests, workshop inspection and testing, certification

4.1 Type tests - General

4.1.1 Upon finalization of the engine design for production of every new engine type intended for installation on board ships, one engine is to be presented for type testing as required below.

A type test carried out for a particular type of engine at any place in any manufacturer's works will be accepted for all engines of the same type (see [1.3.4]) built by licensees and licensors.

In any case, one type test suffices for the whole range of engines having different numbers of cylinders.

Engines which are subjected to type testing are to be tested in accordance with the scope specified below, it being taken for granted that:

- the engine is optimised as required for the conditions of the type test
- the investigations and measurements required for reliable engine operation have been carried out during preliminary internal tests by the engine Manufacturer
- the documentation to be submitted as required in Pt E, Ch 1, Sec 1, [1.4] has been examined and, when necessary, approved by the Society and the latter has been informed about the nature and extent of investigations carried out during pre-production stages.

4.1.2 At the request of the Manufacturer, an increase in power and/or mean effective pressure up to a maximum of 10% may be accepted by the Society for an engine previously subjected to a type test without any further such test being required, provided the engine reliability has been proved successfully by the service experience of a sufficient number of engines of the same type.

For the purpose of the acceptance of the above performance increase, the Manufacturer is in any case to submit for examination and, where necessary, approval, the documentation listed in [1.2] relevant to any components requiring modification in order to achieve the increased performance.

4.2 Type tests of engines not admitted to an alternative inspection scheme

4.2.1 General

Engines which are not admitted to testing and inspections according to an alternative inspection scheme (see NR216 Materials and Welding, Ch 1, Sec 1, [3.2]) are to be type tested in the presence of a Surveyor in accordance with the requirements of the present sub-article.

The type test is subdivided into three stages, namely:

a) Stage A - Preliminary internal tests carried out by the Manufacturer.

   Stage A includes functional tests and collection of operating values including the number of testing hours during the internal tests, the results of which are to be presented to the Surveyor during the type test. The number of testing hours of components which are inspected according to [4.2.5] is to be stated by the Manufacturer.

b) Stage B - Type approval test

   The type approval test is to be carried out in the presence of the Surveyor.

c) Stage C - Inspection of main engine components.

After completion of the test programme, the main engine components are to be inspected.

The engine Manufacturer is to compile all results and measurements for the engine tested during the type test in a type test report, which is to be submitted to the Society.

4.2.2 Stage A - Internal tests (function tests and collection of operating data)

During the internal tests the engine is to be operated at the load points considered important by the engine Manufacturer and the relevant operating values are to be recorded (see item a)).

The load points may be selected according to the range of application.

If an engine can be satisfactorily operated at all load points without using mechanically driven cylinder lubricators, this is to be verified.

For engines which may operate on heavy fuel oil, their suitability for this is to be proved to the satisfaction of the Society.

a) Functional tests under normal operating conditions

   Functional tests under normal operating conditions include:

   1) The load points 25%, 50%, 75%, 100% of the maximum continuous power for which type approval is requested, to be carried out:
      - along the nominal (theoretical) propeller curve and at constant speed, for propulsion engines
      - at constant speed, for engines intended for generating sets.
   2) The limit points of the permissible operating range.

      These limit points are to be defined by the engine Manufacturer.

      The maximum continuous power P is defined in [1.3.2].

b) Tests under particular operating conditions

   The achievable continuous output is to be determined for a situation when:

   - inlet air pressure is set to 0,8 bar before compressing devices
   - exhaust gas pressure is set to 2 bars.

   These values may be modified according to the specification of the Naval Authority, or the acceptance of different values by the Naval Authority. In this case, the Society should be informed of these modifications.

4.2.3 Stage B - Type approval tests in the presence of the Surveyor

During the type test, the tests listed below are to be carried out in the presence of the Surveyor and the results are to be recorded in a report signed by both the engine Manufacturer and the Surveyor.

Any departures from this programme are to be agreed upon by the engine Manufacturer and the Society.

a) Load points

The load points at which the engine is to be operated according to the power/speed diagram are those listed below. The data to be measured and recorded when testing the engine at various load points are to include all necessary parameters for engine operation.

The operating time per load point depends on the engine characteristics (achievement of steady-state condition) and the time for collection of the operating values.

Normally, an operating time of 0,5 hour per load point can be assumed.

At the maximum continuous power as per the following item 1) an operating time of two hours is required. Two sets of readings are to be taken at a minimum interval of one hour.

1) Test at maximum continuous power P, i.e. 100% output at 100% torque and 100% speed

2) Test at 100% power at maximum permissible speed

3) Test at minimum permissible speed at 100% of torque T

4) Test at minimum permissible speed at 90% of torque T

5) Tests at part loads, e.g. 75%, 50%, 25% of maximum continuous power P and speed according to the nominal propeller curve, and tests at the above part loads and at speed n with constant governor setting.

b) Additional tests

- Starting tests for non-reversible engines, or starting and reversing tests for reversible engines
- Governor tests
- Testing of the safety system, particularly for overspeed and low lubricating oil pressure.

For engines intended to be used for emergency services, supplementary tests may be required to the satisfaction of the Society. In particular, for engines intended to drive emergency generating sets, additional tests and/or documents may be required to prove that the engine is capable of being readily started at a temperature of 0°C.

4.2.4 Evaluation of test results

The results of the tests and checks required by [4.2.3] will be evaluated by the attending Surveyor. Normally the main operating data to be recorded during the tests are those listed in [4.3.4].

In particular, the maximum combustion pressure measured with the engine running at the maximum continuous power P is not to exceed the value taken for the purpose of checking the scantlings of the engine crankshaft, according to the applicable requirements of Ch 3, App 2.

The values of temperatures and pressures of media, such as cooling water, lubricating oil, charge air, exhaust gases, etc., are to be within limits which, in the opinion of the Surveyor, are appropriate for the characteristics of the engine tested.

4.2.5 Stage C - Inspection of main engine components

Immediately after the test run as per [4.2.3], the components of one cylinder for in-line engines, and two cylinders for V-type engines, are to be presented for inspection to the Surveyor.

The following main engine components are to be inspected:

- piston removed and dismantled
- crosshead bearing, dismantled
- crank bearing and main bearing, dismantled
- cylinder liner in the installed condition
- cylinder head and valves, disassembled
- control gear, camshaft and crankcase with opened covers.

Where deemed necessary by the Surveyor, further dismantling of the engine may be required.

4.3 Type tests of mass produced engines admitted to an alternative inspection scheme

4.3.1 General

Engines for which the Manufacturer is admitted to testing and inspections according to an alternative inspection scheme (see NR216 Materials and Welding, Ch 1, Sec 1, [3.2]) and which have a cylinder bore not exceeding 300 mm are to be type tested in the presence of a Surveyor in accordance with the requirements of the present sub-article.

The selection of the engine to be tested from the production line is to be agreed upon with the Surveyor.

4.3.2 Type test

The programme of the type test is to be in general as specified below, P being the maximum continuous power and n the corresponding speed. The maximum continuous power is that stated by the engine Manufacturer and accepted by the Society, as defined in [4.2.2].

a) 80 hours at power P and speed n

b) 8 hours at overload power (110% of power P), if practicable

c) 10 hours at partial loads (25%, 50%, 75% and 90% of power P)

d) 2 hours at intermittent loads

e) starting tests

f) reverse running for direct reversing engines

g) testing of speed governor, overspeed device and lubricating oil system failure alarm device

h) testing of the engine with one turbocharger out of action, when applicable

i) testing of the minimum speed with no brake load, for auxiliary engines.

The tests at the above-mentioned outputs are to be combined together in working cycles which are to be repeated in succession for the entire duration within the limits indicated.

In particular, the overload test, to be carried out at the end of each cycle, is to be of one hour's duration and is to be carried out alternately, if possible:

- at 110% of the power P and 103% of the speed n
- at 110% of the power P and 100% of the speed n.

The partial load tests specified in c) are to be carried out:

- along the nominal (theoretical) propeller curve and at constant speed, for propulsion engines
- at constant speed, for engines intended for generating sets.

In the case of prototype engines, the duration and programme of the type test will be specially considered by the Society.

4.3.3 In cases of engines for which the Manufacturer submits documentary evidence proving successful service experience or results of previous bench tests, the Society, at its discretion, may allow a type test to be carried out in the presence of the Surveyor according to a programme to be agreed upon in each instance.

In the case of engines which are to be type approved for different purposes and performances, the programme and duration of the type test will be decided by the Society in each case to cover the whole range of engine performances for which approval is requested, taking into account the most severe values.

4.3.4 During the type test, at least the following particulars are to be recorded:

a) ambient air temperature, pressure and atmospheric humidity in the test room

b) cooling raw water temperature at the inlet of heat exchangers

c) characteristics of fuel and lubricating oil used during the test

d) engine speed

e) brake power

f) brake torque

g) maximum combustion pressure

h) indicated pressure diagrams, where practicable

i) exhaust smoke (with a smoke meter deemed suitable by the Surveyor)

j) lubricating oil pressure and temperature

k) cooling water pressure and temperature

l) exhaust gas temperature in the exhaust manifold and, where facilities are available, from each cylinder

m) minimum starting air pressure necessary to start the engine in cold condition.

Table 3 : Material and non-destructive tests

Engine component	Material tests **(1)** (mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic
1) Crankshaft	all	all	all
2) Crankshaft coupling flange (non-integral) for main power transmissions	if bore > 400 mm	–	–
3) Coupling bolts for crankshaft	if bore > 400 mm	–	–
4) Steel piston crowns **(2)**	if bore > 400 mm	if bore > 400 mm	all
5) Piston rods	if bore > 400 mm	if bore > 400 mm	if bore > 400 mm
6) Connecting rods, together with connecting rod bearing caps	all	all	if bore > 400 mm
7) Crossheads	if bore > 400 mm	–	–
8) Cylinder liners	if bore > 300 mm	–	–
9) Steel cylinder covers **(2)**	if bore > 300 mm	if bore > 400 mm	all
10) Bedplates of welded construction; plates and transverse bearing girders made of forged or cast steel **(2) (3)**	all	all	all
11) Frames and crankcases of welded construction **(3)**	all	–	–
12) Entablatures of welded construction **(3)**	all	–	–
13) Tie rods	all	if bore > 400 mm	–
14) Shafts and rotors, including blades, for turbochargers	(see [5])	–	–
15) Bolts and studs for cylinder covers, crossheads, main bearings and connecting rod bearings; nuts for tie rods	if bore > 300 mm	if bore > 400 mm	–
16) Steel gear wheels for camshaft drives	if bore > 400 mm	if bore > 400 mm	–

(1) In addition, material tests may also be required, at the Society's discretion, for piping and valves for starting air lines and any other pressure piping fitted on the engines.

(2) For items 4), 9) and 10), material tests are also required for parts made of materials other than steel: e.g. aluminium and its alloys, ductile and spheroidal or nodular graphite cast iron.

(3) Material tests for bedplates, frames, crankcases and entablatures are required even if these parts are not welded and for any material except grey cast iron.

In addition to the above, for supercharged engines the following data are also to be measured and recorded:

- turbocharger speed
- air temperature and pressure before and after turbocharger and charge air coolers
- exhaust gas temperatures and pressures before and after turbochargers and cooling water temperature at the inlet of charge air coolers.

4.3.5 Inspection of main engine components and evaluation of test results

The provisions of [4.2.4] and [4.2.5] are to be complied with, as far as applicable.

4.4 Material and non-destructive tests

4.4.1 Material tests

Engine components are to be tested in accordance with Tab 3 and in compliance with the requirements of NR216 Materials and Welding.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 3 and are to be effected by the Manufacturer in positions agreed upon by the Surveyor, where Manufacturer's experience shows defects are most likely to occur.

The magnetic particle test of tie rods/stay bolts is to be carried out at each end, for a portion which is at least twice the length of the thread.

For important structural parts of engines, in addition to the above-mentioned non-destructive tests, examination of welded seams by approved methods of inspection may be required.

Where there are grounds to doubt the soundness of any engine component, non-destructive tests using approved detecting methods may be required.

Engines of a cylinder diameter not exceeding 300 mm may be tested according to an alternative survey scheme.

4.4.2 Hydrostatic tests

Parts of engines under pressure are to be hydrostatically tested at the test pressure specified for each part in Tab 4.

The following parts of auxiliaries which are necessary for operation of engines as per [1.1.1], items a), b) and c):

- cylinders, cylinder covers, coolers and receivers of independent air compressors
- water, oil and air coolers (tube bundles or coils, shells and heads) not fitted on the engine and filters
- independently driven lubricating oil, fuel oil and water pumps
- pressure pipes (water, lubricating oil, fuel oil, and compressed air pipes), valves and other fittings,

are to be subjected to hydrostatic tests at 1,5 times the maximum working pressure, but not less than 0,4 MPa.

Table 4 : Test pressure of engine parts

	Parts under pressure	Test pressure (MPa) **(1) (2)**
1	Cylinder cover, cooling space **(3)**	0,7
2	Cylinder liner, over the whole length of cooling space	0,7
3	Cylinder jacket, cooling space	0,4 (but not less than 1,5 p)
4	Exhaust valve, cooling space	0,4 (but not less than 1,5 p)
5	Piston crown, cooling space **(3) (4)**	0,7
6	Fuel injection system	
	a) Fuel injection pump body, pressure side	1,5 p (or p + 30, if lesser)
	b) Fuel injection valve	1,5 p (or p + 30, if lesser)
	c) Fuel injection pipes	1,5 p (or p + 30, if lesser)
7	Hydraulic system	
	• Piping, pumps, actuators etc. for hydraulic drive of valves	1,5 p
8	Scavenge pump cylinder	0,4
9	Turbocharger, cooling space	0,4 (but not less than 1,5p)
10	Exhaust pipe, cooling space	0,4 (but not less than 1,5 p)
11	Engine driven air compressor (cylinders, covers, intercoolers and aftercoolers)	
	a) Air side	1,5 p
	b) Water side	0,4 (but not less than 1,5 p)
12	Coolers, each side **(5)**	0,4 (but not less than 1,5 p)
13	Engine driven pumps (oil, water, fuel, bilge)	0,4 (but not less than 1,5 p)

(1) In general, parts are to be tested at the hydraulic pressure indicated in the Table. Where design or testing features may call for modification of these testing requirements, special consideration will be given by the Society.

(2) p is the maximum working pressure, in MPa, in the part concerned.

(3) For forged steel cylinder covers and forged steel piston crowns, test methods other than hydrostatic testing may be accepted, e.g. suitable non-destructive tests and documented dimensional tests.

(4) Where the cooling space is sealed by the piston rod, or by the piston rod and the shell, the pressure test is to be carried out after assembly.

(5) Turbocharger air coolers are tested on the water side only.

4.5 Workshop inspections and testing

4.5.1 General

In addition to the type test, diesel engines are to be subjected to works trials, normally witnessed by the Surveyor except where an Alternative Inspection Scheme has been granted or where otherwise decided by the Society on a case by case basis.

For all stages at which the engine is to be tested, the relevant operating values are to be measured and recorded by the engine Manufacturer.

In each case all measurements conducted at the various load points are to be carried out at steady operating conditions.

The readings for 100% of the rated power P at the corresponding speed n are to be taken twice at an interval of at least 30 minutes.

At the discretion of the Surveyor, the programme of trials given in [4.5.2], [4.5.3] or [4.5.4] may be expanded depending on the engine application.

4.5.2 Engines driving electric generators used for main propulsion purposes

Engines driving electric generators are to be subjected to trials to be performed with a constant governor setting, as follows:

a) at least 60 min., after having reached steady conditions, at 100% of rated power P and rated speed n

b) at least 30 min., after having reached steady conditions, at 110% of rated power P and rated speed n

c) 75%, 50% and 25% of rated power P, carried out at constant rated speed n

d) idle run

e) starting tests

f) testing of the speed governor ([2.6.4]) and of the independent overspeed protective device (when applicable)

g) testing of alarm and/or shutdown devices.

Note 1: After running on the test bed, the fuel delivery system of diesel engines driving electric generators is to be adjusted if practicable such that overload (110%) power can be produced but not exceeded in service after installation on board, so that the governing characteristics, including the activation of generator protective devices, can be maintained at all times. This possibility of overloading can be ignored if it is justified that engines will not be submitted to more than 100% load in any condition of operation. In this case, power output of engine shall be limited to 100%.

4.5.3 Engines driving auxiliary machinery

Engines driving auxiliary machinery are to be subjected to the tests stated in [4.5.2] for variable speed and constant speed drives, respectively.

Note 1: After running on the test bed, the fuel delivery system of diesel engines driving electric generators is to be adjusted if practicable such that overload (110%) power can be produced but not exceeded in service after installation on board, so that the governing characteristics, including the activation of generator protective devices, can be maintained at all times. This possibility of overloading can be ignored if it is justified that engines will not be submitted to more than 100% load in any condition of operation. In this case, power output of engine shall be limited to 100%.

4.5.4 Inspection of engine components

After the works trials, several components are to be selected for inspection by the Manufacturer or by the Surveyor if the works trials are witnessed.

4.5.5 Parameters to be measured

The data to be measured and recorded, when testing the engine at various load points, are to include all necessary parameters for engine operation. The crankshaft deflection is to be verified when this check is required by the Manufacturer during the operating life of the engine.

4.5.6 Testing report

In the testing report for each engine the results of the tests carried out are to be compiled and the reference number and date of issue of the Type Approval Certificate (see [4.6]), relevant to the engine type, are always to be stated; the testing report is to be issued by the Manufacturer and enclosed with the testing certificate as per [4.6].

4.6 Certification

4.6.1 Type Approval Certificate and its validity

After the satisfactory outcome of the type tests and inspections specified in [4.2] or [4.3], the Society will issue to the engine manufacturer a "Type Approval Certificate" valid for all engines of the same type.

The Society reserves the right to consider the test carried out on one engine type valid also for engines having a different cylinder arrangement, following examination of suitable, detailed documentation submitted by the Manufacturer and including bench test results.

4.6.2 Testing certification

a) Engines admitted to an alternative inspection scheme

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for components and tests indicated in Tab 3 and Tab 4 and for works trials as per [4.5].

b) Engines not admitted to an alternative inspection scheme

Society's certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for material tests of components in Tab 3 and for works trials as per [4.5].

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for non-destructive and hydrostatic tests of components in Tab 3 and Tab 4.

In both cases a) and b), the Manufacturer is to supply:

a) the following information:
   - engine type
   - rated power
   - rated speed
   - driven equipment
   - operating conditions
   - list of auxiliaries fitted on the engine

b) a statement certifying that the engine is in compliance with that type tested. The reference number and date of the Type Approval Certificate are also to be indicated in the statement.

5 Air inlet compressing devices

5.1 General

5.1.1 Application

These Rules apply to turbochargers and motocompressors fitted on the diesel engines listed in [1.1.1].

In the case of special types of turbochargers, the Society reserves the right to modify the requirements of this Section, demand additional requirements in individual cases and require that additional plans and data be submitted.

5.1.2 Documentation to be submitted

The Manufacturer is to submit to the Society the documents listed in Tab 5.

For Manufacturers who have facilities for testing the turbocharger unit on an engine for which the turbocharger is to be type approved, replacement of the hot running test by a test run of one hour's duration at overload (110% of the rated output) may be considered.

5.2 Design and construction

5.2.1 Approved materials

a) Gas turbine materials are to fulfill the requirements imposed by the operating conditions of the individual components. In the choice of materials, account is to be taken of effects such as creep, thermal fatigue, oxidation and corrosion to which individual components are subject when in service. Evidence of the suitability of the materials is to be supplied to the Society in the form of details of their chemical and mechanical properties and of the heat treatment applied. Where composite materials are used, their method of manufacture is to be described.

b) Turbine blades are to be built of corrosion and heat-resistant materials.

5.2.2 Design and construction details

a) Rotors and stators
   1) All components of turbines and compressors are to be free from defects and are to be built and installed with tolerances and clearances in order to allow thermal expansion and to minimize the distortions of casings and rotors in all expected service conditions.
   2) Adequate drain tubes and cocks are to be arranged in a suitable position, in the lower parts of the casings. Cocks are to be easily operated.
   3) Suitable protective devices are to be provided in order to prevent heat, noise or possible failure of rotating parts from causing injury to personnel. If, to this end, the whole gas turbine is enclosed in a protective covering, the covering is to be adequately ventilated inside.
   4) Particular attention is to be paid to the connection in the casings of pipes to the turbine stators in order to avoid abnormal loads in service.
   5) Smooth fillets are to be provided at changes of sections of rotors, discs and blade roots. The holes in discs are to be well rounded and polished.

b) Access and inspection openings

   Inspection openings are to be provided to allow the gas turbine flow path air to be inspected with special equipment, e.g. a bore-scope or similar, without the need for dismantling.

c) Bearings
   1) Turbine bearings are to be so located that their lubrication is not impaired by overheating from hot gases or adjacent hot parts.
   2) Lubricating oil or fuel oil is to be prevented from dripping on high temperature parts.
   3) Bearings one exhaust gas side of turbo compressors must be fitted with sealing glands devices providing gastight properties on ambient normal conditions.
   4) Roller bearings are to be identifiable and are to have a life adequate for their intended purpose. In any event, their life cannot be less than 40000 hours.

d) Cooling

   The turbines and their external exhaust system are to be suitably insulated or cooled to avoid excessive outside temperature.

e) Air supply

   The air intake ducting is to be equipped to prevent extraneous substances from entering the compressor and turbine.

5.2.3 Monitoring

a) General

   In addition to those of this item, the general requirements given in Part D, Automation, apply.

b) Indicators

   The local indicators for turbochargers and motocompressors are to be defined.

Table 5 : Documentation to be submitted

No.	I/A **(1)**	Document
1	A	Longitudinal cross-sectional assembly with main dimensions
2	A	Rotating parts (shaft, wheels and blades)
3	A	Details of blade fixing
4	A	Details of gearings for motocompressor
5	A	Technical specification of the turbocharger and motocompressor including the maximum operating conditions (maximum permissible rotational speed and maximum permissible temperature)
6	A	Material specifications for the main parts, including their physical, chemical and mechanical properties, values of tensile strength, average stress to produce creep, resistance to corrosion and heat treatments
7	I	Operation and service manual

(1) A = to be submitted for approval, in four copies;
I = to be submitted for information, in duplicate.

Note 1: Plans mentioned under items (2) and (3) are to be constructional plans with all main dimensions and are to contain any necessary information relevant to the type and quality of the materials employed. In the case of welded rotating parts, all relevant welding details are to be included in the above plans and the procedures adopted for welding or for any heat treatments will be subject to approval by the Society

5.3 Arrangement and installation

5.3.1 The arrangement and installation are to be such as to avoid any unacceptable load on turbocharger or motocompressor.

5.3.2 Arrangement of air inlet compressing device is generally to enable to reach at least same continuous rated power for engine on ambient referent conditions navigating on surface as during subwater navigation. If particular arrangement (i.e. air by-pass) is chosen to reach this goal, corresponding drawings are to be submitted to the Society.

5.4 Type tests, material tests, workshop inspection and testing, certification

5.4.1 Type tests

Turbochargers and motocompressors are to be type approved.

The type test is to be carried out on a standard unit taken from the assembly line and is to be witnessed by the Surveyor. Normally, the type test is to consist of:

- for a turbocharger: a hot gas running test of one hour duration at the maximum permissible speed and maximum permissible temperature, on ambient reference conditions. After testing, turbocharger is to be opened up and examined.
- for a motocompressor: a running test of one hour duration at the maximum speed on ambient reference conditions. After testing, motocompressor is to be opened and examined.

5.4.2 Material tests

Material tests (mechanical properties and chemical composition) are required for shafts and rotors, including blades (see [5.4.4], item b) as regards the certificate required).

5.4.3 Workshop inspections and testing

a) Overspeed test

All wheels (impellers and inducers), when machine-finished and complete with all fittings and blades, are to undergo an overspeed test for at least 3 minutes at one of the following test speeds:

1) 20% above the maximum speed at room temperature
2) 10% above the maximum speed at the maximum working temperature.

b) Balancing

Each shaft and bladed wheel, as well as the complete rotating assembly, is to be dynamically balanced by means of equipment which is sufficiently sensitive in relation to the size of the rotating part to be balanced.

c) Bench running test

Each turbocharger is to undergo a mechanical running test at the bench for 20 minutes at maximum rotational speed at room temperature.

Subject to the agreement of the Society, the duration of the running test may be reduced to 10 minutes, provided that the Manufacturer is able to verify the distribution of defects found during the running tests on the basis of a sufficient number of tested turbochargers.

For Manufacturers who have facilities in their works for testing turbochargers on an engine for which they are intended, the bench test may be replaced by a test run of 20 minutes at overload (110% of the maximum continuous output) on such engine.

Where turbochargers are admitted to an alternative inspection scheme, the Society may accept a bench test carried out on a sample basis.

d) Hydrostatic tests

The cooling spaces of turbochargers are to be hydrostatically tested at a test pressure of 0,4 MPa or 1,5 times the maximum working pressure, whichever is the greater.

5.4.4 Certification

a) Type Approval Certificate and its validity

Subject to the satisfactory outcome of the type tests specified in [5.4.1], the Society will issue to the turbocharger Manufacturer a Type Approval Certificate valid for all turbochargers or motocompressors of the same type.

b) Testing certification

1) Turbochargers and motocompressors admitted to an alternative inspection scheme

A statement, issued by the Manufacturer, is required certifying that the turbocharger conforms to the one type tested. The reference number and date of the Type Approval Certificate are also to be indicated in the statement.

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for material tests as per [5.4.2] and for works trials as per [5.4.3].

2) Turbochargers not admitted to an alternative inspection scheme and motocompressors

Society's certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for the bench running test as per [5.4.3] item c) and the overspeed test as per [5.4.3] item a), as well as for material and hydrostatic tests as per [5.4.2] and [5.4.3], item d).

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) may be accepted for material tests, in place of the Society's certificates, for turbochargers fitted on diesel engines having a cylinder diameter of 300 mm or less.

SECTION 3 PRESSURE EQUIPMENT

1 General

1.1 Principles

1.1.1 Scope of the Rules

The boilers and other pressure vessels, associated piping systems and fittings are to be of a design and construction adequate for the service for which they are intended and is to be so installed and protected as to reduce to a minimum any danger to persons on board, due regard being paid to moving parts, hot surfaces and other hazards. The design is to have regard to materials used in construction, the purpose for which the equipment is intended, the working conditions to which it will be subjected and the environmental conditions on board.

So these Rules apply to "pressure equipment" for the following requirements:

- be safe in sight of pressure risk
- be safe in sight of other risks, moving parts, hot surfaces
- ensure capability of propulsion and other essential services.

"Pressure equipment" means pressure vessels, piping (see Ch 3, Sec 5), safety accessories and pressure accessories.

1.1.2 Overpressure risk

Where main or auxiliary boilers and other pressure vessels or any parts thereof may be subject to dangerous overpressure, means are to be provided where practicable to protect against such excessive pressure. Exception to this requirement are granted for pressure vessel dedicated to compressed air storage.

1.1.3 Tests

All boilers and other pressure vessels including their associated fittings which are under internal pressure are to be subjected to appropriate tests including a pressure test before being put into service for the first time (see also [2]).

1.2 Application

1.2.1 Pressure vessels covered by the Rules

The requirements of this Section apply to:

- all fired or unfired pressures vessels of metallic construction, including the associated fittings and mountings with maximum allowable pressure greater than 0,5 bar above atmospheric pressure with the exception of those indicated in [1.2.2]
- all boilers and other steam generators, including the associated fittings and mountings with maximum allowable pressure greater than 0,5 bar above atmospheric pressure with the exception of those indicated in [1.2.2].

1.2.2 Pressure vessels not covered by the Rules

Among others the following boilers and pressure vessels are not covered by the Rules and are to be considered on a case-by-case basis:

a) boilers with design pressure $p > 10$ MPa

b) pressure vessel intended for radioactive material

c) equipment comprising casings or machinery where the dimensioning, choice of material and manufacturing rules are based primarily on requirements for sufficient strength, rigidity and stability to meet the static and dynamic operational effects or other operational characteristics and for which pressure is not a significant design factor. Such equipment may include:
   - engines including turbines and internal combustion engines
   - steam engines, gas/steam turbines, turbo-generators, compressors, pumps and actuating devices

d) small pressure vessels included in self-contained domestic equipment.

1.3 Definitions

1.3.1 Pressure vessel

"Pressure vessel" means a housing designed and built to contain fluids under pressure including its direct attachments up to the coupling point connecting it to other equipment. A vessel may be composed of more than one chamber.

1.3.2 Fired pressure vessel

Fired pressure vessel is a pressure vessel which is completely or partially exposed to fire from burners or combustion gases or otherwise heated pressure vessel with a risk of overheating.

Boiler is one or more fired pressure vessels and associated piping systems used for generating steam or hot water at a temperature above 120°C.

Any equipment directly connected to the boiler, such as economisers, superheaters and safety valves, is considered as part of the boiler, if it is not separated from the steam generator by means of any isolating valve. Piping connected to the boiler is considered as part of the boiler upstream of the isolating valve and as part of the associated piping system downstream of the isolating valve.

1.3.3 Unfired pressure vessel

Any pressure vessel which is not a fired pressure vessel is an unfired pressure vessel.

a) Heat exchanger

A heat exchanger is an unfired pressure vessel used to heat or cool a fluid with an another fluid. In general heat exchangers are composed of a number of adjacent chambers, the two fluids flowing separately in adjacent chambers. One or more chambers may consist of bundles of tubes.

b) Steam generator

A steam generator is a heat exchanger and associated piping used for generating steam. In general in these Rules, the requirements for boilers are also applicable for steam generators, unless otherwise indicated.

1.3.4 Safety accessories

"Safety accessories" means devices designed to protect pressure equipment against the allowable limits being exceeded. Such devices include:

- devices for direct pressure limitation, such as safety valves, bursting disc safety devices, buckling rods, controlled safety pressure relief systems, and
- limiting devices, which either activate the means for correction or provide for shutdown or shutdown and lockout, such as pressure switches or temperature switches or fluid level switches and safety related measurement control and regulation devices.

1.3.5 Design pressure

The design pressure is the pressure used by the manufacturer to determine the scantlings of the vessel. This pressure cannot be taken less than the maximum working pressure and is to be limited by the set pressure of the safety valve, as prescribed by the applicable Rules. Pressure is indicated as gauge pressure above atmospheric pressure, vacuum is indicated as negative pressure.

When pressure vessel is also submitted to external pressure, maximum external pressure used for calculation shall not be less than pressure corresponding to accidental diving depth.

1.3.6 Design temperature

a) Design temperature is the actual metal temperature of the applicable part under the expected operating conditions, as modified in Tab 1. This temperature is to be stated by the manufacturer and is to take in account of the effect of any temperature fluctuations which may occur during the service.

b) The design temperature is not to be less than the temperatures stated in Tab 1, unless specially agreed between the manufacturer and the Society on a case-by-case basis.

1.3.7 Volume

Volume V means the internal volume of a chamber, including the volume of nozzles to the first connection or weld and excluding the volume of permanent internal parts.

1.3.8 Boiler heating surface

Heating surface is the area of the part of the boiler through which the heat is supplied to the medium, on the side exposed to fire or hot gases.

1.3.9 Maximum steam output

Maximum steam output is the maximum quantity of steam than can be produced continuously by the boiler or steam generator operating under the design steam conditions.

1.3.10 Toxic and corrosive substances

Toxic and corrosive substances are those which are listed in the IMO "International Maritime Dangerous Goods Code (IMDG Code)", as amended.

1.3.11 Liquid and gaseous substances

a) Liquid substances are liquids having a vapour pressure at the maximum allowable temperature of not more than 0,5 bar above normal atmospheric pressure.

b) Gaseous substances are gases, liquefied gases, gases dissolved under pressure, vapours and also those liquids whose vapour pressure at the maximum allowable temperature is greater than 0,5 bar above normal atmospheric pressure.

1.3.12 Ductile material

For the purpose of this Section, ductile material is a material having an elongation over 12%.

Table 1: Minimum design temperature

Type of vessel	Minimum design temperature
Pressure parts of pressure vessels and boilers not heated by hot gases or adequately protected by insulation	Maximum temperature of the internal fluid
Pressure vessel heated by hot gases	25°C in excess of the temperature of the internal fluid
Water tubes of boilers mainly subjected to convection heat	25°C in excess of the temperature of the saturated steam
Water tubes of boilers mainly subjected to radiant heat	50°C in excess of the temperature of the saturated steam
Superheater tubes of boilers mainly subjected to convection heat	35°C in excess of the temperature of the saturated steam
Superheater tubes of boilers mainly subjected to radiant heat	50°C in excess of the temperature of the saturated steam
Economiser tubes	35°C in excess of the temperature of the internal fluid
For combustion chambers of the type used in wet-back boilers	50°C in excess of the temperature of the internal fluid
For furnaces, fire-boxes, rear tube plates of dry-back boilers and other pressure parts subjected to similar rate of heat transfer	90°C in excess of the temperature of the internal fluid

1.4 Classes

1.4.1 Significant parameters

Pressure vessels are classed in three types of class, in consideration of:

- the type of equipment (pressure vessel or steam generator)
- the state (gaseous or liquid) of the intended fluid contents
- the substances listed or not in the IMDG Code
- the design pressure p, in MPa
- the design temperature T, in °C
- the actual thickness t_A of the vessel, in mm
- the volume V, in litres.

1.4.2 Pressure vessel classification

Pressure vessels are classed as indicated in Tab 2.

1.4.3 Implication of class

The class of a pressure vessel has, among others, implication in:

- design
- material allowance
- welding design
- efficiency of joints
- examination and non-destructive tests
- stress relieving.

See Tab 6.

1.5 Applicable Rules

1.5.1 Alternative standards

a) Boilers and pressure vessels are to be designed, constructed, installed and tested in accordance with the applicable requirements of this Section.

b) The acceptance of national and international standards as an alternative to the requirements of this Section may be considered by the Society on a case-by-case basis.

1.5.2 Requirements for design and arrangement are located in Ch 3, App 3.

1.6 Documentation to be submitted

1.6.1 General

Documents mentioned in the present sub-article are to be submitted for class 1 and class 2 and not for class 3, unless the equipment is considered as critical.

1.6.2 Boilers and steam generators

The drawings listed in Tab 3 are to be submitted. They are to contain:

- the constructional details of all pressure parts, such as shells, headers, tubes, tube plates, nozzles
- strengthening members, such as stays, brackets, opening reinforcements and covers
- installation arrangements, such as saddles and anchoring system,

as well as the information and data indicated in Tab 4.

1.6.3 Pressure vessels

The drawings listed in Tab 5 are to be submitted. They are to contain the constructional details of:

- pressure parts, such as shells, headers, tubes, tube plates, nozzles, opening reinforcements and covers
- strengthening members, such as stays, brackets and reinforcements.

Table 2 : Pressure vessel classification

Equipment	Class 1	Class 2	Class 3
Steam generators or boilers	p > 3,2 and V > 2 or p V > 20 and V > 2	all steam generators or boilers which are not class 1 or class 3	p V ≤ 5 or V ≤ 2
Pressure vessels for toxic substances	all	–	–
Pressure vessels for corrosive substances	p > 20 or p V > 20 or T > 350 or located outside main hull	all pressure vessels which are not class 1	–
Pressure vessels for gaseous substances	p > 100 or p V > 300 or located outside pressure hull	V > 1 and p V > 100 and not in class 1	all pressure vessels which are not class 1 or class 2
Pressure vessels for liquid substances	V > 10 and p V > 1000 and p > 50 or located outside main hull	V ≤ 10 and p > 100 or 1 < p ≤ 50 and p V > 1000	all pressure vessels and heat exchangers which are not class 1 or class 2
Whatever type of equipment	t_A > 40	15 < t_A ≤ 40	–
Note 1: Whenever the class is defined by more than one characteristic, the equipment is to be considered belonging to the highest class of its characteristics, independently of the values of the other characteristics.			

Table 3 : Drawings to be submitted for boilers and steam generators

No.	A/I	Item
1	I	General arrangement plan, including valves and fittings
2	A	Material specifications
3	A	Sectional assembly
4	A	Evaporating parts
5	A	Superheater
6	A	De-superheater
7	A	Economiser
8	A	Air heater
9	A	Tubes and tube plates
10	A	Nozzles and fittings
11	A	Safety valves and their arrangement
12	A	Boiler seating
13	I	Fuel oil burning arrangement
14	I	Forced draught system
15	I	Refractor or insulation arrangement
16	A	Boiler instrumentation, monitoring and control system
17	A	Type of safety valves and their lift, discharge rate and setting
18	A	Welding details, including at least: • typical weld joint design • welding procedure specifications • post-weld heat treatment
Note 1: A = to be submitted for approval in four copies I = to be submitted for information in duplicate		

Table 4 : Information and data to be submitted for boilers and steam generators

No.	Item
1	Design pressure and temperature
2	Pressure and temperature of the superheated steam
3	Pressure and temperature of the saturated steam
4	Maximum steam production per hour
5	Evaporating surface of the tube bundles and waterwalls
6	Heating surface of the economiser, superheater and air-heater
7	Surface of the furnace
8	Volume of the combustion chamber
9	Temperature and pressure of the feed water
10	Type of fuel to be used and fuel consumption at full steam production
11	Number and capacity of burners

Table 5 : Drawings, information and data to be submitted for pressure vessels and heat exchangers

No.	A/I	Item
1	I	General arrangement plan, including nozzles and fittings
2	A	Sectional assembly
3	A	Safety valves (if any) and their arrangement
4	A	Material specifications
5	A	Welding details, including at least: • typical weld joint design • welding procedure specifications • post-weld heat treatments
6	I	Design data, including at least design pressure and design temperatures (as applicable)
7	A	For seamless (extruded) pressure vessels, the manufacturing process, including: • a description of the manufacturing process with indication of the production controls normally carried out in the manufacturer's works • details of the materials to be used (specification, yield point, tensile strength, impact strength, heat treatment) • details of the stamped marking to be applied
8	I	Type of fluid or fluids contained
Note 1: A = to be submitted for approval in four copies I = to be submitted for information in duplicate		

2 Material test, workshop inspection and testing, certification

2.1 Material testing

2.1.1 General

Materials, including welding consumables, for the constructions of boilers and pressure vessels are to be certified by the material manufacturer in accordance with the appropriate material specification.

2.1.2 Boilers, other steam generators

In addition to the requirement in [2.1.1], testing of materials intended for the construction of pressure parts of boilers and other steam generators is to be witnessed by the Surveyor.

2.1.3 Class 1 pressure vessels and heat exchangers

In addition to the requirement in [2.1.1], testing of materials intended for the construction of class 1 pressure parts of pressure vessels and heat exchangers is to be witnessed by the Surveyor.

This requirement may be waived at the Society's discretion for mass produced small pressure vessels (such as accumulators for valve controls, gas bottles, etc.).

2.2 Workshop inspections

2.2.1 Boilers and individually produced class 1 and 2 pressure vessels

The construction, fitting and testing of boilers and individually produced class 1 and 2 pressure vessels are to be attended by the Surveyor, at the builder's facility.

2.2.2 Mass produced pressure vessels

Construction of mass produced pressure vessels which are type approved by the Society need not be attended by the Surveyor.

2.3 Hydrostatic tests

2.3.1 General

Hydrostatic tests of all class 1, 2 and 3 pressure vessels are to be witnessed by the Surveyor with the exception of mass produced pressure vessels which are built under the conditions stated in [2.2.2].

2.3.2 Testing pressure

a) Upon completion, pressure parts of boilers and pressure vessels are to be subjected to a hydraulic test under a pressure p_t defined below as a function of the design pressure p:

- $p_t = 1,5\ p$ where $p \leq 4$ MPa
- $p_t = 1,4\ p + 0,4$ where $4 \text{ MPa} < p \leq 25$ MPa
- $P_t = p + 10,4$ where $p > 25$ MPa

b) The test pressure may be determined as a function of a pressure lower than p; however, in such case, the setting and characteristics of the safety valves and other overpressure protective devices are also to be determined and blocked as a function of this lower pressure.

c) If the design temperature exceeds 300°C, the test pressure p_t is to be as determined by the following formula:

$$p_t = 1,5 \cdot \frac{K_{100}}{K} \cdot p$$

where:

p : Design pressure, in MPa

K_{100} : Permissible stress at 100°C, in N/mm^2

K : Permissible stress at the design temperature, in N/mm^2.

d) Consideration is to be given to the reduction of the test pressure below the values stated above where it is necessary to avoid excessive stress. In any event, the general membrane stress is not to exceed 90% of the yield stress at the test temperature.

e) Economisers which cannot be shut off from the boiler in any working condition are to be submitted to a hydraulic test under the same conditions as the boilers.

f) Economisers which can be shut off from the boiler are to be submitted to a hydraulic test at a pressure determined as a function of their actual design pressure p.

2.3.3 Hydraulic test of boiler and pressure vessel accessories

a) Boilers and pressure vessel accessories are to be tested at a pressure p_t which is not less than 1,5 times the design pressure p of the vessels to which they are attached.

b) The test pressure may be determined as a function of a pressure lower than p; however, in such case, the setting and characteristics of the safety valves and other overpressure protective devices are also to be determined and blocked as a function of this lower pressure.

2.3.4 Hydraulic test procedure

a) The hydraulic test specified in [2.3.1] is to be carried out after all openings have been cut out and after execution of all welding work and of the heat treatment, if any. The vessel to be tested is to be presented without lagging, paint or any other lining and the pressure is to be maintained long enough for the Surveyor to proceed with a complete examination.

b) Hydraulic tests of boilers are to be carried out either after installation on board, or at the manufacturer's plant. Where a boiler is hydrotested before installation on board, the Surveyor may, if deemed necessary, request to proceed with a second hydraulic test on board under a pressure at least equal to 1,1 p. For this test, the boiler may be fitted with its lagging. However, the Surveyor may require this lagging to be partially or entirely removed as necessary.

c) For water tube boilers, the hydraulic test may also be carried out separately for different parts of the boiler upon their completion and after heat treatment. For drums and headers, this test may be carried out before drilling the tube holes, but after welding of all appendices and heat treatment. When all parts of the boiler have been separately tested and following assembly the boiler is to undergo a hydraulic test under a pressure of 1,25 p.

2.3.5 Hydraulic tests of condensers

Condensers are to be subjected to a hydrostatic test at the following test pressures:

- steam space: 0,1 MPa
- water space:
  - maximum pressure which may be developed by the pump with closed discharge valve increased by 0,07 MPa. However, the test pressure is not to be less than 0,2 MPa. When the characteristics of the pump are not known, the hydrostatic test is to be carried out at a pressure not less than 0,35 MPa
  - when relevant, Rules for systems likely to withstand immersion pressure (see Ch 3, Sec 5) shall be contemplated.

2.3.6 Hydraulic test of pressure vessels located outside pressure hull

Additionally to test mentioned previously for internal pressure, pressure vessels located outside pressure hull are to be subjected to an external hydrostatic test of 1,5 times the pressure corresponding the accidental diving depth or at least the pressure corresponding to the collapse diving depth.

This external test does not need to be undertaken if ratio between internal design pressure and pressure corresponding to accidental diving depth is at least equal to 5. It is not required for each pressure vessel in case it has been type approved and undertaken during type approval.

2.4 Certification

2.4.1 Certification of boilers and individually produced pressure vessels

Boilers and individually produced pressure vessels of classes 1, 2 and 3 are to be certified by the Society in accordance with the procedures stated in Part A.

2.4.2 Mass produced pressure vessels

Small mass produced pressure vessels of classes 1, 2 and 3 may be accepted provided they are type approved by the Society in accordance with the procedures stated in Part A.

Table 6: Pressure vessel certification

Class	Drawing / Calculation		Material testing		Hydraulic test	
	Manufacturer	The Society	Manufacturer	The Society	Manufacturer	The Society
1	X	review	X	witness + workshop inspection	X	witness
2	X	review	X	review	X	witness
3	X	–	X	review	X	witness
Note 1: Certificates of the Manufacturer and the Society to be issued for all cases for pressure vessels covered by the Rules of the Society.						

SECTION 4 MASTS

1 General

1.1 Application

1.1.1 This Section applies to masts likely to be hoisted when submarine is navigating at periscope depth or on surface.

1.2 Definitions

1.2.1 Obturating systems

These systems are mechanically independent from mast. They enable to keep form continuity of hull when mast is not hoisted.

2 Design and arrangements for masts

2.1 Masts

2.1.1 Availability

a) One shall be able to lower a mast whenever energy source enabling to hoist it is lost. Navigating at very low speed or adapting submarine immersion is accepted as a need to obtain such effect.

b) Two optical watch masts should normally be implemented aboard submarines.

2.1.2 Provision against consequences of collision at periscopic immersion

As a principle masts should be designed in a way that collisions at periscopic immersion would not involve uncontrollable entry of water inside submarine.

Where a mobile cable linked to mast is crossing pressure hull, a device enabling to cut cable and recover pressure hull integrity shall be provided.

2.1.3 Masts crossing pressure hull

Corresponding hull crossings shall be equipped with two sealing glands in line and with a leak detection piping system at the level of the most external sealing gland.

2.2 Mast associated piping

2.2.1 Compliance to other parts of Rules

Piping linked to masts shall comply with requirements mentioned in Ch 3, Sec 5, as applicable.

2.2.2 Safety in case of over-immersion with mast hoisted

Masts should be provided with safety device in order to avoid excessive pressure on associated piping system inside pressure hull or damage on pressure hull when mast remains hoisted while submarine is immersion. When it is proven that such situation could not affect pressure hull integrity or seizure of an internal piping system by overpassing design pressure, this requirement may be avoided.

3 Control and monitoring

3.1 Command system

3.1.1 Individual command of masts

Remote command for hoisting and lowering shall be available in control room.

SECTION 5 PIPING SYSTEMS

1 General

1.1 Application

1.1.1

a) General requirements applying to piping systems are contained in Articles:

- [2] for their design and construction
- [3] for the welding of steel pipes
- [4] for the bending of pipes
- [5] for their arrangement and installation
- [19] for their certification, inspection and testing.

About piping systems likely to withstand immersion pressure, the following requirements are to be followed except if otherwise mentioned in [6].

b) Specific requirements for ship piping systems and machinery piping systems are given in Articles [6] to [18].

1.2 Documentation to be submitted

1.2.1 Documents

The documents listed in Tab 1 are to be submitted.

1.2.2 Additional information

The information listed in Tab 2 is also to be submitted.

Table 1 : Documents to be submitted

Item No.	I/A **(1)**	Document **(2)**
1	A	Drawing showing the arrangement of wall penetrations and isolating valves
2	A	Diagram of the vent valves and associated power system
3	A	Specification of the bilge system
4	A	Diagram of the air, sounding and overflow systems
5	A	Diagram of cooling systems (sea water and fresh water)
6	A	Diagram of fuel oil system
7	A	Drawings of the fuel oil tanks not forming part of the ship's structure
8	A	Diagram of the lubricating oil system
9	A	Diagram of the sea water systems, mentioning classification of piping according to hull and hull valves
10	A	Diagram of the hydraulic systems intended for essential services or located in machinery spaces
11	A I	For high temperature steam pipes: • stress calculation note • drawing showing the actual arrangement of the piping in three dimensions
12	A	Diagram of the compressed air system, including: • air capacity calculation as per Rule requirements
13	A	Diagram of the hydraulic and pneumatic remote control systems
14	A	Diagram of the remote level gauging system
15	A	Diagram of the exhaust gas system
16	A	Diagram of drip trays and gutterway draining system
17	A	Diagram of regulating and trim tank piping system
18	A	Diagram of piping associated to trunks
19	A	Drawings and specification of valves and accessories, where required in [2.7]

(1) A = to be submitted for approval, in four copies
I = to be submitted for information, in duplicate.

(2) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems.

Table 2 : Information to be submitted

Item No.	I/A **(1)**	Document
1	I	Nature, service temperature and pressure of the fluids
2	A	Material, external diameter and wall thickness of the pipes
3	A	Type of the connections between pipe lengths, including details of the weldings, where provided
4	A	Material, type and size of the accessories
5	A	Capacity, prime mover and, when requested, location of the pumps
6	A	Type of piping according to classification related to pipings likely to withstand immersion pressure
7	A	For plastic pipes: • the chemical composition • the physical and mechanical characteristics in function of temperature • the characteristics of inflammability and fire resistance • the resistance to the products intended to be conveyed
8	A / I	Technology plan grouping information mentioned above by systems. This document may contain information asked above and be sufficient in this case
(1) A = to be submitted for approval, in four copies I = to be submitted for information, in duplicate.		

1.3 Definitions

1.3.1 Piping and piping systems

a) Piping includes pipes and their connections, flexible hoses and expansion joints, valves and their actuating systems, other accessories (filters, level gauges, etc.) and pump casings.

b) Piping systems include piping and all the interfacing equipment such as tanks, pressure vessels, heat exchangers, pumps and centrifugal purifiers, but do not include boilers, turbines, internal combustion engines and reduction gears.

Note 1: The equipment other than piping is to be designed in accordance with the relevant Sections of Part D.

1.3.2 Design pressure

a) The design pressure of a piping system is the pressure considered by the manufacturer to determine the scantling of the system components. It is not to be taken less than the maximum working pressure expected in this system or the highest setting pressure of any safety valve or relief device, whichever is the greater.

b) The design pressure of a boiler feed system is not to be less than 1,25 times the design pressure of the boiler or the maximum pressure expected in the feed piping, whichever is the greater.

c) The design pressure of steam piping located upstream of pressure reducing valves (high pressure side) is not to be less than the setting pressure of the boiler or superheater safety valves.

d) The design pressure of a piping system located on the low pressure side of a pressure reducing valve where no safety valve is provided is not to be less than the maximum pressure on the high pressure side of the pressure reducing valve.

e) The design pressure of a piping system located on the delivery side of a pump or a compressor is not to be less than the setting pressure of the safety valve for displacement pumps or the maximum pressure resulting from the operating (head-capacity) curve for centrifugal pumps, whichever is the greater.

1.3.3 Design temperature

The design temperature of a piping system is the maximum temperature of the medium inside the system.

1.3.4 Flammable oils

Flammable oils include fuel oils, lubricating oils, thermal oils and hydraulic oils.

1.4 Symbols and units

1.4.1 The following symbols and related units are commonly used in this Section:

p : Design pressure, in MPa

T : Design temperature, in °C

t : Rule required minimum thickness, in mm

D : Pipe external diameter, in mm.

Additional symbols, related to some formulae indicated in this Section, are listed wherever it is necessary.

1.5 Class of piping systems

1.5.1 Purpose of the classes of piping systems

Piping systems are subdivided into three classes, denoted as class I, class II and class III, for the purpose of acceptance of materials, selection of joints, the design of pipework and assemblies, whether welded or not, the manufacture of piping, onboard fitting, and inspections and tests to perform during or at the end of production (manufacture, fitting).

Table 3 : Class of piping systems

Media conveyed by the piping system	Class I	Class II	Class III
Seawater subject to immersion pressure **(1)**	Irrespective of p, T (except balanced circuits)	not applicable	Balanced circuits outside pressure hull
Hydraulic fluid **(2)**	Irrespective of p, T	not applicable	not applicable
Air **(2)**	p > 1,6 and T ≤ 110	other (e.g. safety circuits such as breathable air)	p ≤ 1,6 and T ≤ 110 excluding safety circuits (e.g. tool air)
Gas (oxygen, hydrogen) discharge	Inside pressure hull, Irrespective of p, T (except purge circuits excluding fire risk compartment)	Outside pressure hull Irrespective of p, T	p ≤ 1,6 and T ≤ 110 for purge circuits excluding fire risk compartment
Exhaust Gases **(2)**	p > 1,6 or T > 450	other **(3)**	not applicable
Steam	p > 1,6 or T > 300	other **(3)**	p ≤ 0,7 and T ≤ 170
Other media: Gas (CO2, Nitrogen,…), Water, Diesel-oil, Lubricating oils, Lubricant **(2) (5)**	p > 10 and T ≤ 110	other **(3)** excluding fire or toxicity risk compartment **(4)**	p ≤ 1,6 and T ≤ 110 excluding fire or risk toxicity compartment **(4)**
Ventilation circuits - Tank vents - polluted gases	not applicable	not applicable	p ≤ 0,1 and T ≤ 110

(1) Piping, valves and fittings likely to withstand immersion pressure belong to class I. See also [6] and [19.4.4].

(2) Circuit inside pressure hull only. Parts of piping outside pressure hull shall c.omply with specific requirements due to immersion pressure.

(3) Pressure, temperature and risks conditions other than those required for class I and class III.

(4) Circuits excluding fire risk compartment or with Special Safeguards for reducing leakage possibility and limiting its consequences: e.g. pipes led in positions where leakage of internal fluids will not cause a potential hazard or damage to surrounding areas which may include the use of pipe ducts, shielding, screening etc, prevention of fire risk with flammable oil or toxicity risks such as H2S with grey & black waters.

(5) Isolating valves under static pressure on oil fuel tanks or lubricating oil tanks belong to class II.

Note 1:

p : Design pressure, in MPa, as defined in [1.3.2]

T : Design temperature, in °C, as defined in [1.3.3].

These classes have been defined in consideration of p and T but also of the risks concerning circuits that are essential to vessel safety and crew safety. Any failure of a component on these circuits is likely to provoke serious accidents involving crew members or may endanger the safety of the vessel.

1.5.2 Definitions of the classes of piping systems

a) Classes I, II and III are defined in Tab 3.

b) The following systems are not covered by Tab 3:

- fluids for refrigerating plants (see Ch 3, Sec 6).

2 General requirements for design and construction

2.1 Materials

2.1.1 General

Materials to be used in piping systems are to be suitable for the medium and the service for which the piping is intended.

2.1.2 Pipes used in specific spaces

Material of pipes used in specific spaces shall be chosen taking into account specific environment that could be met in such spaces. For instance, piping entering a battery compartment and likely to withstand acid projections shall be made out of a material able to bear such projections.

2.1.3 Use of metallic materials

a) Metallic materials are to be used in accordance with Tab 4.

b) Materials for class I and class II piping systems are to be manufactured and tested in accordance with the appropriate requirements of NR216 Materials and Welding.

c) Materials for class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable national or international standards or specifications.

d) Mechanical characteristics required for metallic materials are specified in NR216 Materials and Welding.

Table 4 : Conditions of use of metallic materials in piping systems

Material	Allowable classes	Maximum design temperature **(1)**	Particular conditions of use
Carbon and carbon-manganese steels	III, II, I	400 **(2)**	Class I and II pipes are to be seamless drawn pipes **(3)**
Copper and aluminium brass	III, II, I	200	• Not to be used in fuel oil systems inside pressure hull, except for class II pipes of a diameter not exceeding 25 mm not passing through fuel oil tanks • Not to be used for boiler blow-down valves and pieces for connection to the shell plating **(4)**
Copper-nickel	III, II, I	300	
Special high temperature resistant bronze	III, II, I	260	
Stainless steel	III, II, I	300	Austenitic stainless steel is not to be used for sea water systems
Spheroidal graphite cast iron	III, II **(5)**	350	• Minimum elongation is not to be less than 12% on a gauge length of $5{,}65 \cdot S^{0,5}$, where S is the actual cross-sectional area of the test piece • Not to be used for boiler blow-down valves and pieces for connection to the shell plating
Grey cast iron	III II **(6)**	220	Grey cast iron is not to be used for the following systems: • boiler blow-down systems and other piping systems subject to shocks, high stresses and vibrations • bilge lines in tanks • hull valves and fittings • valves fitted to fuel oil and lubricating oil tanks under static pressure head • fuel oil systems
Aluminium and aluminium alloys	III, II	200	Aluminium and aluminium alloys are not to be used on the following systems: • flammable oil systems • sounding and air pipes of fuel oil tanks • fire-extinguishing systems • bilge system in boiler or machinery spaces or in spaces containing fuel oil tanks or pumping units • boiler blow-down valves and pieces for connection to the shell plating

(1) Maximum design temperature is not to exceed that assigned to the class of piping.

(2) Higher temperatures may be accepted if metallurgical behaviour and time dependent strength (ultimate tensile strength after 100 000 hours) are in accordance with national or international standards or specifications and if such values are guaranteed by the steel manufacturer.

(3) Pipes fabricated by a welding procedure approved by the Society may also be used.

(4) Pipes made of copper and copper alloys are to be seamless.

(5) Use of spheroidal cast iron for class I piping systems will be given special consideration by the Society.

(6) Use of grey cast iron is not allowed when the design pressure exceeds 1,3 MPa.

2.1.4 Use of plastics

a) Plastics may be used for piping systems belonging to class III in accordance with Ch 3, App 1. The use of plastics for other systems or in other conditions will be given special consideration.

b) Plastics intended for piping systems dealt with in this Section are to be of a type approved by the Society.

2.2 Thickness of pressure piping

2.2.1 Calculation of the thickness of pressure pipes

a) The thickness t, in mm, of pressure pipes is to be determined by the following formula:

$$t \geq (t_0 + a + b + c)$$

but, in any case, t is not to be less than the minimum thickness given in Tab 5 to Tab 8,

where:

t_0 : Coefficient, in mm, equal to:

$$t_0 = \frac{p \cdot D}{2Ke + p}$$

Note 1: The formula of t_0 is applicable for pipes with a ratio of external versus internal diameters equal to or less than 1,7

p, D : As defined in [1.4.1]

K : Permissible stress defined in [2.2.2]

e : Weld efficiency factor to be:
- equal to 1 for seamless pipes and pipes fabricated according to a welding procedure approved by the Society
- specially considered by the Society for other welded pipes, depending on the service and the manufacture procedure

b : Thickness reduction due to bending, defined in [2.2.3], in mm

c : Corrosion allowance defined in [2.2.4], in mm

a : Negative manufacturing tolerance in % of thickness t, as described in product standard.

b) The thickness thus determined does not take into account the particular loads to which pipes may be subjected. Attention is to be drawn in particular to the case of high temperature and low temperature pipes.

Table 5 : Minimum wall thickness for steel pipes

External diameter (mm)	Minimum nominal wall thickness (mm)	
	Thick series for p > 1,6 MPa or reinforced wall thickness **(1) (3) (4)**	Thin series for p ≤ 1,6 MPa or other pipes **(2)**
10,2 - 12,0	–	–
13,5 - 19,3	–	–
20,0	–	–
21,3 - 25,0	3,6	2,3
26,9 - 33,7	3,6	2,3
38,0 - 44,5	3,6	2,6
48,3	4,0	2,6
51,0 - 63,5	4,0	2,9
70,0	4,0	2,9
76,1 - 82,5	5,0	2,9
88,9 - 108,0	6,3	3,2
114,3 - 127,0	6,3	3,2
133,0 - 139,7	8,0	4,0
152,4 - 168,3	8,8	4,0
177,8	8,8	4,0
193,7	8,8	4,5
219,1	8,8	6,3
244,5 - 273,0	8,8	6,3
298,5 - 368,0	8,8	6,3
406,4 - 457,2	8,8	6,3

(1) Thick series for internal sea water not bearing immersion pressure pipes, Vent, overflow and sounding pipes for integral tanks or when a minimum reinforced wall thickness is required.

(2) Attention is drawn to the special requirements regarding:
- bilge and regulating tank systems
- sounding, air and overflow pipes
- ventilation systems.

(3) Reinforced wall thickness applies to pipes passing through tanks containing a fluid distinct from that conveyed by the pipe and to pipe connections fitted to the tanks.

(4) For sounding pipes, the minimum wall thickness is intended to apply only to the part outside the tank.

Note 1: A different thickness may be considered by the Society on a case by case basis, provided that it complies with standards approved by the Society.

Note 2: The thickness of threaded pipes is to be measured at the bottom of the thread.

Note 3: Exhaust gas pipe minimum wall thickness is to be subject to special consideration by the Society.

Table 6 : Minimum wall thickness for copper and copper alloy pipes

External diameter (mm)	Minimum wall thickness (mm)	
	Copper	Copper alloy
8 - 10	1,0	1,6
12 - 20	1,6	1,6
25 - 44,5	2,0	2,4
50 - 76,1	2,0	3,0
88,9 - 108	2,5	4,0
133 - 159	3,0	5,0
193,7 - 267	3,5	5,0
273 - 457,2	4,0	5,0
Note 1: A different thickness may be considered by the Society on a case by case basis, provided that it complies with recognised standards.		

Table 7 : Minimum wall thickness for austenitic stainless steel pipes

External diameter (mm)	Minimum wall thickness (mm)
10,2 to 17,2	1,5
21,3 to 48,3	2,0
60,3 to 88,9	2,9
114,3 to 168,3	3,6
219,1	3,6
273,0	3,6
323,9 to 406,4	3,6
over 406,4	4,0
Note 1: Diameters and thicknesses according to national or international standards may be accepted.	

Table 8 : Minimum wall thickness for aluminium and aluminium alloy pipes

External diameter (mm)	Minimum wall thickness (mm)
0 - 10	1,5
12 - 38	2,0
43 - 57	2,5
76 - 89	3,0
108 - 133	4,0
159 - 194	4,5
219 - 273	5,0
above 273	5,5
Note 1: A different thickness may be considered by the Society on a case by case basis, provided that it complies with recognised standards. **Note 2:** For internal sea water pipes, the minimum thickness is not to be less than 5 mm.	

2.2.2 Permissible stress

a) The permissible stress K is given:

- in Tab 9 for service situation
- in Tab 10 for test situation,

as a function of the temperature. Intermediate values may be obtained by interpolation.

b) After calculation of the thickness, the stresses during the pressure test resistance situation must be lower or equal to the following permissive stresses K. The thickness to be considered for this checking is the minimal possible thickness for the pipe after manufacturing: t-a-b. The corresponding allowance c is also to be considered when a pipe with a thickness lower than t-a-b can be submitted to a pressure test.

Table 9 : Permissible stress K for service situation

MATERIAL		Permissible stress K	
		Products with specific control **(1)**	Products with non-specific control
Carbon and carbon-manganese steel		Min ($R^t_{p0,2}$ / 1,5 ; R_m / 2,4)	Min ($R^t_{p0,2}$ / 1,8 ; R_m / 2,7)
Stainless steel	A > 30%	$R^t_{p1,0}$ / 1,5	
	A > 35%	Min ($R^t_{p1,0}$ / 1,2 ; R^t_m / 3)	
Aluminium and aluminium alloys		Min ($R^t_{p0,2}$ / 1,6 ; R_m / 3)	Min ($R^t_{p0,2}$ / 1,9 ; R_m / 3)
Copper and copper alloys		R^t_m/4	
(1) According to a recognised standard (i.e. NF EN 10204).			

Table 10 : Permissible stress K for pressure test situation

Material	Permissible stress K
Carbon and carbon-manganese steel	0,95 $R^t_{p0,2}$
Stainless steel	R^t_m / 2
Aluminium and aluminium alloys	0,95 $R^t_{p0,2}$
Copper and copper alloys	R^t_m / 2,6

2.2.3 Thickness reduction due to bending

a) The minimal thickness in extrados e' for pressure resistance is:

$$e' \geq e\left[\frac{(\rho/D)+0,25}{(\rho/D)+0,5}\right]$$

where:

ρ : Bending radius measured on the centre line of the pipe, in mm

D : As defined in [1.4.1]

$e = t_0$, with t_0 as defined in [2.2.1].

b) The thickness reduction due to bending, b, to be considered in the calculation is the permissible one during manufacturing, as mentioned in Tab 11.

Intermediate values can be obtained by interpolation.

c) For straight pipes, the thickness reduction is to be taken equal to 0.

d) For the folding of plates the thinning down to be taken into account in the calculations is equivalent to the rate of strain hardening defined by the relative extension of the outside generator.

e) As regards the extrusions on pipes, the permissible thinning down when the branch has a diameter lower then the diameter of the pipes is determined from the minimal thickness calculated for the diameter of the branch.

Table 11 : Thickness reduction b due to bending

ρ / D	b (% of t + a), in mm
5	8
4	10
3	20
2	25

2.2.4 Corrosion allowance

The values of corrosion allowance c are given for steel pipes in Tab 12, for stainless steel pipes in Tab 13, for non-ferrous pipes in Tab 14.

2.2.5 Tees

As well as complying with the provisions of [2.2.1] to [2.2.4], the thickness of pipes on which a branch is welded to form a Tee will be reinforced according to a recognised standard if the following condition is verified:

$$d_t > 0,14\sqrt{D_m \cdot t}$$

where:

d_t : Internal diameter of the branch

t : Thickness of the main pipe, as defined in [2.2.1]

D_m : Medium diameter of the main pipe.

Note 1: This requirement may be dispensed with for Tees provided with a reinforcement or extruded.

Table 12 : Corrosion allowance c for steel pipes

Piping system	c, in mm
Superheated steam	0,3
Saturated steam	0,8
Feed water for boilers in open circuit systems	1,5
Feed water for boilers in closed circuit systems	0,5
Blow-down systems for boilers	1,5
Compressed air	1,0
Hydraulic oil	0,3
Lubricating oil	0,3
Fuel oil	1,0
Fresh water	0,8
Sea water	3,0
Refrigerants referred to in Section 13	0,3

Note 1: For pipes passing through tanks, an additional corrosion allowance is to be considered in order to account for the external corrosion.

Note 2: The corrosion allowance of pipes efficiently protected against corrosion may be reduced by no more than 50%.

Note 3: When the corrosion resistance of alloy steels is adequately demonstrated, the corrosion allowance may be disregarded.

Table 13 : Corrosion allowance c for stainless steel pipes

Piping system	c, in mm
Sea water	**(1)**
Flammable liquid Superheated steam	0,25
Compressed air5	0,50
Other media	0

(1) Austenitic stainless steel is forbidden on seawater systems (see Tab 4) - Special considerations for others stainless steel resistant or protected to sea water corrosion risk

Table 14 : Corrosion allowance c for non-ferrous metal pipes

Piping material **(1)**	c, in mm **(2)**
Copper	0,8
Brass	0,8
Copper-tin alloys	0,8
Copper-nickel alloys with less than 10% of Ni	0,8
Copper-nickel alloys with at least 10% of Ni	0,5
Aluminium and aluminium alloys	0,5

(1) The corrosion allowance for other materials will be specially considered by the Society. Where their resistance to corrosion is adequately demonstrated, the corrosion allowance may be disregarded.

(2) In cases of media with high corrosive action, a higher corrosion allowance may be required by the Society.

2.3 Calculation of high temperature pipes

2.3.1 General

For main steam piping having a design temperature exceeding 400°C, calculations are to be submitted to the Society concerning the stresses due to internal pressure, piping weight and any other external load, and to thermal expansion, for all cases of actual operation and for all lengths of piping.

The calculations are to include, in particular:

- the components, along the three principal axes, of the forces and moments acting on each branch of piping
- the components of the displacements and rotations causing the above forces and moments
- all parameters necessary for the computation of forces, moments and stresses.

In way of bends, the calculations are to be carried out taking into account, where necessary, the pipe ovalisation and its effects on flexibility and stress increase.

A certain amount of cold springing, calculated on the basis of expected thermal expansion, is to be applied to the piping during installation. Such springing is to be neglected in stress calculations; it may, however, be taken into account in terms of its effect on thrusts on turbines and other parts.

2.3.2 Thermal stress

The combined stress σ_{ID} due to thermal expansion, in N/mm^2, calculated by the following formula:

$$\sigma_{ID} = (\sigma^2 + 4\,\tau^2)^{0,5}$$

is to be such as to satisfy the following equation:

$$\sigma_{ID} \leq 0,75\,K_{20} + 0,25\,K_T$$

where:

σ : Value of the longitudinal stress due to bending moments caused by thermal expansion, increased, if necessary, by adequate factors for bends, in N/mm^2; in general it is not necessary to take account of the effect of axial force

τ : Value of the tangential stress due to torque caused by thermal expansion, in N/mm^2; in general it is not necessary to take account of the effect of shear force

K_{20} : Value of the permissible stress for the material employed, calculated according to [2.2.2], for a temperature of 20°C, in N/mm^2

K_T : Value of the permissible stress for the material employed, calculated according to [2.2.2], for the design temperature T, in N/mm^2.

2.3.3 Longitudinal stresses

The sum of longitudinal stresses σ_L, in N/mm^2, due to pressure, piping weight and any other external loads is to be such as to satisfy the following equation:

$$\sigma_L \leq K_T$$

where K_T is defined in [2.3.2].

2.3.4 Alternative limits for permissible stresses

Alternative limits for permissible stresses may be considered by the Society in special cases or when calculations have been carried out following a procedure based on hypotheses other than those considered above.

2.4 Junction of pipes

2.4.1 General

a) The junctions between metallic pipe lengths or between metallic pipe lengths and fittings are to be made by:
   - direct welding (butt-weld, socket-weld)
   - bolted flanges (welded-on or screwed-on)
   - threaded sleeve joints, or
   - mechanical joints (see [2.4.5]).

   The joints are to comply with a recognised standard or to be of a design proven to be suitable for the intended purpose and acceptable to the Society. See also [2.1.3].

   The expression "mechanical joints" means devices intended for direct connection of pipe lengths other than by welding, flanges or threaded joints described in [2.4.2]. [2.4.3]. [2.4.4].

b) The number of joints in flammable oil piping systems is to be kept to the minimum necessary for mounting and dismantling purposes.

c) The gaskets and packings used for the joints are to suit the design pressure, the design temperature and the nature of the fluids conveyed.

d) The junction between plastic pipes is to comply with Ch 3, App 1.

2.4.2 Welded metallic joints

a) Welded joints are to be used in accordance with Tab 15. Welding and non-destructive testing of welds are to be carried out in accordance with [3].

b) Butt-welded joints are to be of full penetration type, with or without special provision for a high quality of root side.

   The expression "special provision for a high quality of root side" means that butt welds were accomplished as double welded or by use of a backing ring or inert gas back-up on first pass, or other similar methods accepted by the Society.

c) Slip-on sleeve and socket welded joints are to have sleeves, sockets and weldments of adequate dimensions in compliance with a standard recognised by the Society.

Table 15 : Use of welded and threaded metallic joints in piping systems

Joints	Permitted classes of piping	Restrictions of use
Butt-welded, with special provision for a high quality of root side **(1)**	III, II, I	no restrictions
Butt-welded, without special provision for a high quality of root side **(1)**	III, II	no restrictions
Slip-on sleeve and socket welded **(2)**	III	restrictions for piping systems conveying toxic media or services where fatigue, severe erosion or crevice corrosion is expected to occur
Threaded sleeve joints with tapered thread **(3)**	I	not allowed for: • pipes with outside diameter of more than 33,7 mm • pipes inside tanks • piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur
	III, II	not allowed for: • pipes with outside diameter of more than 60,3 mm • pipes inside tanks • piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur
Threaded sleeve joints with parallel thread **(3)**	III	not allowed for: • pipes with outside diameter of more than 60,3 mm • pipes inside tanks • piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur

(1) For expression "special provision for a high quality of root side" see [2.4.2], item b).

(2) Particular cases may be allowed by the Society for piping systems of Class I and II having outside diameter ≤ 88,9 mm except for piping systems conveying toxic media or services where fatigue, severe erosion or crevice corrosion is expected to occur.

(3) In particular cases, sizes in excess of those mentioned above may be accepted by the Society if found in compliance with a recognised national and/or international standard.

Note 1: Other applications will be specially considered by the Society.

2.4.3 Metallic flange connections

a) In general, the metallic flange connections used for piping systems are to be in compliance with a standard recognised by the Society.

b) The material used for flanges and gaskets is to be suitable for the nature and temperature of the fluid, as well as pipes on which the flanges are to be fitted.

c) The dimensions and configuration of flanges and bolts are to be chosen in accordance with recognised standard intended for design pressure and design temperature of the piping system. Otherwise, the flange connections are subject to special consideration.

d) Flanges are to be attached to the pipes by welding or screwing. Examples of acceptable metallic flange connections are shown in Fig 1. However, other types of flange connections may be also considered by the Society in each particular case, provided that they are in accordance with national or international standards applicable to the piping system and recognise the boundary fluids, design pressure and temperature conditions, external or cyclic loading and location.

e) Permitted applications are indicated in Tab 16.

2.4.4 Slip-on threaded joints

a) Slip-on threaded joints having pipe threads where pressure-tight joints are made on the threads with parallel or tapered threads are to comply with requirements of a recognised national or international standard and are to be acceptable to the Society.

b) Slip-on threaded joints may be used for piping systems in accordance with Tab 15.

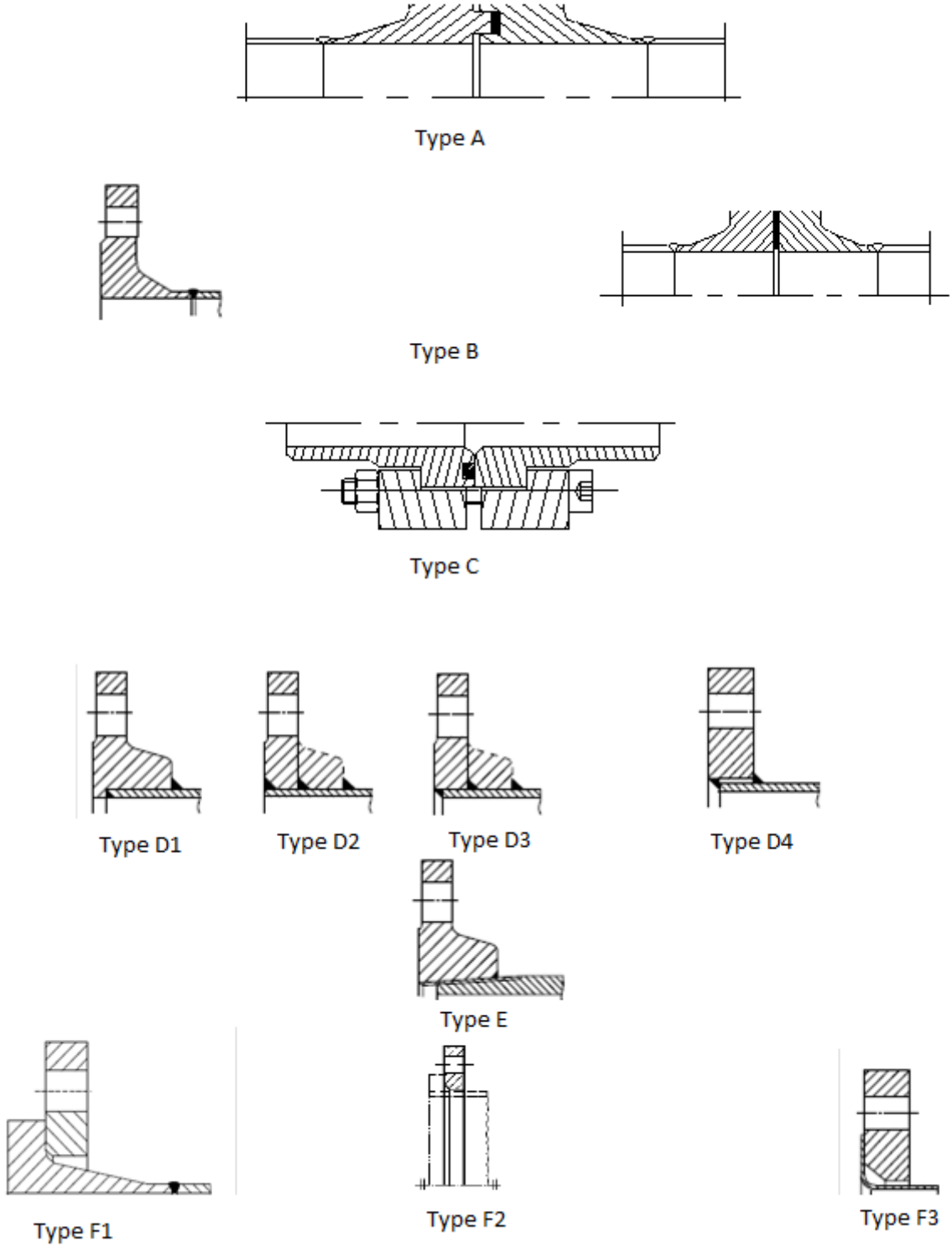
c) Threaded joints may be accepted also in CO_2 piping systems, provided that they are used only inside protected spaces and in CO_2 cylinder rooms.

2.4.5 Mechanical joints

Due to the great variations in design and configuration of mechanical joints, specific recommendation regarding calculation method for theoretical strength calculations is not specified. The Type Approval is to be based on the results of testing of the actual joints.

The specified requirements in the list below are applicable to pipe unions, compression couplings, slip-on joints as shown in Fig 2. Similar joints complying with these requirements may be acceptable.

Figure 1 : Examples of metallic flange connections



Note 1: For type E, the pipe and flange are to be screwed with a tapered thread and the diameter of the screw portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unthreaded pipe. For certain types of thread, after the flange has been screwed hard home, the pipe is to be expanded into the flange.

Note 2: The leg length of the fillet weld, as well as the dimension of the groove penetration in the flange, is to be in general equal to 1,5 times the pipe thickness but not less than 5 mm.

Table 16 : Use of metallic flange connections in piping systems (types as shown in Fig 1)

Type of media conveyed	Class of piping (see Tab 3)		
	I	II	III
Seawater and fluids carried in piping systems withstanding immersion pressure outside pressure hull	A **(1)**	not applicable	not applicable
Hydraulic fluid	B, C	not applicable	not applicable
Toxic or corrosive media Flammable liquids (where heated above flashpoint or having flashpoint < 60°C)	B	B, F1	not applicable
Fuel oil (internal piping) Lubricating oil	B	B,F1	B, D1, D2, D3, D4, F1
Steam	B	B, F1	B, D1,D2,D3,D4, F1
Other media as water, air, gases (refrigerants), non-flammable hydraulic oil, freshwater	B, C	B, C, D1, D2, D3, D4, E, F1, F2, **(2) (3) (4)**	B, C, D1, D2, D3, D4, E, F1, F2, F3 **(2) (3) (4)**

(1) In certain cases justified by corrosion risk, other type than double-socketed flange can be submitted to the Society.
(2) When design temperature T (see [1.3.3]) exceeds 400°C, types B and F1 only.
(3) Type D4 and F2, only for design pressure p ≤ 1,6 MPa and design temperature T ≤ 150°C.
(4) Type F3, only for design temperature T ≤ 250°C.

a) The application and pressure ratings of different mechanical joints are to be approved by the Society. The approval is to be based on the Type Approval procedure. Mechanical joints including pipe unions, compression couplings, slip-on joints and similar joints are to be of approved type for the service conditions and the intended application.

b) Where the application of mechanical joints results in reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

c) Construction of mechanical joints is to prevent the possibility of tightness failure affected by pressure pulsation, piping vibration, temperature variation and other similar adverse effects occurring during operation on board.

d) Material of mechanical joints is to be compatible with the piping material and internal and external media.

e) As far as applicable, the mechanical joints are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar the required burst pressure is to be specially considered by the Society.

f) In general, mechanical joints are to be of fire resistant type as required by Tab 17.

g) Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the shell openings or tanks containing flammable fluids.

h) The mechanical joints are to be designed to withstand internal and external pressure as applicable and, where used in suction lines, are to be capable of operating under vacuum.

i) The number of mechanical joints in flammable liquid systems is to be kept to a minimum. In general, flanged joints conforming to recognised standards are to be used.

j) Piping in which a mechanical joint is fitted is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.

k) Slip-on joints are not to be used in pipelines in tanks, and other spaces which are not easily accessible, unless approved by the Society. Application of these joints inside tanks may be permitted only for the same media that is in the tanks. Unrestrained slip-on joints are to be used only in cases where compensation of lateral pipe deformation is necessary. Usage of these joints as the main means of pipe connection is not permitted.

l) Application of mechanical joints and their acceptable use for each service is indicated in Tab 17; dependence upon the class of piping, pipe dimensions, working pressure and temperature is indicated in Tab 17.

m) In some particular cases, sizes in excess of those mentioned above may be accepted by the Society if they are in compliance with a recognised national and/or international standard.

n) Application of various mechanical joints may be accepted as indicated by Tab 17. However, in all cases, acceptance of the joint type is to be subject to approval for the intended application, and subject to conditions of the approval and applicable Rules.

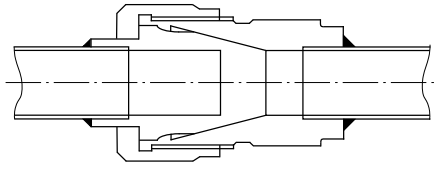
o) Mechanical joints are to be tested in accordance with a program approved by the Society, which is to include at least the following:

1) leakage test
2) vacuum test (where necessary)
3) vibration (fatigue) test
4) fire endurance test (where necessary)
5) burst pressure test
6) pressure pulsation test (where necessary)
7) assembly test (where necessary)
8) pull out test (where necessary).

p) The installation of mechanical joints is to be in accordance with the manufacturer's assembly instructions. Where special tools and gauges are required for installation of the joints, these are to be supplied by the manufacturer.

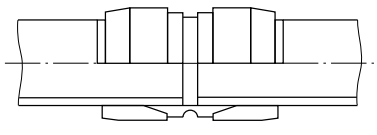
Figure 2 : Examples of mechanical joints

Pipe Unions

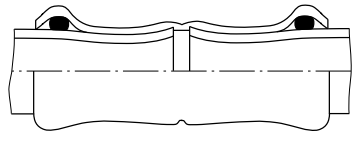


Welded and brazed types

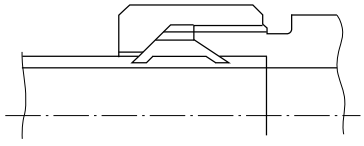
Compression Couplings



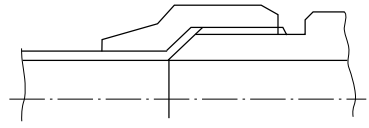
Swage type



Press type

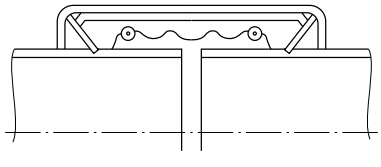


Bite type

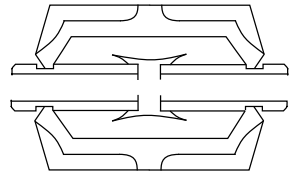


Flared type

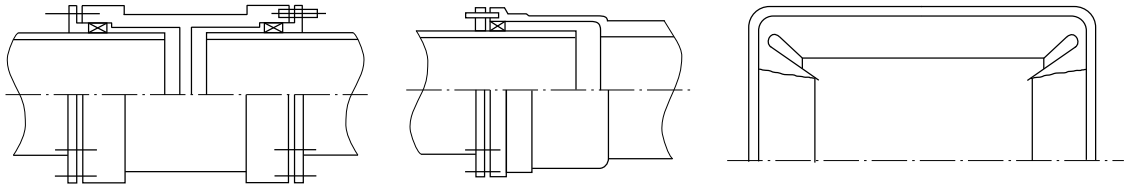
Slip-on Joints



Grip type



Machine grooved type



Slip types

Table 17 : Application of mechanical joints depending upon the class of piping

Types of joints	Classes of piping systems			
	Class I (sea water piping system)	Class I (other than sea water piping system)	Class II	Class III
Pipe Unions				
Welded and brazed types	+ (OD ≤ 26,9 mm)	+ (OD ≤ 60,3 mm)	+ (OD ≤ 60,3 mm)	+
Compression Couplings				
Swage type	+ (OD ≤ 26,9 mm)	+	+	+
Bite type	+ (OD ≤ 26,9 mm)	+ (OD ≤ 60,3 mm)	+ (OD ≤ 60,3 mm)	+
Flared type	+ (OD ≤ 26,9 mm)	+ (OD ≤ 60,3 mm)	+ (OD ≤ 60,3 mm)	+
Press type	–		–	+
Slip-on Joints				
Machine grooved type	–		+	+ **(1)**
Grip type	–		–	+ **(1)**
Slip type	–		–	+ **(1)**

(1) Mechanical joints shall be of a fire resistant type if installed in a fire risk compartment.

Note 1:

\+ : Application is allowed

– : Application is not allowed.

2.5 Protection against overpressure

2.5.1 General

a) These requirements deal with the protection of piping systems against overpressure, with the exception of heat exchangers and pressure vessels, which are dealt with in Ch 3, App 3, [2.4].

b) Safety valves are to be sealed after setting.

2.5.2 Protection of flammable oil systems

Provisions shall be made to prevent overpressure in any flammable oil tank or in any part of the flammable oil systems, including the filling lines served by pumps on board.

2.5.3 Protection of pump and compressor discharges

a) Provisions are to be made so that the discharge pressure of pumps and compressors cannot exceed the pressure for which the pipes located on the discharge of these pumps and compressors are designed.

b) When provided on the pump discharge for this purpose, safety valves are to lead back to the pump suction or to any other suitable place.

c) The discharge capacity of the safety valves installed on pumps and compressors is to be such that the pressure at the discharge side cannot exceed by more than 10% the design pressure of the discharge pipe in the event of operation with closed discharge.

2.5.4 Protection of pipes

a) Pipes likely to be subjected to a pressure exceeding their normal working pressure are to be provided with safety valves or equivalent overpressure protecting devices.

b) In particular, pipes located on the low pressure side of pressure reducing valves are to be provided with safety valves unless they are designed for the maximum pressure on the high pressure side of the pressure reducing valve.

c) The discharge capacity of the devices fitted on pipes for preventing overpressure is to be such that the pressure in these pipes cannot exceed the design pressure by more than 10%.

2.6 Flexible hoses and expansion joints

2.6.1 General

a) The Society may permit the use of flexible hoses and expansion joints, both in metallic and non-metallic materials, provided they are approved for the intended service.

b) Flexible hoses and expansion joints are to be of a type approved by the Society, designed in accordance with [2.6.3] and tested in accordance with [19].

c) Flexible hoses and expansion joints are to be installed in accordance with the requirements stated in [5.8.3].

d) Flexible hoses and expansion joints intended for piping systems with a design temperature below the ambient temperature will be given special consideration by the Society.

e) Flexible hoses and expansion joints considered by the Society or those:

- which are implemented on an essential system, or
- which are implemented on a Class I or Class II piping systems, or
- which are carrying some flammable fluid, or
- whose failure may lead, even for a short period, to a communication between inside and outside pressure hull, or
- which are granted with a design pressure more than 1 MPa

2.6.2 Documentation

The information, drawings and documentation listed in [1.2.1] and [1.2.2] are to be submitted to the Society for each type of flexible hose or expansion joint intended to be used.

2.6.3 Design of flexible hoses and expansion joints

a) Flexible pipes and expansion joints are to be made of materials resistant to the marine environment and to the fluid they are to convey. Metallic materials are to comply with [2.1].

b) Flexible pipes and expansion joints are to be designed so as to withstand:

- external contact with hydrocarbons
- internal pressure
- vibrations
- pressure impulses.

c) Flexible pipes intended to convey fuel oil or lubricating oil and end attachments are to be of fire-resisting materials of adequate strength and are to be constructed to the satisfaction of the Society.

Where a protective lining is provided for this purpose, it is to be impervious to hydrocarbons and to hydrocarbon vapours.

d) Flexible pipes intended to convey gaseous fluid at a pressure higher than 1 MPa are to be fitted with a metallic braid.

e) As a general rule, flexible hoses are to be fitted with crimped connections or equivalent. For water pipes subject to a pressure not exceeding 0,5 MPa, as well as for scavenge air and supercharge air lines of internal combustion engines, clips made of galvanised steel or corrosion-resistant material with thickness not less than 0,4 mm may be used.

f) Flexible pipes and expansion joints are to be so designed that their bursting pressure at the service temperature is not less than 4 times their maximum service pressure, with a minimum of 2 MPa. Exemptions from this requirement may be granted for expansion joints of large diameter used on sea water lines.

g) The junctions of flexible hoses and expansion joints to their couplings are to withstand a pressure at least equal to the bursting pressure defined in item f).

2.6.4 Conditions of use of flexible hoses and expansion joints

a) The use of flexible hoses and expansion joints is to be limited as far as practicable.

b) The position of flexible hoses and expansion joints is to be clearly shown on the piping drawings submitted to the Society.

c) The use of non-metallic expansion joints on pipes connected to sea inlets and overboard discharges is forbidden.

d) Flexible hoses shall not be used on piping systems carrying hydraulic fluid to essential services.

e) Expansion joints may be fitted in sea water lines, provided they are arranged with guards which effectively enclose, but do not interfere with, the action of the expansion joints and reduce to the minimum practicable any flow of water into the machinery spaces in the event of failure of the flexible elements.

2.7 Valves and accessories

2.7.1 General

a) Valves and accessories are normally to be built in accordance with a recognised standard. Otherwise, they are subject to special consideration for approval by the Society.

Valves and fittings in piping systems are to be compatible with the pipes to which they are attached in respect of their strength (see [1.3.2] for design pressure) and are to be suitable for effective operation at the maximum working pressure they will experience in service.

Valves and accessories which are fitted:

- in a class I piping system, or
- in a class II piping system, or
- on the pressure hull, on fuel oil tanks or on lubricating oil tanks under static pressure,

are to be subject to the applicable testing and inspection required by the Rules. See [19].

b) Shut-off valves are to be provided where necessary to isolate pumps, heat exchangers, pressure vessels, etc., from the rest of the piping system when necessary, and in particular to allow the isolation of duplicate components without interrupting the fluid circulation.

2.7.2 Design of valves and accessories

a) Materials of valve and accessory bodies are to comply with the provisions of [2.1].

b) Connections of valves and accessories with pipes are to comply with the provisions of [2.4].

c) All valves and accessories are to be so designed as to prevent the loosening of covers and glands when they are operated.

d) Valves are to be so designed as to shut with a right-hand (clockwise) motion of the wheels.

e) Valves are to be provided with local indicators showing whether they are open or shut, unless this is readily apparent.

2.7.3 Valves with remote control

a) All valves which are provided with remote control are also to be designed for local manual operation.

b) The remote control system and means of local operation are to be independent. In this respect, arrangement of the local operation by means of a fixed hand pump will be specially considered by the Society.

c) In the case of valves which are to be provided with remote control in accordance with the Rules, opening and/or closing of the valves by local manual means is not to render the remote control system inoperable. Exceptions to this principle shall be detailed and justified. Provision shall be adopted in order to protect crew dealing with local operation whenever valve is remotely operated.

d) Power failure of the remote control system is not to cause an undesired change of the valve position.

e) Unless otherwise specified, indicators are to be provided on the remote controls to show whether the valves are open or closed.

2.8 Control and monitoring

2.8.1 General

a) Local indicators are to be provided for at least the following parameters:

- pressure, in pressure vessels, at pump or compressor discharge, at the inlet of the equipment served, on the low pressure side of pressure reducing valves
- temperatures, in tanks and vessels, at heat exchanger inlet and outlet
- levels, in tanks and vessels containing liquids.

b) Safeguards are to be provided where an automatic action is necessary to restore acceptable values for a faulty parameter.

c) Automatic controls are to be provided where it is necessary to maintain parameters related to piping systems at a pre-set value.

2.8.2 Level gauges

Level gauges used in flammable oil systems are to be of a type approved by the Society and are not to require penetration below the top of the tank and their failure or overfilling of the tanks is not to permit release of fuel.The Society may permit the use of oil-level gauges with:

a) flat glasses and self-closing valve between the gauge and tank

b) gauge with fuel completely enclosed inside steel casing. Connexions between tank and steel casing can be of the flanged type.

Level gauges, when allowed, are to be made of heat-resistant material and efficiently protected against shocks.

3 Welding of steel piping

3.1 Application

3.1.1

a) Unless otherwise justified by qualification welding procedure, the following requirements apply to welded joints belonging to class I or II piping systems.

They may also be applied to class III piping systems, at the discretion of the Society.

b) This Article does not apply to refrigerated installation piping systems operating at temperatures lower than minus 40°C.

c) The requirements for qualification of welding procedures are given in NR216 Materials and Welding.

d) Additional requirements for sea water piping systems are given in Article [6].

3.2 General

3.2.1 Welding processes

a) Welded joints of pipes are to be made by means of electric arc or oxyacetylene welding, or any other previously approved process.

b) When the design pressure exceeds 0,7 MPa, oxyacetylene welding is not permitted for pipes with an external diameter greater than 100 mm or a thickness exceeding 6 mm.

3.2.2 Location of joints

The location of welded joints is to be such that as many as possible can be made in a workshop. The location of welded joints to be made on board is to be so determined as to permit their joining and inspection in satisfactory conditions.

3.3 Design of welded joints

3.3.1 Types of joints

a) Except for the fixing of flanges on pipes in the cases mentioned in Fig 1 and for the fixing of branch pipes, joints between pipes and between pipes and fittings are to be of the butt-welded type.

b) For butt-welded joints between pipes or between pipes and flanges or other fittings, correctly adjusted backing rings may be used; such rings are to be either of the same grade of steel as the elements to be welded or of such a grade as not to adversely influence the weld; if the backing ring cannot be removed after welding, it is to be correctly profiled.

3.3.2 Assembly of pipes of unequal thickness

If the difference of thickness between pipes to be butt-welded exceeds 10% of the thickness of the thinner pipe plus 1 mm, subject to a maximum of 4 mm, the thicker pipe is to be thinned down to the thickness of the thinner pipe on a length at least equal to 4 times the offset, including the width of the weld if so desired.

3.3.3 Accessories

a) When accessories such as valves are connected by welding to pipes, they are to be provided with necks of sufficient length to prevent abnormal deformations during the execution of welding or heat treatment.

b) For the fixing by welding of branch pipes on pipes, it is necessary to provide either a thickness increase as indicated in [2.2.5] or a reinforcement by doubling plate or equivalent.

3.4 Preparation of elements to be welded and execution of welding

3.4.1 General

Attention is drawn to the provisions of Ch 3, Sec 3, which apply to the welding of pressure pipes.

3.4.2 Edge preparation for welded joints

The preparation of the edges is preferably to be carried out by mechanical means. When flame cutting is used, care is to be taken to remove the oxide scales and any notch due to irregular cutting by matching, grinding or chipping back to sound metal.

3.4.3 Abutting of parts to be welded

a) The elements to be welded are to be so abutted that surface misalignments are as small as possible.

b) As a general rule for elements which are butt-welded without a backing ring, the misalignment between internal walls is not to exceed the lesser of:

- the value given in Tab 18 as a function of thickness t and internal diameter d of these elements, and
- t / 4

Where necessary, the pipe ends are to be bored or slightly expanded so as to comply with these values; the thickness obtained is not to be less than the rule thickness.

c) In the case of welding with a backing ring, smaller values of misalignment are to be obtained so that the space between the backing ring and the internal walls of the two elements to be assembled is as small as possible; normally this space is not to exceed 0,5 mm.

d) The elements to be welded are to be adequately secured so as to prevent modifications of their relative position and deformations during welding.

Table 18 : Maximum value of misalignment, in mm

Internal diameter	t ≤ 6 mm	6 < t ≤ 10	10 mm < t
d < 150 mm	1,0	1,0	1,0
150 ≤ d < 300	1,0	1,5	1,5
300 mm ≤ d	1,0	1,5	2,0

3.4.4 Protection against adverse weather conditions

a) Pressure pipes are to be welded, both on board and in the shop, away from draughts and sudden temperature variations.

b) Unless special justification is given, no welding is to be performed if the temperature of the base metal is lower than 0°C.

3.4.5 Preheating

a) Preheating is to be performed as indicated in Tab 19, depending on the type of steel, the chemical composition and the pipe thickness.

b) The temperatures given in Tab 19 are based on the use of low hydrogen processes. Where low hydrogen processes are not used, the Society reserves the right to require higher preheating temperatures.

Table 19 : Preheating temperature

Type of steel		Thickness of thicker part (mm)	Minimum preheating temperature (°C)
C and C-Mn steels	$C + \frac{Mn}{6} \leq 0,40$	t ≥ 20 **(2)**	50
	$C + \frac{Mn}{6} > 0,40$	t ≥ 20 **(2)**	100
0,3 Mo		t ≥ 13 **(2)**	100
1 Cr 0,5 Mo		t < 13	100
		t ≥ 13	150
2,25 Cr 1 Mo **(1)**		t < 13	150
		t ≥ 13	200
0,5 Cr 0,5 Mo V **(1)**		t < 13	150
		t ≥ 13	200

(1) For 2,25 Cr 1 Mo and 0,5 Cr 0,5 Mo V grades with thicknesses up to 6 mm, preheating may be omitted if the results of hardness tests carried out on welding procedure qualification are considered acceptable by the Society.

(2) For welding in ambient temperature below 0°C, the minimum preheating temperature is required independent of the thickness unless specially approved by the Society.

3.5 Post-weld heat treatment

3.5.1 General

a) As far as practicable, the heat treatment is to be carried out in a furnace. Where this is impracticable, and more particularly in the case of welding on board, the treatment is to be performed locally by heating uniformly a circular strip, extending on at least 75 mm on both sides of the welded joint; all precautions are to be taken to permit accurate checking of the temperature and slow cooling after treatment.

b) For austenitic and austenitic ferritic steels, post-weld head treatment is generally not required.

3.5.2 Heat treatment after welding other than oxyacetylene welding

a) Stress relieving heat treatment after welding other than oxyacetylene welding is to be performed as indicated in Tab 20, depending on the type of steel and thickness of the pipes.

b) The stress relieving heat treatment is to consist in heating slowly and uniformly to a temperature within the range indicated in Tab 20, soaking at this temperature for a suitable period, normally one hour per 25 mm of thickness with a minimum of half an hour, cooling slowly and uniformly in the furnace to a temperature not exceeding 400°C and subsequently cooling in still atmosphere.

c) In any event, the heat treatment temperature is not to be higher than $(T_T - 20)$°C, where T_T is the temperature of the final tempering treatment of the material.

Table 20 : Heat treatment temperature

Type of steel	Thickness of thicker part (mm)	Stress relief treatment temperature (°C)
C and C-Mn steels	t ≥ 15 **(1) (3)**	550 to 620
0,3 Mo	t ≥ 15 **(1)**	580 to 640
1 Cr 0,5 Mo	t ≥ 8	620 to 680
2,25 Cr 1 Mo 0,5 Cr 0,5 Mo V	any **(2)**	650 to 720

(1) Where steels with specified Charpy V notch impact properties at low temperature are used, the thickness above which post-weld heat treatment is to be applied may be increased, subject to the special agreement of the Society.

(2) For 2,25Cr 1Mo and 0,5Cr 0,5Mo V grade steels, heat treatment may be omitted for pipes having thickness lower than 8 mm, diameter not exceeding 100 mm and service temperature not exceeding 450°C.

(3) For C and C-Mn steels, stress relieving heat treatment may be omitted up to 30 mm thickness, subject to the special agreement of the Society.

3.5.3 Heat treatment after oxyacetylene welding

Stress relieving heat treatment after oxyacetylene welding is to be performed as indicated in Tab 21, depending on the type of steel.

Table 21 : Heat treatment after oxyacetylene welding

Type of steel	Heat treatment and temperature (°C)
C and C-Mn	Normalising 880 to 940
0,3 Mo	Normalising 900 to 940
1Cr-0,5Mo	Normalising 900 to 960 Tempering 640 to 720
2,25Cr-1Mo	Normalising 900 to 960 Tempering 650 to 780
0,5Cr-0,5Mo-0,25V	Normalising 930 to 980 Tempering 670 to 720

3.6 Inspection of welded joints

3.6.1 General

a) The inspection of pressure pipe welded joints is to be performed at the various stages of the fabrication further to the qualifications defined in [3.1.1], item c).

b) The examination mainly concerns those parts to be welded further to their preparation, the welded joints once they have been made and the conditions for carrying out possible heat treatments.

c) The required examinations are to be carried out by qualified operators in accordance with procedures and techniques to the Surveyor's satisfaction.

3.6.2 Visual examination

Welded joints, including the inside wherever possible, are to be visually examined.

3.6.3 Non-destructive examinations

a) Non-destructive tests for class I pipes are to be performed as follows:

- butt-welded joints of pipes are to be subjected to full X-ray examination or equivalent
- welded joints other than butt-welded joints and which cannot be radiographic are to be examined by magnetic particle or liquid penetrant tests
- fillet welds of flange connections are to be examined by magnetic particle tests or by other appropriate non-destructive tests.

b) Non-destructive tests for class II pipes are to be performed as follows:

- butt-welded joints of pipes with an external diameter exceeding 100 mm are to be subjected to at least 10% random radiographic examination or equivalent and at least 5% of all diameters of a same batch (same material and same production conditions)
- welded joints other than butt-welded joints are to be examined by magnetic particle tests or by other appropriate non-destructive tests
- fillet welds of flange connections may be required to be examined by magnetic particle tests or by other appropriate non-destructive tests, at the discretion of the Surveyor.

3.6.4 Defects and acceptance criteria

a) Joints for which non-destructive examinations reveal unacceptable defects are to be re-welded and subsequently to undergo a new non-destructive examination. The Surveyor may require that the number of joints to be subjected to non-destructive examination is larger than that resulting from the provisions of [3.6.3].

b) Acceptance criteria and repairs

- Indications evaluated to be crack, lack of fusion or lack of penetration for class I pipes are not acceptable. Indications evaluated to be crack or lack of fusion in welds for class II pipes are not acceptable. Other types of imperfection are to be assessed in accordance with a recognised standard accepted by the Society.
- Unacceptable indications are to be eliminated and repaired where necessary. The repair welds are to be examined on their full length using magnetic particle or liquid penetrant test and ultrasonic or radiographic testing.

  When unacceptable indications are found, additional area of the same weld length are to be examined unless the indication is judged isolated without any doubt. In case of automatic welded joints, additional NDE is to be extended to all areas of the same weld length.

  The extent of examination can be increased at the surveyor's discretion when repeated non-acceptable indications are found.

4 Bending of pipes

4.1 Application

4.1.1 This Article applies to pipes made of:

- alloy or non-alloy steels
- copper and copper alloys.

Unless otherwise justified by qualification bending procedure, the following requirements apply to bending of Class I or II piping systems.

At the discretion of the Society, it may also apply to Class III piping systems.

4.1.2 Other standards may be applied submitted to acceptance by the Society.

4.2 Bending process

4.2.1 General

The bending process is to be such as not to have a detrimental influence on the characteristics of the materials or on the strength of the pipes.

4.2.2 Bending radius

Unless otherwise justified, the bending radius measured on the centerline of the pipe is not to be less than:

- twice the external diameter for copper and copper alloy pipes
- 3 times the external diameter for cold bent steel pipes.

4.2.3 Acceptance criteria

a) The pipes are to be bent in such a way that, in each transverse section, the difference between the maximum and minimum diameters after bending does not exceed 10% of the mean diameter; higher values, but not exceeding 15%, may be allowed in the case of pipes which are not subjected in service to appreciable bending stresses due to thermal expansion or contraction.

b) The bending is to be such that the depth of the corrugations is as small as possible and does not exceed 9% of their length.

4.2.4 Hot bending

a) In the case of hot bending, all arrangements are to be made to permit careful checking of the metal temperature and to prevent rapid cooling, especially for alloy steels.

b) Hot bending is to be generally carried out in the temperature range 850°C-1000°C for all steel grades; however, a decreased temperature down to 750°C may be accepted during the forming process.

4.3 Heat treatment after bending

4.3.1 Copper and copper alloy

Copper and copper alloy pipes are to be suitably annealed after cold bending if their external diameter exceeds 50 mm.

4.3.2 Steel

a) After hot bending carried out within the temperature range specified in [4.2.4], the following applies:
   - for C, C-Mn and C-Mo steels, no subsequent heat treatment is required
   - for Cr-Mo and C-Mo-V steels, a subsequent stress relieving heat treatment in accordance with Tab 20 is required.

b) After hot bending performed outside the temperature range specified in [4.2.4], a subsequent new heat treatment in accordance with Tab 21 is required for all grades.

c) After cold bending at a radius lower than 4 times the external diameter of the pipe, a heat treatment in accordance with Tab 21 is required.

5 Arrangement and installation of piping systems

5.1 General

5.1.1 Unless otherwise specified, piping and pumping systems covered by the Rules are to be permanently fixed on board ship.

5.2 Location of tanks and piping system components

5.2.1 Flammable oil systems

Location of tanks and piping system components conveying flammable fluids under pressure is to comply with [5.9].

5.2.2 Pipe lines located inside tanks

a) The passage of pipes through tanks, when permitted, normally requires special arrangements such as reinforced thickness or tunnels, in particular for:
   - bilge pipes
   - scuppers and sanitary discharges
   - air, sounding and overflow pipes
   - fuel oil pipes.

b) Junctions of pipes inside tanks are to be made by welding or flange connections. See also [2.4.3].

c) Pipes likely to withstand immersion pressure should not pass through tanks inside pressure hull. When this occurrence cannot be avoided, no joints are to be fitted in these sections of piping and strengths exerted between structure and pipe are to be taken into account in any configuration.

5.2.3 Piping and electrical apparatus

As far as possible, pipes (likely to withstand immersion pressure or not) are not to pass near switchboards or other electrical apparatus.Where this is unavoidable, pipes and ducts are to have welded joints only or to be provided with protection against spray from steam or pressurised liquids or dripping.

Alternatively the degree of protection of the switchboard is to be adequately increased.

5.3 Passage through watertight bulkheads or decks

5.3.1 Penetration of watertight bulkheads and decks and fire integrities

a) Where penetrations of bulkheads and decks are necessary for piping and ventilation, arrangements are to be made to maintain the watertight integrity, and (or) fire integrity of those decks and bulkheads or gastight integrity for compartments where this requirement is searched (i.e.: battery compartments).

On bulkheads where watertight integrity is to be reached when one side of bulkhead is designed to bear maximum immersion pressure or a water pressure more than 2 bars while the other side bears atmospheric pressure, these penetrating devices are to be type approved and the following goals are to be reached in the scope of type approving:

- resistance to fire in accordance with bulkhead requirements
- hydraulic water test at maximum design pressure of bulkhead increased of 50% when non-welded devices are used.

On bulkheads where gastight integrity is to be reached, penetrating devices are to be type approved, and the following goals are to be reached in the scope of type approving:

- resistance to fire in accordance with bulkhead requirements.

b) Lead or other heat sensitive materials are not to be used in piping systems which penetrate watertight subdivision bulkheads or decks, where deterioration of such systems in the event of fire would impair the watertight integrity of the bulkhead or decks. Use of copper will be taken into account on case by case basis by the Society.

c) Where bolted connections are used when passing through watertight bulkheads or decks, the bolts are not to be screwed through the plating. Where welded connections are used, they are to be welded on both sides of the bulkhead or deck.

d) Penetrations of watertight bulkheads or decks by plastic pipes are to comply with Ch 3, App 1, [3.6.2].

5.4 Independence of lines

5.4.1 As a rule, bilge lines are to be entirely independent and distinct from any other line with the exception of regulating tanks line. Interconnections between these lines will be treated on case-by-case basis by the Society, keeping as a principle that:

- any risk of communication between sea and inside submarine must be impossible even in case of dysfunction of any active equipment
- in any case, it must not be physically possible to submit to immersion pressure any part of circuit unable to bear this pressure (for instance in case of pressurisation by air of a circuit portion when relevant).

5.5 Provision for expansion

5.5.1 General

Piping systems are to be so designed and pipes so fixed as to allow for relative movement between pipes and the ship's structure, having due regard to the:

- temperature of the fluid conveyed
- coefficient of thermal expansion of the pipes material
- deformation of the ship's structure.

5.5.2 Fitting of expansion devices

All pipes subject to thermal expansion and those which, due to their length, may be affected by deformation of the hull, are to be fitted with expansion pieces or loops.

5.6 Supporting of the pipes

5.6.1 General

Unless otherwise specified, the fluid lines referred to in this Section are to consist of pipes connected to the ship structure by means of collars or similar devices.

5.6.2 Arrangement of supports

Shipyards are to take care that:

a) the arrangement of supports and collars is to be such that pipes and flanges are not subjected to abnormal bending stresses, taking into account their own mass, the metal they are made of, and the nature and characteristics of the fluid they convey, as well as the contractions and expansions to which they are subjected

b) heavy components in the piping system, such as valves, are to be independently supported.

5.7 Protection of pipes

5.7.1 Protection against corrosion and erosion

a) Pipes are to be efficiently protected against corrosion, particularly in their most exposed parts, either by selection of their constituent materials, or by an appropriate coating or treatment.

b) The layout and arrangement of sea water pipes are to be such as to prevent sharp bends and abrupt changes in section as well as zones where water may stagnate. The inner surface of pipes is to be as smooth as possible, especially in way of joints. Where pipes are protected against corrosion by means of galvanising or other inner coating, arrangements are to be made so that this coating is continuous, as far as possible, in particular in way of joints.

c) Arrangements are to be made to avoid galvanic corrosion.

d) To prevent corrosion due to stagnation in the circuit or erosion, minimal and maximal velocity in Tab 22 must be fulfilled. Theses provisions are depending on the piping technology and circulation conditions, like rinsing and will have to be described in the logistic documentation. Other velocities shall be submitted to the Society with a justification (e.g.: higher speed for exceptional situations).

Table 22 : Velocity conditions in seawater permanent circulation

Material	Min. velocity (m/s)	Max velocity (m/s)		
		Dint ≤ 65	65 < Dint < 100	Dint ≥ 100
Galvanised steel	0	3,0	3,0	3,0
90/10 copper-nickel	0,8	2,5	3,0	3,5
70/30 copper-nickel	1,5	3,0	3,6	4,5
Copper	0,3	0,6	1,2	1,2
Aluminium	0	3,0		
GRP	0	5,0		

5.7.2 Protection against frosting

Pipes are to be adequately insulated against cold wherever deemed necessary to prevent frost.

This applies specifically to pipes passing through refrigerated spaces and which are not intended to ensure the refrigeration of such spaces.

5.7.3 Protection of high temperature pipes and components

a) All pipes and other components where the temperature may exceed 220°C are to be efficiently insulated. Where necessary, precautions are to be taken to protect the insulation from being impregnated with flammable oils.

b) Particular attention is to be paid to lagging in way of flanges.

5.8 Valves, accessories and fittings

5.8.1 General

Cocks, valves and other accessories are generally to be arranged so that they are easily visible and accessible for manoeuvring, control and maintenance. They are to be installed in such a way as to operate properly.

5.8.2 Valves and accessories

In machinery spaces and tunnels, the cocks, valves and other accessories of the fluid lines referred to in this Section are to be placed:

- above the floor, or, when this is not possible,
- immediately under the floor, provided provision is made for their easy access and control in service.

5.8.3 Flexible hoses and expansion joints

These accessories should comply with the following requirements:

a) flexible hoses and expansion joints are to be so arranged as to be accessible at all times

b) flexible hoses and expansion joints are to be as short as possible

c) the radius of curvature of flexible hoses is not to be less than the minimum recommended by the manufacturer.

d) the adjoining pipes are to be suitably aligned, supported, guided and anchored

e) isolating valves are to be provided permitting the isolation of flexible hoses intended to convey flammable oil or compressed air

f) where they are likely to suffer external damage, flexible hoses and expansion joints of the bellows type are to be provided with adequate protection.

5.8.4 Thermometers

Thermometers and other temperature-detecting elements in fluid systems under pressure are to be provided with pockets built and secured so that the thermometers and detecting elements can be removed while keeping the piping under pressure.

5.8.5 Pressure gauges

Pressure gauges and other similar instruments are to be fitted with an isolating valve or cock at the connection with the main pipe.

5.8.6 Nameplates

a) Accessories such as cocks and valves on the fluid lines referred to in this Section are to be provided with nameplates indicating the apparatus and lines they serve except where, due to their location on board, there is no doubt as to their purpose.

b) Nameplates are to be fitted at the upper part of air and sounding pipes.

5.9 Additional arrangements for flammable fluids

5.9.1 General

The requirements in [5.9.2] and [5.9.3] apply to:

- fuel oil systems, in all spaces
- lubricating oil systems, in machinery spaces
- other flammable oil systems, in locations where means of ignition are present.

5.9.2 Prevention of flammable oil leakage ignition

a) No flammable oil tanks are to be situated where spillage or leakage therefrom can constitute a hazard by falling on:
   - hot surfaces with temperature close to self ignition temperature of fluid, including those of boilers, heaters, steam pipes, exhaust manifolds and silencers
   - electrical equipment
   - air intakes
   - other sources of ignition.

b) Parts of flammable oil systems under pressure exceeding 0,18 MPa such as pumps, filters and heaters are to comply with the provisions of item a) above.

c) Mechanical joints, expansion joints and flexible parts of flammable oil lines are to be screened or otherwise suitably protected to avoid as far as practicable oil spray or oil leakages onto hot surfaces having a temperature more elevated than media auto-inflammation temperature, into machinery air intakes, or on other sources of ignition.

d) Any relief valve of fuel oil and lubricating oil systems is to discharge to a safe position, such as an appropriate tank.

5.9.3 Provisions for flammable oil leakage containment

a) Tanks used for the storage of flammable oils together with their fittings are to be so arranged as to prevent spillages due to leakage or overfilling.

b) Drip trays with adequate drainage to contain possible leakage from flammable fluid systems are to be fitted, when applicable:

- under independent tanks
- under burners
- under purifiers and any other oil processing equipment
- under pumps, heat exchangers and filters
- under valves and all accessories subject to oil leakage
- surrounding internal combustion engines.

c) The coaming height of drip trays is to suit the amount of potential oil spillage.

d) Where boilers are located in machinery spaces on 'tweendecks and the boiler rooms are not separated from the machinery spaces by watertight bulkheads, the 'tweendecks are to be provided with oil-tight coamings at least 200 mm in height.

e) Where drain pipes are provided for collecting leakages, they are to be led to an appropriate drain tank.

5.9.4 Drain tank

The drain tank is not to form part of an overflow system and is to be fitted with an overflow alarm device.

5.9.5 Valves

All valves and cocks forming part of flammable oil systems are to be capable of being operated from readily accessible positions and, in machinery spaces, from above the working platform.

5.9.6 Level switches

Level switches fitted to flammable oil tanks are to be contained in a steel or other fire-resisting enclosure. when they are located in a compartment with risk of ignition.

6 Piping systems likely to withstand immersion pressure

6.1 Application

6.1.1 Systems concerned

This Article applies to systems in contact with immersion pressure carrying sea water or likely to carry sea water. These circuits will be called generally "sea water circuits". For piping systems conveying other fluids than sea water and crossing pressure hull, it is to be referred to Pt B, Ch 1, Sec 4, [1.1.3].

6.2 Definitions

6.2.1 Hull obturation

This expression is used for any removable device making a watertight barrier settled on a pipe passing through pressure hull as described in [6.1.1].

6.2.2 Hull valves

This expression denominates a valve settled on a piping system conveying a fluid and crossing submarine's pressure hull and normally anchored on the pressure hull or in the vicinity.

When a set of two hull valves is considered, conventionally, valve that is located on piping upstream considering the direction of fluid flow in case of leakage is called external valve. Valve located downstream is called internal valve.

These denominations don't describe the actual physical position of these valves regarding pressure hull: one of them, exceptionally both of them, may be located outside pressure hull; but most of the time, they should be settled inside pressure hull.

6.2.3 Safety shut-off valve

Safety shut-off valve is a hull valve able to be shut off quickly and safely in order to recover integrity of pressure hull. The aim is to limit volume of water embarked in case of leakage.

6.3 Design

6.3.1 Piping systems

a) Class of piping

Pipings covered by this Article are to be considered as Class I elements as mentioned in Tab 3.

b) Design pressure

Piping system shall have a design pressure at least equal to pressure reached at the accidental diving depth that submarine may experience.

Exemption may be granted for:

- piping systems used only when navigating in surface:

  Position of safety shut-off valves should be reported to the control room and when navigating in depth, any uncontrolled opening of these valves shall be prevented by devices that cannot be by-passed.

- piping systems used between surface and periscopic depth should fulfil the following requirements:
  - closing of communication with the sea is undertaken through an automated system, independent from the normal control systems and takes place before immersion corresponding to design pressure of piping system is reached. This automated system remains operational even if its normal power sources fail, and
  - a remote control enabling to close safety shut-off valves is available preferably in control room or in the place where piping system is operated.

When these systems exist, they should be connected to the internal atmosphere of pressure hull while they are isolated form the sea or equipped with devices avoiding a pressure to build-up more than design pressure in case of leakage of hull valves.

c) Piping design

Piping are to be designed taking into account a weld efficiency factor as defined in [2.2.1] equal to 1,0. Seamless pipes are to be used.

d) Piping joints

Additionally to requirements mentioned in [3.6], joints in piping likely to withstand immersion pressure are to be designed to insure water tightness in any condition of use of submarine. Only butt-welded joints or metallic flanges are accepted on these types of circuit. 100% of welding joints are to be controlled through X-ray examinations. Exception is done for copper or copper alloy pipes with ND ≤ 20 mm: in that case, welded and brazed type pipe unions may be used. Any other type of coupling shall be type approved by the Society.

e) Nozzle connection

Extruded collars are to be used in order to have butt-welded joints.

f) Coolers

Design of coolers fitted on sea water pipes shall enable to detect immediately any leakage of sea water into cooling fluid. Design file is to be submitted to the Society, including a risk analysis taking into account that any thin bulkhead likely to corrode, any welding joint, crimp element or sealing device that cannot not be inspected during building shall be considered as a certain source of leakage.

6.3.2 Accessories

a) Equipment in order to prevent corrosion

This requirement applies to pipes conveying sea water.

Accessories used to prevent the phenomenon of corrosion in case of proximity of pipes with different material generating electrolytic corrosion are:

- flange made of galvanic anode material when two pipes of different metallic material are to be connected. Each part of pipe is to be connected to flange by a electric conducting braid
- galvanic anode fitted inside sea water capacity (for instance: sea water cooler shell).

b) Flexible devices on lines carrying sea water

Elastometric flexible hoses are forbidden, except for lines with ND ≤ 40 mm and when flexible is not located between hull external and internal valves or between external hull valve and pressure hull. Flexible should be located in a place where any leakage should be easy to detect.

The only devices enabling misalignment are metallic flexible devices fitted with knuckle joints.

Devices enabling misalignment may be accepted on sea water systems as long as they are type approved by the Society following a specific qualification program previously submitted, see Pt A, Ch 1, Sec 2, [3.3].

c) Pumps

Pumps on circuits carrying sea water are to be type approved. See [19.2.3].

6.4 Arrangement

6.4.1 General principles

Circuits conveying sea water are to be as less as possible developed. Materials integrated in each circuit must be as less numerous as possible.

Whenever possible, devices used for measurement and regulation should be set on elements not submitted to immersion pressure.

No watertight bulkhead shall be crossed by piping conveying sea water: the Society may examine exception to this principle on case by case basis.

No internal capacity shall be crossed by piping conveying sea water: the Society may examine exception to this principle on case by case basis.

6.4.2 Organisation of piping

a) Hull valves

1) General

Any sea water piping system crossing pressure hull shall be fitted with two valves close to the hull. Only one valve may be accepted for piping systems:

- crossing a connex bulkhead of pressure hull and ending between this connex bulkhead and pressure hull
- crossing pressure hull and ending between pressure hull and a connex bulkhead of pressure hull.

At least one of the two hull valves shall be fitted directly on the hull passage.

A check valve cannot be used as a safety shut-off valve.

2) Hull valves located inside pressure hull

- Hull valves must be connected one on another without any part of piping between them. Circuits with ND ≤ 40 mm with ramificated element are the only exception to this requirement. In this case, shut-off safety valve is to be the external hull valve that must be settled inside pressure hull.
- A check valve may be used as internal valve if it is fitted with an indicator showing position of check valve.
- Safety shut-off valve shall be the hull valve which can be closed in the quickest and the safest way between both hull valves located on same piping line. When possible, the external valve shall be preferred to the internal one.

3) Hull valves located outside pressure hull

- Hull valves may be connected one on another or by a part of piping.
- The internal valve will be the shut-off safety valve.

b) Control of hull valves

1) Control of safety shut-off valves

Piping systems inside pressure hull carrying permanently or occasionally sea water under pressure shall fulfil the following requirements:

- Safety shut-off valve must be remotely controlled. The remote control must be available in a place where there is permanent watch at sea. Position must be reported to control room. Where valve is normally closed at sea and seldom opened with the constant attendance of an operator, remote control may be not be required as long as another barrier between immersion pressure and inner atmosphere of submarine remains closed while manoeuvring.
- Energy sources involved have to be reliable and duplicated. In case of main energy source failure, system must remain able to carry out at least two closing movements.
- Command chains must be reliable.
- Additionally, a remote controlled safety shut-off valve must be fitted with a manual control easily usable. This manual command must be located in such a way that control by sight of valve position is possible. Manual command must be possible and handy in any circumstances (for instance while sea water leakage).
- Other requirements on safety shut-off valves controls are mentioned on Pt E, Ch 3, Sec 1.

All these requirements apply to piping systems with diameter for which means of actions of submarine to fight sea water flooding would not be efficient without quickly isolating the piping system in case of failure. Unless proper justification is provided, these requirements apply to piping systems with DN ≥ 40 mm.

Other safety shut-off valves fitted only with manual commands are to be easily reachable.

2) Control of hull valves other than safety shut-off valves

Other hull valves are to be fitted with a manual control system easily usable. One must be able to check by sight position of valve.

3) Hull valves with restrictions

Some hull valves may be bound to strict restrictions for opening and/or closing. These valves have to be mentioned on drawings and a device must be fitted in order to ensure that any motion of valve will be impossible. This device has to be detailed on drawing.

4) Shore connections crossing pressure hull

Such a circuit must include a deck plug and an internal hull valve. Design must permanently separate shore connection device from corresponding inside pressure hull device except when bunkering, thanks to a drain located downstream from internal hull valve, or a removable spool.

c) Tanks and piping systems external to pressure hull

Tanks external or connex to pressure hull normally empty and occasionally in direct communication with the sea and designed to resist external sea water pressure (e.g. trunks, diesel engines exhaust gas piping) shall be connected to the internal atmosphere of submarine through a drain pipe normally opened in order to check permanently water tightness of capacity.

d) Tank located inside pressure hull and occasionally communicating with the sea for filling or emptying purpose

1) Tank communicating with the sea only for emptying purpose thanks to a pump

Risk of pressure built-up in tank shall be avoided thanks to two check valves (one may be incorporated to the pump) in line on piping system connected to the sea, or with one check valve and one valve that will close automatically piping system if pump stops unexpectedly.

2) Tank communicating to the sea only for emptying purpose thanks to air blowing

This tank shall be designed in order to resist sea water pressure and piping system connected to the sea shall be fitted with at least one check valve.

3) Tank communicating with the sea for filling purpose

- If filling is undertaken only with manual control:

  Filling valve shall be of the self-closing type and an overflow pipe connected to tank shall be fitted close to manoeuvring position of valve.
- If filling is undertaken normally through remote control:
  - tanks designed to resist sea water pressure and filled with purging and venting devices closed shall be fitted with an interlock device preventing the filling of tank if purging or venting devices are opened
  - tanks designed to resist sea water pressure and filled with purging and venting devices opened shall be fitted with automated system independent from normal control installations that will close safety shut-off valve when maximum acceptable high level is reached. Additionally, an overflow system is to be fitted in order to prevent the pressure in the tank from exceeding the tank design pressure if tank was not designed to withstand sea pressure. This overflow system should remain always opened in normal circumstances.

4) Connexion between tanks likely to be connected with the sea and other tanks located inside pressure hull

When a tank is connected to the sea, the connection to this tank with any other tanks located inside the pressure hull is not to be possible thanks to:

- mechanical interlocks that cannot be by-passed
- at least one automated system with components (sensor, actuator, automation devices, data links, source of energy) preferably independent from equipment involved in normal operation.

Table 23 : Systems likely to withstand immersion pressure

Symbol convention H = High, HH = High high, G = Group alarm L = Low, LL = Low low, I = Individual alarm X = Function is required, R = Remote	Monitoring	
Identification of system parameter	Alarm	Indication
Position of hull valves **(1)**		Local + R
Position of hull obturations		local + R
(1) Hull valves concerned for remote indication are safety shut-off valves: • with remote control command, and • settled on permanently opened circuits conveying sea water.		

6.5 Control and monitoring

6.5.1 Control and monitoring of systems likely to withstand immersion pressure deal with the following items:

- hull valves position control
- hull obturations likely to be manoeuvred at sea must be fitted with sensor positions (opened/closed), see Tab 23.

6.5.2 Reliability of control and monitoring system

Normal energy source failure for monitoring shall not involve a system failure: auxiliary energy source shall be able to replace nominal one without interruption.

7 Ballast systems (vent valves and normal blowing systems)

7.1 Design of vent valve systems

7.1.1 Vent valve

Vent valves are to be designed in such a way that the effect of internal pressure inside the water ballast tanks and the effect of nominal diving pressure when the ship is submerged lead to the closing of the vent.

When a ballast is divided in two half-ballasts on transversal plane of submarine, ducts and obturating devices are separated but manoeuvring organ shall be common.

7.1.2 Filling inlets

Filling inlets of ballasts shall not be fitted with any obturating device.

7.1.3 Vent valve manoeuvring system

Mechanical links between actuators and valves must include devices enabling self locking of system in the open and in the closed position.

When a ballast is divided in two half-ballasts (connected or not), design of manoeuvring system will forbid any unsynchronous manoeuvring of vent valves.

7.2 Design of normal blowing system

7.2.1 Application

This sub-article deals with normal blowing systems. Specific requirements of emergency blowing are described in Pt E, Ch 3, Sec 2.

This sub-article deals with the following devices:

- device enabling inlet of compressed air in ballast
- piping crossing pressure hull
- distribution valves and associated controls.

7.2.2 Piping and accessories design

Piping is to be designed according to:

- applicable requirements of Articles [1] to [5]
- requirements of Article [10] on hydraulic systems
- requirements of Article [11] on compressed air systems.

Whenever a piping system is concerned by different requirements listed above, the more stringent is to be applied

7.3 Arrangement of vent valves

7.3.1 Outside hull protection of vent valves

Protection around vent valves and venting holes must be fitted in order to avoid foreign objects to jeopardize good working of vent valve.

Table 24 : Ballast systems (air vents and normal blowing system)

Symbol convention H = High, HH = High high, G = Group alarm L = Low, LL = Low low, I = Individual alarm X = Function is required, R = Remote	Monitoring	
Identification of system parameter	Alarm	Indication
Position of group of vent valves		local + R
Position of distribution valves for air blowing		local + R

7.3.2 Locking of vent valve on closed position

One must be able to lock manoeuvring system of vent valves on closed position when submarine is navigating on surface thanks to a locking device. Locking at command system level is not sufficient: device must forbid any opening of valve through any way as long as it is not removed.

7.3.3 Vent valve control system

a) Command system

Vent valves opening and closing commands must be available:

- remotely, from the control room, easily reachable
- locally, using same energy source than when remotely controlled
- locally, using strength of one man, when applicable.

b) Information

Visual signals showing closed and opened position have to be provided in control room and locally for each ballast group of vent valves. These signals must be easily visible from the places where vents are manoeuvred (see Tab 24).

c) Reliability of control and monitoring system

Normal energy source failure for monitoring and control shall not involve a system failure: auxiliary energy source shall be able to replace nominal one without interruption.

7.4 Arrangement of normal blowing system

7.4.1 Application

This sub-article deals with matters as mentioned in [7.2.1].

7.4.2 Piping and accessories arrangement

a) Source of energy

Compressed air for normal blowing system is supplied by general compressed air system of submarine. No pressure reduction unit shall be fitted between source compressed air and ballast check valve.

Completion of withdrawal of water from ballast tanks may be obtained thanks to the blowing of exhaust gas of diesel engines into ballast tanks when the submarine is navigating on surface.

b) Piping

- Ballast check valve are to be of an approved type by the Society. Refer to Pt A, Ch 1, Sec 2, [3.3].
- Piping is not to be used for any other matter than normal blowing.
- System must enable the blowing on each ballast. When ballast is transversely separated in two half-ballast tanks, blowing system shall be common to these half ballasts unless they are equipped to correct trim when submarine is navigating on surface.
- A control device must be fitted in order to check that water has not accumulated upstream of ballast check valve. This system shall not jeopardize proper working of blowing system, in any circumstance.

c) Commands are to be located in control room, available where permanent watch is taking place.

7.4.3 Control and monitoring

a) Reliability of control and monitoring system

Normal energy source failure for remote monitoring and control shall not involve a system failure: auxiliary energy source shall be able to replace nominal one without interruption.

Duplicated distribution valves, when fitted, are not to be controlled thanks to the same source of energy. Alternative arrangement must take this aspect into account when reliability is to be demonstrated.

b) Half ballast blowing

Whenever blowing is possible on a single half ballast or on the two corresponding half-ballasts, remote system is to be arranged in such a way that blowing on a single half-ballast needs at least two manual operations.

c) Distribution valves position reporting

Position of air distribution valves is to be shown in control room.

d) Local control without source of energy

It should be possible to operate locally normal blowing system without any source of energy for control.

8 Bilge systems

8.1 Principle

8.1.1 General

An efficient bilge pumping system shall be provided, capable of pumping from and draining any watertight compartment and waste liquid tank (except heads) located inside pressure hull other than a space permanently appropriated for the carriage of fresh water, fuel oil or other liquid and for which other efficient means of pumping are to be provided, under all practical conditions.

Bilge pumping system is not intended to cope with water ingress resulting from structural or main sea water piping damage.

Bilge system shall be available in the whole range of immersion of submarine.

Bilge system is to comply with the relevant requirements of Article [6] on systems likely to withstand immersion pressure.

8.1.2 Availability of the bilge system

The bilge system is to be able to work while the other essential installations of the ship are in service.

8.2 Design of bilge systems

8.2.1 General

a) The bilge pumping system is to consist of pumps connected to a bilge main line so arranged as to allow the draining of all spaces mentioned in [8.1.1] through bilge branches, distribution boxes and bilge suctions.

b) If deemed acceptable by the Society, bilge pumping arrangements may be dispensed with in specific compartments provided the safety of the ship is not impaired.

c) Draining of watertight spaces is to be possible on trim and list limits defined for submarine in normal environment conditions.

8.2.2 Prevention of communication between spaces Independence of the lines

a) Bilge lines are to be so arranged as to avoid inadvertent flooding of any dry compartment.

b) Bilge lines are to be entirely independent and distinct from other lines except where permitted in [5.4].

8.3 Bilge pumps

8.3.1 Application

Bilge pumps mentioned here are pumps remove liquid out from inside pressure hull. They are to fulfil requirements of pumps likely to withstand immersion pressure.

8.3.2 Number and arrangement of pump

At least two pumps shall be fitted in order to remove water out from the submarine when navigating on surface. As an alternative arrangement, pump used in regulating tank system may be considered as a second pump as long as:

- switching from one pump to the other can be safely undertaken in less than 30 min
- sources of energy used for both pumps are different
- provisions of sub-article [5.4] are fulfilled.

8.3.3 Capacity of the main pumps

Capacity of main pumps shall be justified by calculation taking into account minimum flow at maximum immersion that needs to be defined.

8.3.4 Choice of the pumps

Bilge pumps are to be of the self-priming type. Centrifugal pumps are to be fitted with efficient priming means, unless an approved priming system is provided to ensure the priming of pumps under normal operating conditions.

The isolation of any bilge pump for examination, repair or maintenance is to be made possible without impeding the operation of the remaining bilge pumps.

8.4 Bilge accessories

8.4.1 Screw-down non-return valves

a) Accessories are to be provided to prevent intercommunication of compartments or lines which are to remain segregated from one another. For this purpose, non-return devices are to be fitted:
   - on the outlet side of local pumps
   - on direct suction located in battery compartments.

b) Screw-down and other non-return valves are to be of a recognised type which does not offer undue obstruction to the flow of water.

8.4.2 Strum boxes

a) The total area of holes in strum boxes is to be not less than twice the cross-sectional area of the suction pipe.

b) Strum boxes are to be so designed that they can be cleaned without having to remove any joint of the suction pipe.

8.4.3 Bilge tanks

Tanks are to be fitted in order to collect waste waters and grey waters.

These bilge tanks must include:

- a suction pipe fitted with a valve reachable outside tank
- an overflow pipe
- a high level detection device.

8.5 Bilge piping arrangement

8.5.1 Great size compartments

Great size compartments are to be fitted with several bilge suctions.

8.5.2 Connections

Connections used for bilge pipes passing through tanks are to be welded joints or reinforced flange connections.

8.5.3 Access to valves and distribution boxes

All distribution boxes and manually operated valves in connection with the bilge pumping arrangement shall be in positions which are accessible under ordinary circumstances

8.5.4 Compartment with bilge tanks

Whenever a compartment is fitted with auxiliary pumps, pumping waste water to a tank, direct suction pipes must be fitted in order to allow main pumps to aspirate liquid from this compartment through distribution box or directly.

As an alternative arrangement, spare pumps shall be available in order to replace auxiliary pump in case of failure. Spare pumps shall be of equivalent capacity than auxiliary pumps. Spare pumps shall be able to installed in less than half an hour.

8.5.5 Special arrangement for battery compartments

Permanent connection between bilge system and battery compartments is forbidden. A bilge pipe is to be installed between battery compartment and another compartment fitted with a bilge box. When necessary battery compartment may be pumped out thanks to bilge system connected with removable devices to permanent pipe.

8.6 Control and monitoring

8.6.1 Pumps

Bilge pumps in connection with immersion pressure are to be remotely and locally controlled. Remote control is to take place in control room. Signal indicating pump is on (signal must be dealing with actual state of pump, not command signal) must be sent at control room. This signal must also be available on electrical panel, see Tab 25.

Table 25 : Bilge systems

Symbol convention H = High, HH = High high, G = Group alarm L = Low, LL = Low low, I = Individual alarm X = Function is required, R = Remote	Monitoring	
Identification of system parameter	Alarm	Indication
Detection of water presence in compartments (default level)	H	local + R
Detection of high level in tanks	H	local + R
Detection of bilge pump status		local + R
Detection of remotely controlled bilge valve position		local + R

8.6.2 Detectors

Compartment and waste water tanks involved have to be fitted with a high level detection device. These detectors also take part, at another level of detection, to flooding fighting in case of external leakage. These detectors are to be of a type approved by the Society, see Tab 25.

8.6.3 Valves

When bilge valve are remotely controlled, position of valves is to be indicated in control room: signal must indicate actual position of valve, not order sent.

Control of valve shall also remain possible locally, see Tab 25.

9 Regulating and trim tank piping system

9.1 Application

9.1.1 This Article deals with the following systems:

- regulating tanks accessories
- piping between regulating tanks and sea
- piping between regulating tanks and other systems
- trim tank accessories and piping system.

9.2 Definition

9.2.1 Regulating tank

Regulating tank is a tank used for storage of sea water. It is intended to be set on communication with external sea water when one needs to admit or evacuate sea water in order to balance the weight of submarine. When two regulating tanks are installed, they may be used in order to compensate list when submarine is navigating on surface. These regulating tanks may be located inside or outside pressure hull.

9.2.2 Trim tank

Trim tank is a tank used for storage of water in order to balance weight repartition of submarine longitudinally. it is normally never in communication with sea water outside pressure hull and located inside pressure hull.

9.2.3 Compensating tank

Compensating tank fulfils same function as regulating tank unless it is never directly communicating with the sea. It is located inside pressure hull.

9.3 Design of tank piping system

9.3.1 Piping systems communicating with the sea shall fulfil the requirements of systems likely to withstand immersion pressure (see Article [6]).

9.3.2 Piping systems connecting tanks between them and regulating tank and the sea shall fulfil either requirements mentioned in [6] and requirements mentioned in Pt B, Ch 1, Sec 4, [1.1.3]

9.3.3 Means of transfer between:

- regulating tanks and the sea
- all concerned tanks,

shall be provided.

9.4 Control and monitoring

9.4.1 Water transfers

Means to handle water transfers shall be available remotely or locally. Remote control is to take place in control room.

9.4.2 Remote valves

When for regulating tank system and trim tank system valves are remotely controlled, position of valves is to be indicated in control room: signal must indicate actual position of valve, not order sent.

Control of valve shall also remain possible locally.

9.4.3 Level of tanks

Level of any tank involved in regulating tank and trim tank systems is to be known in control room. Local mean of measurement must be available.

9.4.4 Liquid quantity transfer measurement

For regulating tank system, quantity of water transferred between inside and outside submarine is to be reported on control room and locally.

For trim tank system, quantity of water tranfert between trim tanks is to be reported to control room and locally.

10 Hydraulic systems

10.1 Application

10.1.1 Hydraulic installations intended for essential services

Unless otherwise specified, this Article applies to all hydraulic power installations intended for essential services located outside or inside pressure hull. One single installation lay serve together essential and non-essential systems.

10.1.2 Hydraulic installations located in spaces containing sources of ignition

Hydraulic power installations not serving essential services but located in spaces where sources of ignition are present are to comply with the provisions of [10.3.2], [10.3.3], [10.4.6] and [10.4.7].

10.1.3 Very high pressure hydraulic installations

Hydraulic power installations with a design pressure exceeding 35 MPa will be given special consideration by the Society.

10.2 General

10.2.1 Design requirements

As far as practicable, hydraulic systems are to be so designed as to:

- avoid any overload of the system
- maintain the actuated equipment in the requested position (or the driven equipment at the requested speed)
- avoid overheating of the hydraulic oil
- prevent hydraulic oil from coming into contact with sources of ignition
- avoid any entry of external sea water in hydraulic installations in case of leakage of parts of systems likely to withstand immersion pressure.

10.2.2 Availability

a) As a rule, hydraulic systems are to be so designed that, in the event that any one essential component becomes inoperative, the hydraulic power supply to essential services can be maintained.

b) When a hydraulic power system is simultaneously serving one essential system and other systems, it is to be ensured that:

- operation of such other systems, or
- a single failure in the installation external to the essential system,

is not detrimental to the operation of the essential system.

c) Supply of hydraulic oil to essential duplicated systems (including steering gear) shall be undertaken by:

- two independent installations or by a common installation fitted with two production and storage modules
- two separated piping systems for oil distribution.

Production and storage modules may serve one piping system or the other as long as no failure on a part of one piping system will affect availability of the other.

d) Supply of non-duplicated essential systems shall be provided by production modules fitted with two power units. One single power unit and a storage module with capacity enabling to put installation in a safe situation could be accepted otherwise.

e) Hydraulic systems serving lifting or hoisting appliances, including platforms, ramps, etc., are to be so designed that a single failure of any component of the system may not result in a sudden undue displacement of the load or in any other situation detrimental to the safety of the ship and persons on board.

f) Safety essential services using hydraulic oil should be fitted, additionally to normal supply, with a dedicated storage of hydraulic energy. The criteria used to determine the quantity of energy stored shall be submitted to the Society.

10.3 General

10.3.1 Definitions

a) Power unit

Assembly formed by the hydraulic pump and its driving motor

b) Actuator

Component which directly converts hydraulic pressure into mechanical action

c) Centralised hydraulic station

Group of power units and pressure vessels delivering hydraulic energy to several installations geographically dispatched

d) Dedicated hydraulic station

Group of power units and of pressure vessels if necessary delivering hydraulic energy to one or a limited number of installations geographically grouped.

10.3.2 Limitations of use of hydraulic oils

a) Oils used for hydraulic power installations are to have a flashpoint not lower than 150°C and be suitable for the entire service temperature range.

b) The hydraulic oil is to be replaced in accordance with the specification of the installation manufacturer.

10.3.3 Location of hydraulic power units

Unless hydraulic fluid is proven as resisting to inflammation:

a) whenever practicable, hydraulic power units are to be located outside diesel engine room

b) where this requirement is not complied with, shields or similar devices are to be provided around the units in order to avoid an accidental oil spray or jet on heated surfaces which may ignite oil.

10.4 Design of hydraulic pumps and accessories

10.4.1 Hydraulic stations

Hydraulic stations should fulfil criteria mentioned in [10.2.2].

10.4.2 Hydraulic installations located outside pressure hull

a) Equipment and piping systems located outside pressure hull shall be designed in a way that, when operated or not, the inner pressure should always be 0,5 MPa more than sea water pressure.

b) It should be possible to detect any leakage of oil into the sea through evolution of global parameter(s) of hydraulic system.

10.4.3 Pressure reduction units

Pressure reduction unit shall not be used on piping systems delivering pressure fluid.

10.4.4 Use of flexible hoses

As mentioned in [6.4.2], use of flexible hoses on piping systems serving essential services is not allowed.

10.4.5 Filtering equipment

a) A device is to be fitted which efficiently filters the hydraulic oil in the circuit.

b) Where filters are fitted on the discharge side of hydraulic pumps, a relief valve leading back to the suction or to any other convenient place is to be provided on the discharge of the pumps.

10.4.6 Provision for cooling

Where necessary, appropriate cooling devices are to be provided.

10.4.7 Provision against overpressure

a) Safety valves are not allowed on high pressure oil delivery piping systems and on oil return pipes.

b) Each hydraulic power unit shall be provided with a safety valve on the higher pressure side, leading fluid to low pressure side of installation or to the service tank when operating.

c) Operation of a safety valve should not de-pressurize connected accumulators or high pressure pipes.

10.4.8 Provision for venting

Cocks are to be provided in suitable positions to vent the air from the circuit.

10.4.9 Provision for drainage

Provisions are to be made to allow the drainage of the hydraulic oil contained in the installation to a suitable collecting tank.

10.5 Design of hydraulic tanks and other components

10.5.1 Hydraulic oil service tanks

a) Service tanks intended for hydraulic power installations supplying essential services are to be provided with at least:

- a level gauge

  this level gauge shall comply with [2.8.2] unless the fluid is considered as non-flammable

- a level switch complying with [10.6.2].

b) When submarine is at zero trim, volume of service shall enable to collect the whole volume of fluid released by systems during normal operation.

c) Design of tank and its venting system shall enable to avoid spilling of fluid when submarine remains in thresholds of abnormal conditions.

d) When several hydraulic fluid networks have their lower pressure return pipe connected to the same service tank, tank should be fitted with separation pans in order to prevent the effect of failure of one fluid network on the higher or lower pressure side on the other networks.

10.5.2 Hydraulic oil storage tanks

a) Dedicated hydraulic stations supplying essential services are to include a storage tank of sufficient capacity to refill the low pressure tank. Storage means may consist of sealed drums or tins stored in satisfactory conditions, provided that quality of fluid is ensured.

b) Centralised hydraulic stations are to include a storage tank that will at least enable to refill one fluid network serving essential systems of ships.

10.5.3 Hydraulic accumulators

Separation between hydraulic fluid and pressurized air, when not separated by a membrane, shall be fitted with two sealing devices, including a leakage detection between seals: leakage must be easily seen when it occurs.

10.6 Control and monitoring

10.6.1 Control and monitoring of power units

Hydraulic power units belonging to centralised hydraulic stations shall be remotely and locally controlled. Remote control shall take place in control room.

10.6.2 Monitoring

Defaults that may occur on power units are to be reported locally and to control room.

Remote indication of parameters should, at least, feature for centralised hydraulic stations:

- pressure at high pressure side of power units
- temperature at low pressure side of power units
- indication of hydraulic energy available
- temperature of cooling media
- levels in service tanks, including low level alarms.

This list may be revised according to specific designs approved by the Society.

Dedicated hydraulic stations defaults may not need to be reported to control room if serving non-essential systems. Otherwise, only a synthesis of defaults is required in control room.

11 Compressed air systems

11.1 Definitions

11.1.1 Air group

An air group is composed by several connected air receivers. Air receivers inside an air group cannot be isolated one another. Air group is connected to compressed air system just by one pipe.

11.1.2 Air main header

This pipe is delivering compressed air to all equipments aboard using such energy.

11.1.3 Air loading header

This pipe is connecting compressors to air compressed system

11.1.4 Air distribution and loading panel

This device is connecting:

- linked air groups to air main header, and
- air loading header to linked air groups.

11.2 Principle

11.2.1 General

a) As a rule, compressed air systems are to be so designed that the compressed air delivered to the consumers:
   - is free from oil and water, as necessary
   - does not have an excessive temperature.

b) Pressure relief valves shall be fitted after pressure reduction devices.

c) Parts of system likely to withstand immersion pressure shall follow requirements, as defined in [6] and Part B about pressure hull.

d) Use of materials likely to auto-inflame in peculiar circumstances of pressure, pressure gradient, volume and temperature is forbidden for equipments using compressed air.

e) Any permanent connection between compressed air system and other compressed gas piping is forbidden.

11.2.2 Availability

a) Overpressure preventing devices shall not be implemented on capacities designed as compressed air energy storage in order to keep availability of system.

b) Compressed air systems are to be so designed that, in the event of failure of one air compressor or one air group, the air supply to such services can be maintained. The filling connections of the compressed air receivers shall be fitted with a non-return valve.

c) Each installation shall be able to be isolated from main air header and other installations in order to keep full availability of remaining system in case of failure.

11.3 Design of storage capacity

11.3.1 Air supply receivers shall be built in accordance with requirements mentioned in Ch 3, Sec 3, taking into account that no overpressure preventing devices shall be implemented on capacities designed as compressed air energy storage.

11.3.2 Air supply storage capacity

Total air supply volume shall be designed in order to provide, without replenishment:

- two returns to surface from periscopic immersion

  Remaining pressure after these manoeuvres shall not be less than 10 Mpa. Three consecutive starts for each diesel shall be possible when pressure is at 10 MPa.

  and, additionally
- quantity of air corresponding to one hour minimum breathable air used by the whole crew.

Air supply to rescue trunks if fitted should also be taken into account according to specification of the Naval Authority.

11.4 Design of air compressors

11.4.1 Prevention of excessive temperature of discharged air

Air compressors are to be so designed that the temperature of discharged air cannot exceed 85°C. For this purpose, the air compressors are to be provided where necessary with:

- suitable cooling means
- stopping and/or alarm devices in order to avoid reaching excessive temperature.

11.4.2 Prevention of overpressure

a) Air compressors are to be fitted with a relief valve complying with [2.5.3].

b) Means are to be provided to prevent overpressure wherever water jackets or casings of air compressors may be subjected to dangerous overpressure due to leakage from air pressure parts.

c) Water space casings of intermediate coolers of air compressors are to be protected against any overpressure which might occur in the event of rupture of air cooler tubes.

11.4.3 Provision for draining

Air compressors are to be fitted with a drain valve.

11.5 Arrangement of compressed air piping systems

11.5.1 Prevention of overpressure

a) Suitable pressure relief arrangements are to be provided for all systems except on storage installations and delivery piping systems carrying non-relieved air, where safety valves are forbidden.

b) When a tank/capacity is pressurised with non-relieved air, its design pressure should not be less than maximum pressure of air supply. If not, it should be protected by two safety valves, each of them designed with a different technology.

c) When a tank/capacity is pressurised with relieved air, its design pressure should not be less than maximum pressure of air supply. If not, it should protected by one safety valve.

Table 26 : Compressed air systems

Symbol convention H = High, HH = High high, G = Group alarm L = Low, LL = Low low, I = Individual alarm X = Function is required, R = Remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Compressor lubricating oil pressure (except where splash lubrication)	L						
Air pressure after reducing valves	L + H	local					
Main air header		local + R					
Air vessel pressure		local					
Compressed air systems for control and monitoring	L	local + R					
Air temperature at compressor outlet	H	local + R		X			

11.5.2 Air supply to compressors

a) Provisions are to be made to reduce to a minimum the entry of oil into compressed air systems.

b) Air compressors are to be located in spaces provided with sufficient ventilation.

11.5.3 Air treatment and draining

a) Provisions are to be made to drain air pressure systems.

b) Efficient oil and water separators, or filters, are to be provided on the discharge of compressors, and drains are to be installed on compressed air pipes wherever deemed necessary.

11.5.4 Specific parts of compressed air systems requirements

Specific requirements apply on the following parts of compressed air system:

- air receivers
- air distribution and loading panels
- main air header
- blowing air distribution to ballast tanks
- air distribution to breathable air panels and escape trunks
- air distribution to actuators and dedicated storage device belonging to essential safety services.

On these parts of system:

a) flexible hoses shall not be used

b) it is forbidden to supply in air on these items and any other installation by same derivation of main air header.

As additional requirement, installations used for breathable air shall include one piping system per rescue zone.

11.6 Control and monitoring of compressed air systems

11.6.1 Monitoring

Alarms and safeguards are to be provided for compressed air systems in accordance with Tab 26.

12 Cooling systems

12.1 Application

12.1.1 This Article applies to all cooling systems using the following cooling media:

- sea water

  For piping likely to withstand immersion pressure, requirements mentioned in Article [6] apply.

- fresh water.

Air cooling systems will be given special consideration.

12.2 Principle

12.2.1 General

Sea water and fresh water cooling systems are to be so arranged as to maintain the temperature of the cooled media (lubricating oil, hydraulic oil, charge air, etc.) for propulsion machinery and essential equipment within the manufacturers' recommended limits during all operations, including starting and manoeuvring, under the inclination angles and the ambient conditions specified.

12.2.2 Availability of the cooling system

The cooling system is to be so designed that, in the event of one essential component being inoperative, the cooling of propulsion machinery is maintained. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired. Essential components include:

- coolers
- pumps
- any failure of portion of sea water piping likely to withstand immersion pressure.

12.3 Design of sea water cooling systems

12.3.1 Propulsion electric motors

In case of loss of sea water cooling of the propulsion electric motors, submarine shall keep sufficient manoeuvring capacity, on surface and in depth, during enough time to recover a safe situation. Maximum speed reachable in such circumstances shall be submitted to the Society and checked during sea trials.

12.3.2 Cooling of other essential equipment

In case of loss of sea water system, dedicated to an essential element (e.g. cooling system linked to steering gear), submarine shall be able to keep sufficient manoeuvring capacity during enough time to recover a safe situation.

12.3.3 Sea water coolers

Generally, sea water cools fresh water in submarine exchangers. Requirements mentioned in [6.3.1] should be referred to.

12.4 Design of fresh water cooling systems

12.4.1 General

Fresh water cooling systems are to be designed according to the applicable requirements of [12.3].

12.4.2 Cooling systems

Where they are not duplicated, fresh water cooling systems of essential services are to include at least two pumps.

12.4.3 Expansion tanks

Fresh water expansion tanks are to be provided with at least:

- a de-aerating device
- a water level indicator
- a filling connection
- a drain.

12.5 Arrangement of cooling systems

12.5.1 Coolers

Coolers are to be fitted with isolating valves at the inlets and outlets.

12.5.2 Pumps

a) Cooling pumps for which the discharge pressure may exceed the design pressure of the piping system are to be fitted with relief valves in accordance with [2.5].

b) Where any pump may be connected to a cooling system, arrangements are to be made, in accordance with [2.5], to avoid overpressure in any part of the cooling system.

12.5.3 Air venting

Where applicable, cocks are to be installed at the highest points of the pipes conveying cooling water to the water jackets for venting air or gases likely to accumulate therein. In the case of closed fresh water cooling systems, the cock is to be connected to the expansion tank.

12.6 Control and monitoring

12.6.1 Alarms are to be provided for water cooling systems in accordance with Tab 27.

13 Ventilation system

13.1 Definitions

13.1.1 Fresh air

Air coming from outside and introduced inside the submarine, with or without any treatment.

13.1.2 Foul air

Air extracted from inside the submarine polluted with vapours, gases, particles or smells, which is regenerated or rejected outside the submarine.

13.1.3 Snorkel air mast

When installed, the snorkel air mast is deployed in order to allow air to enter inside the submarine at periscopic depth.

13.1.4 Surface air duct

A surface air duct may be used when submarine is navigating on surface to allow air to enter inside submarine.

Table 27 : Cooling systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Sea water pump pressure or flow	L	local					
Fresh water pump pressure or flow	L	local					
Level in cooling water expansion tank	L	local					

13.2 General design

13.2.1 Ventilation system is designed so as to:

a) introduce fresh air inside the submarine, when navigating on surface or at periscopic depth via, in that case, the snorkel air mast

b) extract foul air from inside the submarine, when navigating on the surface or at periscopic depth

c) homogenize air inside the submarine.

13.2.2 Air inlet requirements are detailed in Article [14].

13.2.3 Availability

Redundancies or back-up systems shall enable in case of failure of one ventilator or its energy source to keep:

- minimum air flow inside battery compartments, and
- capacity to homogenize air inside submarine.

13.3 Arrangement

13.3.1 Ventilation controls

Ventilation controls are described in Pt E, Ch 1, Sec 2, [2.1].

13.3.2 Ventilation ducts arrangement

Requirements about ventilation ducts arrangement are detailed in Pt E, Ch 1, Sec 5, [4].

Ventilation ducts passing through fire-resisting divisions are to comply with Pt E, Ch 1, Sec 5, [4.3].

13.3.3 Capacity of the ventilation system

For machinery spaces, requirements are detailed in Ch 3, Sec 1, [2.6].

For battery spaces, requirements are detailed in Ch 4, Sec 3, [9.3] and Ch 4, Sec 11, [5.6].

13.3.4 Release of smoke after fire

Corresponding requirements are detailed in Pt E, Ch 1, Sec 4, [2].

14 Air inlet system

14.1 Application

14.1.1 The following requirements shall apply to piping, valves and capacities used when submarine is navigating at periscopic depth with air mast deployed, and with inner atmosphere of submarine communicating with external air.

14.2 Definitions

14.2.1 Air inlet valve

Hull obturation enabling air inlet when submarine is navigating at periscopic depth.

14.2.2 Drain tank

Tank located inside submarine enabling storage and retention of water entered inboard through air inlet system and through which fresh air is passing.

14.3 Design and arrangement of air inlet system

14.3.1 Elements of piping likely to withstand immersion pressure shall fulfil requirements given in Article [6] or in Pt B, Ch 1, Sec 4, [1.1.3].

14.3.2 Air inlet valve

a) Air inlet valve shall be located on pressure hull.

b) It shall be moved by an actuator providing mechanical energy for both opening and closing operations. Energy used for this actuator shall be normally provided by compressed air system. Any other arrangement shall provide at least equivalent reliability.

c) Closing of valve using actuator must not be more than two seconds long.

d) Air inlet valve shall be able to be locked in closed position.

e) Air inlet valve shall be able to be manoeuvred locally thanks to human force.

f) In case of loss of power or control energy, air inlet valve shall close by itself.

g) Capacity containing air inlet valve, if any, shall be connected thanks to a drain pipe to drain tank. This pipe shall include some visual indication enabling to check whether water is flowing through, easily visible in control room.

14.3.3 Hull obturation for surface air duct

Arrangement for this valve shall fulfil requirements mentioned in Pt B, Ch 1, Sec 4, [1.1.3].

14.3.4 Drain tank

a) Drain tank capacity shall be designed to contain sea water entering into submarine when air inlet system is used. This tank may be used for other purposes.

b) Tank shall be fitted with a level gauge.

c) A high level in tank shall trigger closing of air inlet valve.

14.4 Control and monitoring

14.4.1 Remote control

a) Air inlet valve shall be remotely controlled from control room

b) Whenever no permanent watch is undertaken close to relevant installations, part of bilge system enabling pumping out of drain tank shall be remotely controlled from control room.

14.4.2 Monitoring

Monitoring shall comply with Tab 28.

Position of obturation devices automatically actuated shall be reported in control room. Position shown is the actual position of obturator.

Table 28 : Air inlet systems

Symbol convention H = High, HH = High high, G = Group alarm L = Low, LL = Low low, I = Individual alarm X = Function is required, R = Remote	Monitoring		Automatic control
			Closing of air inlet valve
Identification of system parameter	Alarm	Indication	
Air inlet valve position		local + R	
Level in drain tank **(2)**	H and HH	R	X **(1)**
Excessive Trim **(2)**	H	R	X
Loss of electric source for control and actuators	H	R	X
Excessive underpressure **(2)**	H	R	
Excessive immersion **(2)**	H	R	
(1) Only for HH level. **(2)** Values of threshold parameter shall be justified to the Society.			

15 Exhaust gas systems

15.1 General

15.1.1 Application

This Article applies to exhaust gas piping systems from engines.

15.1.2 Principle

Exhaust gas systems are to be so designed as to:

- prevent water from entering engines and submarine
- limit the risk of fire
- prevent exhaust gas leaks into manned spaces.

15.2 Design and arrangement of exhaust systems

15.2.1 General

Exhaust systems are to be so arranged as to minimise the leaks of exhaust gases into manned spaces, air conditioning systems and engine intakes. Part of piping system likely to withstand immersion pressure shall fulfil the requirements mentioned in Article [6] and in Pt B, Ch 1, Sec 4, [1.1.3].

15.2.2 Limitation of exhaust line surface temperature

a) Exhaust gas pipes, valves and silencers are to be either water cooled or efficiently insulated, where:
   - their surface temperature may exceed 220°C, or
   - they pass through spaces of the ship where a temperature rise may be dangerous.

b) The insulation of exhaust systems is to comply with the provisions of Ch 3, Sec 1.

15.2.3 Limitation of pressure losses

Exhaust gas systems are to be so designed that pressure losses in the exhaust lines do not exceed the maximum values permitted by the engine manufacturers.

15.2.4 Provision for thermal expansion

a) Exhaust pipes and smoke ducts are to be so designed that any expansion or contraction does not cause abnormal stresses in the piping system.

b) The devices used for supporting the pipes are to allow their expansion or contraction.

15.2.5 Intercommunication of engine exhaust gas lines ducts

Exhaust gas from different engines is not to be led to a common exhaust main, unless each exhaust pipe is provided with a suitable isolating device.

15.2.6 Prevention against water penetration

a) Isolation devices of exhaust pipes from sea water shall be implemented:
   1) two hull valves shall be fitted on each exhaust pipe, one of them, the safety shut-off valve, being directly connected to the hull penetration
   2) a third valve called outlet exhaust valve may be fitted at the outside end of the pipe.

b) Drains shall be implemented on each part of exhaust pipes able to be isolated by a valve in order to check absence of water due to leakages.

c) Exhaust pipes shall be arranged in such a way that no water entering from outside of submarine in exhaust pipes should be lead directly in contact with engines; it shall be dropped in a dead end pipe likely to be drained.

d) Valves used to isolate inside and outside pressure hull should be protected against risk of collision as far as practicable when both located outside pressure hull.

15.3 Materials

15.3.1 General

Materials of exhaust gas pipes and fittings are to be resistant to exhaust gases and suitable for the maximum temperature expected. Scantling and arrangement of piping shall take into account immersion pressure where relevant.

Table 29 : Exhaust gas systems

Symbol convention H = High, HH = High high, G = Group alarm L = Low, LL = Low low, I = Individual alarm X = Function is required, R = Remote	Monitoring	
Identification of system parameter	Alarm	Indication
Exhaust valves position		local + R

15.4 Control and monitoring

15.4.1 Remote control and automatic actions

The outlet exhaust valve (if provided) or the safety shut-off valve shall automatically close in case of engine stopping. The closing shall be also operable from the control room.

15.4.2 Monitoring

Monitoring shall be as mentioned in Tab 29.

16 Fuel oil systems

16.1 Application

16.1.1 Scope

This Article applies to all fuel oil systems supplying any kind of installation.

16.1.2 Requirements applying to fuel oil systems and not contained in this Section

Additional requirements are given:

- for fuel oil supply equipment forming part of engines: in the corresponding Section
- for the installation of purifiers: in Pt E, Ch 1, Sec 6
- for the location and scantling of tanks forming part of the ship structure: in Pt C, Ch 2, Sec 1, [2] and in Pt C, Ch 5, Sec 3
- for the parts of piping likely to withstand immersion pressure: in Article [6].

16.2 Principle

16.2.1 General

a) Fuel oil systems are to be so designed as to ensure the proper characteristics (purity, viscosity, pressure) of the fuel oil supply to engines and boilers.

b) Fuel oil systems are to be so designed as to prevent:
   - overflow or spillage of fuel oil from tanks, pipes, fittings, etc.
   - fuel oil from coming into contact with sources of ignition
   - overheating and seizure of fuel oil.

c) Fuel oils used for engines and boilers are to have a flashpoint complying with the provisions of Ch 3, Sec 1.

16.3 General

16.3.1 Arrangement of fuel oil systems

a) In a ship in which fuel oil is used, the arrangements for the storage, distribution and utilisation of the fuel oil are to be such as to ensure the safety of the ship and persons on board.

b) The provisions of [5.9] are to be complied with.

16.3.2 Provision to prevent overpressure

Provisions are to be made to prevent overpressure in any oil tank or in any part of the fuel oil system. Any relief valve is to discharge to a safe position.

16.3.3 Ventilation

The ventilation of machinery spaces is to be sufficient under all normal conditions to prevent accumulation of oil vapour.

16.4 Design of fuel oil filling and transfer systems

16.4.1 General

a) When necessary, a system of pumps and piping for filling and transferring fuel oil is to be provided.

b) Replenishment of daily tank shall be available whenever submarine is in depth or on surface, from any fuel oil storage tank.

16.4.2 Independence of fuel oil transfer lines

Fuel oil transfer piping system shall be completely separate from the other piping systems of the ship.

16.4.3 Transfer pumps

Where necessary, transfer pumps are to be fitted on their discharge side with a relief valve leading back to the suction of the pump or to any other place deemed satisfactory.

16.4.4 Transfer from fuel tanks

Transfer lines from fuel tanks shall generally lead to a fuel settling tank inside ship able to be drained.

16.5 Arrangement of fuel oil tanks and bunkers

16.5.1 Location of fuel oil tanks

a) No fuel oil tank is to be situated where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces (temperature around 220°C).

b) Fuel oil tanks and bunkers are not to be located in compartments where temperature of storage may be increased more than 10°C below fuel flash point.

c) As far as practicable, fuel oil tanks are to be part of the ship's structure and are to be located outside diesel compartments. Where fuel oil tanks are necessarily located adjacent to or within diesel compartments, at least one of their sides is to be contiguous to the diesel compartment boundaries, and the area of the tank boundary common with diesel compartments is to be kept to a minimum. Where such tanks are situated within the boundaries of diesel compartment, they are not to contain fuel oil having a flashpoint of less than 60°C.

16.5.2 Use of free-standing fuel oil tanks

Use of free-standing fuel oil tanks shall be generally avoided.

These tanks shall be made of steel, located in a compartment that can be isolated from the rest of the ship and fitted with fixed means of fire-fighting.

16.6 Design of fuel oil tanks and bunkers

16.6.1 General

Tanks such as collector tanks, de-aerator tanks etc. are to be considered as fuel oil tanks for the purpose of application of this sub-article, and in particular regarding the valve requirements.

Tanks with a volume lower than 500 l will be given special consideration by the Society.

16.6.2 Scantlings

a) The scantlings of fuel oil tanks and bunkers forming part of the ship's structure are to comply with the requirements stated in Pt C, Ch 3, Sec 2.

16.6.3 Replacement of fuel oil consumed by sea water

Fuel tanks intended for long term storage shall be designed in such way that fuel oil is replaced by sea water while it is consumed. This requirement shall be fulfilled whenever submarine is navigating in depth or on surface, using tanks located outside or inside pressure hull. Design of tanks shall allow replacement of fuel oil by water with minimal mixing of fuel and water

Piping system design attached to these tanks shall prevent any entry of air in piping or tank.

External tanks shall always be pressure balanced with sea water, no valve shall be installed between these tanks and sea water pressure.

16.6.4 Filling and suction pipes

a) All suction and filling pipes from fuel oil tanks and bunkers are to be provided with valves.

b) For storage tanks, filling pipes may also be used for suction purposes.

c) Each suction and filling pipe connected to a fuel tank shall be fitted with a remote controlled closing valve. This valve shall be located as close as possible to tank bulkhead as practicable.

16.6.5 Remote control of valves

a) Every fuel oil pipe which, if damaged, would allow oil to escape from a storage, settling or daily service tank located inside pressure hull, is to be fitted with a cock or valve capable of being closed from a safe position outside the space in which such tanks are situated in the event of a fire occurring in such space.

b) Such valves and cocks are also to include local control. Indicators are to be provided on the remote and local controls to show whether they are open or shut (see [2.7.3]). Where quick-closing valves are used, the indicators for remote controls may be omitted.

16.6.6 Drain pipes

Where fitted, drain pipes are to be provided with self-closing valves or cocks. Valves not of the safe closing type may be accepted provided a warning notice is located close to the valve.

16.6.7 Air and overflow pipes

Air and overflow pipes are to comply with [18.1] and [18.3].

16.6.8 Level of tanks

a) When used, oil-level gauges shall comply with [2.8.2].

b) Gauge cocks for ascertaining the level in the tanks are not to be used.

16.7 Design of fuel oil treatment systems

16.7.1 Drains

a) Settling tanks or, where settling tanks are not provided, daily service tanks, are to be provided with drains permitting the evacuation of water and impurities likely to accumulate in the lower part of such tanks.

b) Efficient means are to be provided for draining oily water escaping from the drains.

16.7.2 Purifiers

a) Where fuel oil needs to be purified, one purifier shall be installed on board, capable of efficiently purifying the amount of fuel oil necessary for the normal operation of the engines.

b) Fuel oil purifiers are to be installed as required in Pt E, Ch 1, Sec 6.

16.8 Design of fuel supply systems

16.8.1 General

When necessary, arrangements are to be made for cooling the marine diesel oil from engine return lines.

16.8.2 Fuel oil service tanks

One oil service tank at least is to be provided.

16.8.3 Fuel oil supply to internal combustion engines

a) The suctions of engine fuel pumps are to be so arranged as to prevent the pumping of water and sludge likely to accumulate after decanting at the lower part of service tanks.

b) Oil filters are to be so located that in the event of a leakage the fuel oil cannot be pulverised onto the exhaust manifold.

c) Excess fuel oil from pumps or injectors is to be led back to the service or settling tanks, or to other tanks intended for this purpose.

d) When implemented, de-aeration tanks fitted in pressurised fuel oil return lines are to be equipped with at least:

- an automatic venting valve or equivalent device discharging to the daily service tank or to other safe place deemed satisfactorily having a device for flow detection
- a non-return valve in the return line from the engines.

e) For high pressure fuel oil pipes and other components which may be built-in or attached to the engine, see Ch 3, Sec 2, [2.4].

Anyhow, the components of a diesel engine fuel oil system are to be designed considering the maximum peak pressure which will be experienced in service, including any high pressure pulses which are generated and transmitted back into the fuel supply and spill lines by the action of fuel injection pumps.

f) Connections within the fuel supply and spill lines are to be constructed having regard to their ability to prevent pressurised fuel oil leaks while in service and after maintenance.

16.9 Construction of fuel oil piping systems not likely to withstand immersion pressure

16.9.1 Materials

a) Fuel oil pipes and their valves are to be of steel or other approved material, except that the use of flexible pipes may be accepted provided they comply with [2.6.3].

b) For valves fitted to fuel oil tanks and which are under a static pressure head, steel or nodular cast iron may be accepted. However, ordinary cast iron valves may be used in fuel piping systems where the design pressure is lower than 0,7 MPa and the design temperature is below 60°C.

c) Internal galvanisation of fuel oil pipes and tank or bunker walls is to be avoided. Exemption is to be considered for pipes likely to convey sea water.

16.9.2 Pipe connections

Connections and fittings of pipes containing fuel oil are to be suitable for a design pressure according to Tab 3.

16.10 Control and monitoring

16.10.1 Monitoring

Alarms and safeguards are to be provided for fuel oil systems in accordance with Tab 30.

16.10.2 Automatic controls

Automatic temperature control is to be provided for:

- steam heaters or heaters using other media
- electric heaters.

16.10.3 Remote controls

a) The remote control arrangement of valves fitted on fuel oil tanks is to comply with [16.6.5].

b) The power supply to:

- transfer pumps and other pumps of the fuel oil system, and
- fuel oil purifiers,

is to be capable of being stopped from a position within the space containing the pumps and from another position located outside such space and always accessible in the event of fire within the space.

Table 30 : Fuel oil systems

Symbol convention H = High, HH = High high, G = Group alarm L = Low, LL = Low low, I = Individual alarm X = Function is required, R = Remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil level in daily service tank	L + H	local + R					

17 Lubricating oil systems

17.1 Application

17.1.1 This Article applies to lubricating oil systems serving diesel engines and other equipment intended for propulsion.

17.2 Principle

17.2.1 General

a) Lubricating oil systems are to be so designed as to ensure reliable lubrication of the diesel engines and equipment, including electric motors, intended for propulsion:
   - over the whole speed range, including starting, stopping and, where applicable, manoeuvring
   - for all the inclinations angles stated in Pt B, Ch 1, Sec 3.

b) Lubricating oil systems are to be so designed as to ensure sufficient heat transfer and appropriate filtration of the oil.

c) Lubricating oil systems are to be so designed as to prevent oil from entering into contact with sources of ignition.

17.2.2 Availability

Lubricating oil systems are to be so designed that, in the event that any one pump is inoperative, the lubrication of propulsion system and connected equipment is maintained. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired.

17.3 General

17.3.1 Arrangement of lubricating oil systems

a) The arrangements for the storage, distribution and utilisation of oil used in pressure lubrication systems are to be such as to ensure the safety of the ship and persons on board.

b) The provisions of [5.9] are to be complied with, where applicable.

17.3.2 Filtration

a) In forced lubrication systems, a device is to be fitted which efficiently filters for the lubricating oil in the circuit.

b) The filters provided for this purpose for main machinery and machinery driving electric propulsion generators are to be so arranged that they can be easily cleaned without stopping the lubrication of the machines.

c) The fineness of the filter mesh is to comply with the requirements of the engine or turbine manufacturers.

d) Where filters are fitted on the discharge side of lubricating oil pumps, a relief valve leading back to the suction or to any other convenient place is to be provided on the discharge of the pumps.

17.3.3 Purification

Where provided, lubricating oil purifiers are to comply with [16.7.2].

17.3.4 Heat transfer

Lubricating oil heaters shall be specially considered by the Society.

17.4 Design of engine lubricating oil systems

17.4.1 Lubrication of auxiliary engines

a) For auxiliary engines with their own lubricating pump, no additional pump is required.

b) For auxiliary engines with a common lubricating system, at least two pumps are to be provided.

c) For submarines fitted with one single engine, only one pump may be considered.

17.5 Design of lubricating oil tanks

17.5.1 Remote control of valves

Lubricating oil tanks with a capacity of 500 litres and above are to be fitted with remote controlled valves in accordance with the provisions of [16.6.5].

The remote controlled valves need not be arranged for storage tanks on which valves are normally closed except during transfer operation, or where it is determined that an unintended operation of a quick closing valve on the oil lubricating tank would endanger the safe operation of the main propulsion and essential auxiliary machinery.

17.5.2 Filling and suction pipes

Filling and suction pipes are to comply with the provisions of [16.6.4].

17.5.3 Air and overflow pipes

Air and overflow pipes are to comply with the provisions of [18.1] and [18.3].

17.5.4 Sounding pipes and level gauges

a) Safe and efficient means of ascertaining the amount of lubricating oil contained in the tanks are to be provided.

b) Sounding pipes are to comply with the provisions of [18.2].

c) When used, oil-level gauges shall comply with [2.8.2].

d) Gauge cocks for ascertaining the level in the tanks are not to be used.

17.5.5 Oil collecting tanks for engines

Oil collecting pipes from the engine sump to the oil collecting tank are to be submerged at their outlet ends.

17.6 Construction of lubricating oil piping systems

17.6.1 Materials

Materials used for oil piping system in machinery spaces are to comply with the provisions of [16.9.1].

17.6.2 Sight-flow glasses

The sight-flow glasses may be used in lubricating oil systems, provided that they are shown by testing to have a suitable degree of fire resistance and so designed that the oil does not impinge on the glass (see [18.3.4], item d)) in order to avoid leakage in case of failure.

18 Air, sounding and overflow pipes of capacities located inside pressure hull

18.1 Air pipes

18.1.1 Principle

Air pipes are to be fitted to all tanks, tunnels and other compartments located inside pressure hull which are not fitted with alternative ventilation arrangements, in order to allow the passage of air or liquid so as to prevent excessive pressure or vacuum in the tanks or compartments, in particular in those which are fitted with piping installations.

18.1.2 Number and position of air pipes

a) Air pipes are to be so arranged at the upper part of capacities so designed that air or gas likely to accumulate at any point in the capacities can freely evacuate.

b) Air pipes are to be fitted opposite the filling pipes and/or at the highest parts of the capacities, the ship being assumed to be on an even keel.

c) In general, two air pipes are to be fitted for each capacities, except in small ones, where only one air pipe may be accepted. When the top of the capacity is of irregular form, the position of air pipes will be given special consideration by the Society.

d) Where only one air pipe is provided, it is not to be used as a filling pipe.

18.1.3 Special arrangements for air pipes of flammable oil tanks

a) No permanently opened direct air pipe is allowed for fuel oil tanks located inside pressure hull, except daily tanks or settling tanks.

b) Storage tanks located inside pressure hull shall be connected to a capacity always filled with water, this capacity shall be fitted with an air pipe in relation with inner atmosphere of submarine. During refuelling condition, direct air pipe of storage tank might be opened: corresponding valve shall be otherwise closed and its manoeuvring restricted.

c) Air pipes of lubricating or hydraulic oil storage tanks may be led to machinery spaces, provided that in the case of overflowing the oil cannot come into contact with electrical equipment, hot surfaces or other sources of ignition.

d) Air pipes of fuel oil service, settling and lubrication oil tanks likely to be damaged by impact forces are to be adequately reinforced.

18.1.4 Special arrangement for air pipes for sewage tanks

Air pipes for sewage tanks shall be fitted with anti-odour filters.

18.1.5 Construction of air pipes

a) Air pipes with height exceeding 900 mm are to be additionally supported.

b) In each tank likely to be pumped up, and where no overflow pipe is provided, the total cross-sectional area of air pipes is not to be less than 1,25 times the cross-sectional area of the corresponding filling pipes. Whenever this criteria is not satisfied, some calculation shall be provided in order to demonstrate that capacity integrity won't be affected in any case.

c) Without additional justification the internal diameter of air pipes is not to be less than 50 mm, except for tanks of less than 2 m^3.

d) Air pipes from several tanks or spaces may be led into a common main line, provided that:

- the tanks or spaces are not intended for liquids which are not compatible and that the arrangement could not effect unacceptable condition for the ship
- the cross-sectional area of the air pipes main is generally not less than the aggregate cross-sectional area of the two largest pipes discharging into the main. However, a reduced value may be considered for acceptance in each particular case on the basis of back pressure calculation submitted for all normal working conditions
- as far as practical, each separate air pipe is fitted to the common air pipe from the top side
- where no overflow pipes are provided, the cross-sectional area of a common air pipe from several tanks is not less than 1,25 times the area of the common filling pipeline for these tanks.

e) Vents acting also as overflows may be accepted provided all the requirements applicable to both vents and overflows are complied with.

f) Where tanks are fitted with cross flooding connections, the air pipes are to be of adequate area for these connections.

18.2 Sounding pipes

18.2.1 Principle

Sounding devices shall generally not be used aboard submarines.

18.3 Overflow pipes

18.3.1 Principle

Overflow pipes are to be fitted to tanks where the cross-sectional area of air pipes is less than that prescribed in [18.1.5].

18.3.2 Design of overflow systems

a) Overflow pipes are to be led to the bilge. For flammable fluids like fuel or lubricating oil, overflow pipes are to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes.

b) Where tanks containing the same or different liquids are connected to a common overflow system, the arrangement is to be such as to prevent any risk of:

- intercommunication between the various tanks due to movements of liquid when emptying or filling, or due to the inclination of the ship.

For this purpose, overflow pipes are to be led to a high enough point or, alternatively, non-return valves are to be fitted where necessary.

18.3.3 Overflow tanks

a) Overflow tanks are to be fitted with an air pipe complying with [18.1] which may serve as an overflow pipe for the same tank.

Such means are to discharge to a position which is safe in the opinion of the Society.

b) An alarm device is to be provided to give warning when the oil reaches a predetermined level in the tank, or alternatively, a sight-flow glass is to be provided in the overflow pipe to indicate when any tank is overflowing. Such sight-flow glasses are only to be placed on vertical pipes and in readily visible positions.

18.3.4 Specific arrangements for construction of overflow pipes

a) Internal diameter of overflow pipes is to be justified.

b) In each compartment which can be pumped up, the total cross-sectional area of overflow pipes is not to be less than 1,25 times the cross-sectional area of the corresponding filling pipes.

c) The cross-sectional area of the overflow main is not to be less than the aggregate cross-sectional area of the two largest pipes discharging into the main.

d) Where overflow sight glasses are provided, they are to be in a vertically dropping line and in readily visible position, fitted with adequate protection from mechanical damage. The overflow sight glasses are not to be used in flammable oil systems except for lubricating oil. (see [17.6.2]).

18.4 Constructional requirements applying to sounding, air and overflow pipes

18.4.1 Materials

a) Sounding, air and overflow pipes are to be made of steel or any other material approved for the application considered.

b) Exposed parts of sounding, air and overflow pipes are to be made of approved metallic materials.

18.4.2 Minimum thickness of steel pipes

The minimum thickness of sounding, air and overflow steel pipes is given in Tab 5.

18.4.3 Passage of pipes through certain spaces

a) Air pipes and sounding pipes led through refrigerated spaces are to be suitably insulated.

b) When sounding, air and overflow pipes made of steel are permitted to pass through sea water tanks or fuel oil tanks, they are to be of reinforced thickness, in accordance with Tab 5.

18.4.4 Self-draining of pipes

Air pipes and overflow pipes are to be so arranged as to be self-draining when the ship is on an even keel.

19 Certification, inspection and testing of piping systems

19.1 Application

19.1.1 This Article defines the certification and workshop inspection and testing programme to be performed on:

- the various components of piping systems
- the materials used for their manufacture.

19.2 Type tests

19.2.1 Type tests of flexible hoses, expansion joints

a) Type approval tests are to be carried out on a flexible hose or an expansion joint of each type and each size, in accordance with Tab 31.

b) The flexible pipes or expansion joints subjected to the tests are to be fitted with their connections.

Table 31 : Type tests to be performed for flexible hoses and expansion joints

Test	Flexible hoses and expansion joints in non-metallic material	Flexible hoses and expansion joints in metallic material
Bursting test	X	X
Fire-resistance test	X **(1)**	NR
Vibration test	X **(2)**	X **(2)**
Pressure impulse test	X	NR
Flexibility test	X **(3)**	X
Elastic deformation test	NR	X
Cyclic expansion test	X	X **(4)**
Resistance test	X **(5)**	X **(5)**

(1) only for flexible hoses and expansion joints used in flammable oil and sea water systems.
(2) only for flexible hoses and expansion joints fitted to engines, pumps, compressors or other sources of high vibrations.
(3) only for flexible hoses conveying low temperature fluids.
(4) only for piping systems subjected to expansion cycles.
(5) internal to the conveyed fluid and external to UV.
Note 1: X = required, NR = not required.

19.2.2 Type tests of bulkhead crossing devices

Type approval tests are to be carried out on each type and size of bulkhead crossing devices for bulkheads being boundaries of refuge compartments or being boundaries of gastight compartments (for instance battery compartments). Following tests shall be undertaken:

- tightness test
- fire resistance test.

19.2.3 Type test for sea water pumps withstanding immersion pressure

Type approval tests are to be carried out on each pump withstanding immersion pressure:

- check of nominal parameters working on a inclined plane (one hour for each inclined plane main direction)
- endurance test (eight hours minimum) of pump with water at a pressure at least equal to nominal immersion pressure
- testing providing element for NPSH curve (at least five points)
- resistance and watertightness pressure test as mentioned in [19.4.4].

19.2.4 Type tests for misalignment devices

Program for type test of these devices shall be submitted to Society for approval. See Pt A, Ch 1, Sec 2, [3.3].

19.3 Testing of materials

19.3.1 General

a) Detailed specifications for material tests are given in NR216 Materials and Welding.

b) Requirements for the inspection of welded joints are given in NR216 Materials and Welding.

c) The requirements of this sub-article do not apply to piping systems subjected to low temperatures.

19.3.2 Tests for materials

a) Where required in Tab 32, materials used for pipes, valves and other accessories are to be subjected to the following tests:
   - tensile test at ambient temperature
   - flattening test or bend test, as applicable
   - tensile test at the design temperature, except if one of the following conditions is met:
     - the design temperature is below 200°C
     - the mechanical properties of the material at high temperature have been approved
     - the scantling of the pipes is based on reduced values of the permissible stress.

b) Plastic materials are to be subjected to the tests specified in Ch 3, App 1.

19.4 Hydrostatic testing of piping systems and their components

19.4.1 General

Pneumatic tests are to be avoided wherever possible. Where such testing is absolutely necessary in lieu of the hydraulic pressure test, the relevant procedure is to be submitted to the Society for acceptance prior to testing.

19.4.2 Hydrostatic pressure tests of piping not likely to withstand immersion pressure

a) Hydrostatic pressure tests are to be carried out to the Surveyor's satisfaction for:
   - all class I and II pipes and their integral fittings
   - all steam pipes, feed water pipes, compressed air pipes, and fuel oil and other flammable oil pipes with a design pressure greater than 0,35 MPa and their associated integral fittings.

b) These tests are to be carried out after completion of manufacture and before installation on board and, where applicable, before insulating and coating.

Note 1: Classes of pipes are defined in [1.5.2].

c) Pressure testing of small bore pipes (less than 15 mm) may be waived at the discretion of the Surveyor, depending on the application.

d) Where the design temperature does not exceed 300°C, the test pressure is to be equal to 1,5 p.

e) Where the design temperature exceeds 300°C, the test pressure is to be as follows:
   - for carbon and carbon-manganese steel pipes, the test pressure is to be equal to 2 p
   - for alloy steel pipes, the test pressure p_H is to be determined by the following formula, but need not exceed 2 p:

$$p_H = 1,5\frac{K_{100}}{K_T}p$$

   where:

   K_{100} : Permissible stress for 100°C, as stated in Tab 10

   K_T : Permissible stress for the design temperature, as stated in Tab 10.

Note 2: Where alloy steels not included in Tab 10 are used, the permissible stresses will be given special consideration.

f) Where it is necessary to avoid excessive stress in way of bends, branches, etc., the Society may give special consideration to the reduction of the test pressure to a value not less than 1,5 p. The membrane stress is in no case to exceed 90% of the yield stress at the testing temperature.

g) For pressure tests of plastic pipes after assembly on board, see Ch 1, App 3, [4.3.1].

19.4.3 Hydrostatic tests of valves, fittings and heat exchangers not likely to withstand immersion pressure

a) Valves and fittings non-integral with the piping system and intended for class I and II pipes are to be subjected to hydrostatic tests in accordance with standards recognised by the Society, at a pressure not less than 1,5 times the design pressure p defined in [1.3.2].

b) The shells of appliances such as heaters, coolers and heat exchangers which may be considered as pressure vessels are to be tested under the conditions specified in Ch 3, Sec 3.

c) The nests of tubes or coils of heaters, coolers and heat exchangers are to be submitted to a hydraulic test under the same pressure as the fluid lines they serve.

d) For coolers of internal combustion engines, see Ch 3, Sec 2.

19.4.4 Hydrostatic pressure tests of piping likely to withstand immersion pressure

Hydrostatic test shall be carried for all these pipes, valves and fittings without exception on individual elements during shop tests and after assembly on board.

As a general Rule, two types of pressure testing shall be undertaken:

- pressure tests to state that individual element or assembled systems resist pressure applied, referred as resistance tests
- pressure tests in order to state on watertightness between different parts of assembly, referred as tightness tests.

a) Hull valves:
   - resistance test at ≥ Pc
   - tightness test at Max (1,5 Pn ; Pa)

b) Other material:
   - resistance test at 1,5 Pn
   - tightness test at Pa.

Note 1:

Pn is defined as pressure corresponding to nominal diving depth.

Pa is defined as pressure corresponding to accidental diving depth.

Pc is defined as pressure corresponding to collapse diving depth.

Lower pressure values for tests may be used at the satisfaction of the Society, but:

- these reductions cannot apply for elements directly connected to pressure hull
- resisting test shall not be undertaken at a pressure value under 1,5 Pn
- watertightness test shall not be undertaken at a pressure under 1,2 Pn.

Whenever hydrostatic tests are not able to be undertaken for tightness, test using air depression shall be used.

19.4.5 Hydrostatic tests of fuel oil bunkers and tanks not forming part of the ship's structure

Fuel oil bunkers and tanks not forming part of the ship's structure are to be subjected to a hydrostatic test under a pressure corresponding to the maximum liquid level in such spaces or in the air or overflow pipes, with a minimum of 2,40 m above the top. The minimum height is to be 3,60 m for tanks intended to contain fuel oil with a flashpoint below 60°C.

19.4.6 Hydrostatic tests of pumps and compressors not settled on parts of circuits enables to withstand immersion pressure.

a) Cylinders, covers and casings of pumps and compressors are to be subjected to a hydrostatic test under a pressure at least equal to the test pressure p_H, in MPa, determined by the following formulae:
   - $p_H = 1,5\ p$ where $p \leq 4$
   - $p_H = 1,4\ p + 0,4$ where $4 < p \leq 25$
   - $p_H = p + 10,4$ where $p > 25$

   where:

   p : Design pressure, in MPa, as defined in [1.3.2].

   p_H is not to be less than 0,4 MPa.

b) Intermediate coolers of compressors are to undergo a hydrostatic test under a pressure at least equal to the pressure p_H defined in item a). When determining p_H, the pressure p to be considered is that which may result from accidental communication between the cooler and the adjoining stage of higher pressure, allowance being made for any safety device fitted on the cooler. If cooling system is directly connected with immersion pressure Rules mentioned in [19.4.4] shall apply.

c) The test pressure for water spaces of compressors and their intermediate coolers is not to be less than 1,5 times the design pressure in the space concerned, subject to a minimum of 0,2 MPa. If cooling system is directly connected with immersion pressure Rules mentioned in [19.4.4] shall apply.

d) For air compressors and pumps driven by internal combustion engines, see Ch 3, Sec 2.

19.4.7 Hydrostatic test of flexible hoses and expansion joints

a) Each flexible hose or expansion joint, together with its connections, is to undergo a hydrostatic test under a pressure at least equal to twice the maximum service pressure, subject to a minimum of 1 MPa.

b) During the test, the flexible hose or expansion joint is to be repeatedly deformed from its geometrical axis.

19.5 Testing of piping system components during manufacturing

19.5.1 Pumps

Bilge pumps are to undergo a performance test.

19.5.2 Centrifugal separators

Centrifugal separators used for fuel oil and lubricating oil are to undergo a running test, normally with a fuel water mixture.

19.6 Inspection and testing of piping systems

19.6.1 The inspections and tests required for piping systems and their components are summarised in Tab 32.

Table 32 : Inspection and testing at works for piping systems and their components

Item		Tests for the materials **(1)**		Inspections and tests for the product **(1)**		
		Tests required **(2)**	Type of material certificate **(3)**	During manufacturing (NDT)	After completion	Type of product certificate **(3)**
Valves, pipes and fittings **(4)**	a) class I and Class II	[19.3.2]	W	[3.6.2] **(4)** [3.6.3]	[19.4.3]	C **(5)**
	b) likely to withstand immersion pressure	[19.3.2]	C	[3.6.2] **(4)** [3.6.3]	[19.4.4]	C
Flexible hoses and expansion joints with the limitations mentioned in [2.6.1] Misalignment devices		[19.3.2]	W, C if withstanding immersion pressure	[3.6.2] **(4)** [3.6.3]	[19.4.7] or [19.4.4]	C **(5)**
Pumps and air compressors within piping systems covered by the Sections of this Chapter **(6)**	a) all	NR216 Materials			[19.4.6]	C **(5)**
	b) bilge, regulating tank, trim tank and fire pumps	NR216 Materials			[19.4.6] [19.5.1] a)	C **(5)**
	c) pumps on sea water piping withstanding immersion pressure:					
	- casing and bolts	NR216 Materials **(8)**	C **(7)**	[3.6.2] **(4)** [3.6.3]	[19.4.4]	C **(5)**
	- main parts					
	- rotor					
	- casing and bolts	NR216 Materials	C	[3.6.2] **(4)** [3.6.3]	[19.4.4]	C **(5)**
Centrifugal separators					[19.5.2]	C **(5)**
Prefabricated pipe lines	a) class I and II			[3.6.2] **(4)** [3.6.3]	[19.4.2]	W
	b) class III **(8)**				[19.4.2]	W
	c) sea water piping withstanding immersion pressure	[19.3.2]	C	[3.6.2] **(4)** [3.6.3]	[19.4.4]	C

(1) [x.y.z] : Test required, as per referent regulation.
(2) The material generally shall comply with [2.1.3] and Tab 4. Detail requirements where specified, are giving by NR216 Materials and Welding.
(3) C = class certificate; W = works' certificate.
(4) if of welded construction, for welded connections.
(5) or alternative type of certificate, depending on the Survey Scheme. See Part A.
(6) For other pumps and compressors, see also additional Rules relevant for related systems.
(7) Applies only for casing and bolts.
(8) where required by [19.4.2].

SECTION 6 REFRIGERATING INSTALLATIONS

1 General

1.1 Application

1.1.1 Refrigerating installations on submarines

The minimum safety requirements addressed in this Section are to be complied with for any refrigerating plant installed on board a ship to be classed by the Society. These requirements do not cover any operation or availability aspect of the plants, which are not the subject of class requirements, unless an additional notation is requested.

1.1.2 Additional notations

Where the additional notation **REFSTORE** is requested, the requirements of Pt F, Ch 1, Sec 1 is to be complied with, as applicable.

2 Minimum design requirements

2.1 Refrigerating installation components

2.1.1 General

In general, the specific requirements stated in Part D of the Rules for various machinery and equipment are also applicable to refrigerating installation components.

2.1.2 Pressure vessels and heat exchangers

a) Pressure vessels of refrigerating plants are to comply with the relevant requirements of Ch 3, Sec 3.

b) Vessels intended to contain toxic substances are to be considered as class 1 pressure vessels as indicated in Ch 3, Sec 3, [1.4].

c) The materials used for pressure vessels are to be appropriate to the fluid that they contain.

d) Notch toughness of steels used in low temperature plants is to be suitable for the thickness and the lowest design temperature. A check of the notch toughness properties may be required where the working temperature is below minus 40°C.

2.1.3 Piping systems

a) Where refrigerating installations use sea water systems connected to immersion pressure, these systems shall comply with requirements mentioned in Ch 3, Sec 5, [6].

b) Refrigerant pipes are generally to be regarded as pressure pipes.

c) Refrigerant, brine and sea water pipes are to satisfy the requirements of Ch 3, Sec 5 as applicable.

d) Refrigerant pipes are to be considered as belonging to the following classes:

- class I: where they are intended for toxic substances
- class II: for other refrigerants
- class III: for brine.

e) In general, the pipes conveying the cooling medium are not to come into direct contact with the ship's structure; they are to be carefully insulated on their run outside the refrigerated spaces, and more particularly when passing through bulkheads and decks.

f) The materials used for the pipes are to be appropriate to the fluids that they convey. Methods proposed for joining such pipes are to be submitted to the Society for consideration.

g) Notch toughness of the steels used is to be suitable for the application concerned.

h) Where necessary, cooling medium pipes within refrigerated spaces or embedded in insulation are to be externally protected against corrosion; for steel pipes, this protection is to be ensured by galvanisation or equivalent. All useful precautions are to be taken to protect the joints of such pipes against corrosion.

i) The use of plastic pipes will be considered by the Society on a case by case basis.

2.2 Refrigerants

2.2.1 Prohibited refrigerants

The use of the following refrigerants is not allowed for shipboard installations:

- ammonia
- methyl chloride
- R11 - Trichloromonofluoromethane ($C Cl_3 F$)
- ethane
- ethylene
- any other substances showing inflammability risk on gaseous phase in air
- refrigerants showing toxic effects under a concentration of 400 ppm.

2.2.2 Statutory requirements

Particular attention is to be paid to any limitation on the use of refrigerants imposed by the Administration of the State whose flag the ship is flying.

2.2.3 Toxic refrigerants

The arrangement of refrigerating machinery spaces of plants using toxic refrigerants will be the subject of special consideration by the Society. As an example:

- Measuring devices shall be available continuously, providing concentration of refrigerating fluid(s) on board in the whole range of reachable values in case of leakage. When whole range is not available, an alarm shall clearly be activated when high boundary of measuring range has been overpassed.
- Suitable means shall be implemented in order to contain efficiently and evacuate outboard refrigerating fluid in case of leakage.

SECTION 7 STEERING GEAR

1 General

1.1 Application

1.1.1 Scope

Unless otherwise specified, the requirements of this Section apply to the steering gear systems.

1.1.2 Cross references

In addition to the those provided in this Section, steering gear systems are also to comply with the requirements of:

- Pt A, Ch 1, App 1, as regards sea trials
- Pt C, Ch 6, Sec 1, as regards the rudder and the rudder stock
- Ch 3, Sec 5, as regard hydraulic installation.

1.2 Documentation to be submitted

1.2.1 Documents to be submitted for all steering gears

Before starting construction, all plans and specifications listed in Tab 1 are to be submitted to the Society for approval.

1.3 Definitions

1.3.1 Steering gear

Steering gear includes rudder sets, actuators and connected mechanical equipment enabling submarine to change its course on the vertical and the horizontal plane.

Rudders sets include rudders, mesh and are mechanically connected to a cinematic chain.

1.3.2 Cross rudder system

A submarine fitted with cross rudder system includes at least two steering gears:

- aft diving rudder: port and starboard rudders used for this purpose are generally mechanically coupled
- aft direction rudder: upper and lower rudders used for this purpose are generally mechanically coupled.

Generally, a third steering gear (two rudders coupled, port and starboard) used for immersion control is settled on bow or sail of submarine.

1.3.3 X rudder system

A submarine fitted with X rudder system includes at least four steering gears, located on bow and enabling control of submarine in vertical and horizontal plane.

Generally, a fifth steering gear (two rudders coupled, port and starboard) used for immersion control is settled on bow or sail of submarine.

Table 1 : Documents to be submitted for steering gear

Item No.	Status of the review **(2)**	Description of the document **(1)**
1	I	Assembly drawing of the steering gear including sliding blocks, guides, stops and other similar components
2	I	General description of the installation and of its functioning principle
3	I	Operating manuals of the steering gear and of its main components
4	I	Description of the operational modes intended for steering in normal and emergency conditions
5	A	Assembly drawings of the rudder actuators and constructional drawings of their components, with, for hydraulic actuators, indication of the: • design torque • maximum working pressure
6	A	Functional diagram of control, monitoring and safety systems
7	A	Constructional drawings of the strength parts providing a mechanical transmission of forces to the rudder stock (tiller, quadrant, connecting rods and other similar items), with the calculation notes of the shrink-fit connections

(1) Constructional drawings are to be accompanied by the specification of the materials employed and, where applicable, by the welding details and welding procedures.

(2) Submission of the drawings may be requested:
A = for approval; I = for information.

1.3.4 Steering gear power unit

Steering gear power units are as type described in Ch 3, Sec 5, [10.3.1] and usually included in a centralised hydraulic station as described in Ch 3, Sec 5, [10.4.1].

1.3.5 Power actuating system

Power actuating system is the equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e. tiller, quadrant and rudder stock, or components serving the same purpose.

1.3.6 Rudder actuator

Rudder actuator is the component which directly converts hydraulic pressure power into mechanical action to move the rudder. Other designs like designs based on electric powered actuators will be specially considered by Society.

1.3.7 Steering gear control system

Steering gear control system is the equipment by which orders are transmitted from control room to the steering gear power actuating systems. Steering gear control systems include calculators, transmitters, receivers, hydraulic distribution valves, piping and cables.

2 Availability

2.1 General requirements for any type of steering gear configuration

2.1.1 Loss of energy

Steering gear the system shall be able to operate without interruption in case of single loss of delivery of high pressure hydraulic fluid delivered to steering gear actuators

In these cases derated performances may be accepted.

2.1.2 Loss of control

a) Duplication of control

Each rudder set shall be fitted with at least two segregated control equipment connected to the energy source in use. Equipment enabling to switch from one control system to the other shall be located as close as possible from the rudder actuator(s).

b) Electric source for control

At least one of the control system shall be fitted with an uninterrupted supply of energy to feed system long enough in order to reach a safe situation.

2.1.3 Bow or sail rudders

One rudder set is located in the sail or on bow of submarine, dedicated for course change in the vertical plane. In this case, each rudder may be connected to a specific cinematic chain. No specific requirement exists for availability of these bow or sail rudders.

2.2 Requirements for specific rudder configurations

2.2.1 X rudder system

This applies to aft rudders:

a) mechanical and control chain shall be independent for each rudder set (auto pilot will be common)

b) upper rudder sets and lower rudder sets shall be supplied by two different sources of hydraulic power

c) when one rudder set is not available, it shall be possible to control submarine course and immersion with the remaining rudder sets, with a manual remote control on upper or lower sets of rudders

d) a FMEA related to aft rudders shall be submitted to the Society.

3 Design and construction

3.1 Performance of steering gears

3.1.1 Steering gear performance

Each component of steering gear shall be able to bear efforts necessary to achieve the expected performances of the rudders (rotation speed, angle value) in order to keep the submarine in a safe situation as described in the justification of speed versus depth diagram mentioned in Pt A, Ch 1, App 2, [2.1.2].

The values of these efforts shall be provided to the Society, including the specific cases where part of the rudders may be unavailable (if considered relevant).

3.2 Mechanical components

3.2.1 General

a) All steering gear components and the rudder stock are to be of sound and reliable construction to the satisfaction of the Society.

b) The construction is to be such as to minimise local concentration of stress.

c) All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

3.2.2 Materials and welds

a) All steering gear components transmitting mechanical forces to the rudder stock (such as tillers, quadrants, or similar components) are to be of steel or other approved ductile material complying with the requirements of NR216 Materials and Welding.

In general, such material is to have an elongation of not less than 12% and a tensile strength not greater than 650 N/mm^2.

Greater value of tensile strength up to 800 N/mm^2 may be accepted provided steel grade specification is submitted to the Society.

b) The use of grey cast iron is not permitted, except for redundant parts with low stress level, subject to special consideration by the Society. It is not permitted for cylinders.

c) The welding details and welding procedures are to be submitted for approval.

d) All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be full penetration type or of equivalent strength.

3.2.3 Scantling of components

The scantling of steering gear components is to be determined considering the design load cases and associated safety factors defined in Pt C, Ch 6, Sec 1.

3.2.4 Piston rods

The scantling of the piston rod is to be determined taking into account the bending moments, if any, in addition to compressive or traction forces.

Bending moments and traction forces are to be submitted by the designer and calculated for the load cases defined in Pt C, Ch 6, Sec 1.

The piston rods are to satisfy the following provisions:

a) $\sigma_c \leq \sigma_a$

where:

σ_c : Combined stress

σ_a : Permissible stress as per [3.2.3]

b) in respect of the buckling strength:

$$\frac{4}{\pi D_2^2} \cdot \left(\omega F_c + \frac{8M}{D_2}\right) \leq 0,9\sigma_a$$

where:

D_2 : Piston rod diameter, in mm

F_c : Compression force in the rod, in N, when it extends to its maximum stroke

M : Possible bending moment in the piston rod, in N·mm, in way of the fore end of the cylinder rod bearing

ω : $\omega = \beta + (\beta^2 - \alpha)^{0,5}$

with:

$\alpha = 0,0072\ (\ell_s / D_2)^2 \cdot R'_e / 235$

$\beta = 0,48 + 0,5\ \alpha + 0,1\ \alpha^{0,5}$

ℓ_s = Length, in mm, of the maximum unsupported reach of the cylinder rod.

The Society may accept other standards for these calculations.

3.3 Hydraulic system

3.3.1 General

The hydraulic piping system, including joints, valves, flanges and other fittings, is to comply with the requirements of Ch 3, Sec 5 for class I piping systems, and in particular with the requirements of Ch 3, Sec 5, [10], unless otherwise stated.

3.3.2 Materials

a) Ram cylinders, pressure housings of rotary vane type actuators, hydraulic power piping, valves, flanges and fittings are to be of steel or other approved ductile material.

b) In general, such material is to have an elongation of not less than 12%. Material with tensile strength more than 650 N/mm^2 will have special consideration by the Society.

Grey cast iron shall not be accepted.

3.3.3 Rudder actuators

a) Rudder actuators are to be designed in accordance with the relevant requirements of Ch 3, Sec 3 for class 1 pressure vessels also considering the following provisions.

b) The permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{R}{A} \quad \text{or} \quad \frac{R_e}{B}$$

where A and B are given in Tab 2. Other justified designs may be accepted by Society.

c) Oil seals between moving parts, forming part of the external pressure boundary, are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted.

d) The strength and connection of the cylinder heads (or, in the case of actuators of the rotary type, the fixed vanes) acting as rudder stops are to comply with the provisions of [4.3.1].

e) Design of shells of actuators in contact with immersion pressure shall be specially considered by Society.

f) Strength on piston rod produced by immersion pressure shall be taken into account in design.

Table 2 : Value of coefficients A and B

Coefficient	Steel	Cast steel
A	3,5	4,0
B	1,7	2,0

3.4 Alarms and indications

3.4.1 Control system

In the event of a failure of electrical power supply to the steering gear control systems, an audible an visual alarm shall be given to the control room.

3.4.2 Rudder angle indication

The angular position of the rudder is to be:

a) indicated in control room

b) recognisable in the steering gear compartment, which may be by mechanical indication.

4 Arrangement and installation

4.1 Steering gear arrangement

4.1.1 The steering gear installations shall be:

a) readily accessible and, as far as practicable

b) provided with suitable arrangements to ensure working access to steering gear machinery and controls, as far as practicable.

4.1.2 Path for cables and pipes

Set of cables and pipes associated to one control and/or source of energy capacity should be as far possible geographically separated from the other set(s) on order to avoid common failure mode.

4.2 Rudder actuator installation

4.2.1

a) Rudder actuators are to be installed on foundations of strong construction so designed as to allow the transmission to the ship structure of the forces resulting from the torque applied by the rudder and/or by the actuator, considering the strength criteria defined in [3.2.3] and [4.3.1]. The structure of the ship in way of the foundations is to be suitably strengthened.

b) Where the rudder actuators are bolted to the hull, the grade of the bolts used is not to be less than 8.8. Unless the bolts are adjusted and fitted with a controlled tightening, strong shocks are to be fitted in order to prevent any lateral displacement of the rudder actuator.

4.3 Overload protections

4.3.1 Mechanical rudder stops

a) The steering gear is to be provided with strong rudder stops capable of mechanically stopping the rotation of the rudder at an angle slightly greater than its maximum working angle. Alternatively, these stops may be fitted on the ship to act on another point of the mechanical transmission system between the rudder actuator and the rudder blade. These stops may be built in with the actuator design.

b) The scantlings of the rudder stops and of the components transmitting to the ship's structure the forces applied on these stops are to be determined for the worst loading condition.

5 Certification, inspection and testing

5.1 Testing of materials

5.1.1 Components subject to pressure or transmitting mechanical forces

a) Materials of components subject to pressure or transmitting mechanical forces, specifically:
   - cylindrical shells of hydraulic cylinders, rams and piston rods
   - tillers, quadrants,

   are to be duly tested, including examination for internal defects, in accordance with the requirements of NR216 Materials and Welding.

b) A works' certificate may be accepted for low stressed parts, provided that all characteristics for which verification is required are guaranteed by such certificate.

5.1.2 Hydraulic piping, valves and accessories

Tests for materials of hydraulic piping, valves and accessories are to comply with the provisions of Ch 3, Sec 5, [19].

5.2 Inspection and tests during manufacturing

5.2.1 Components subjected to pressure or transmitting mechanical forces

a) The mechanical components referred to in [4.2.1] are to be subjected to appropriate non-destructive tests. For hydraulic cylinder shells, refer to Ch 3, Sec 3.

b) Defects may be repaired by welding only on forged parts or steel castings of weldable quality. Such repairs are to be conducted under the supervision of the Surveyor in accordance with the applicable requirements of NR216 Materials and Welding.

5.2.2 Hydraulic piping, valves and accessories

Hydraulic piping, valves and accessories are to be inspected and tested during manufacturing in accordance with Ch 3, Sec 5, [19], for a class I piping system.

5.3 Inspection and tests after completion

5.3.1 Hydrostatic tests

a) Hydraulic cylinder shells are to be subjected to hydrostatic tests according to the relevant provisions of Ch 3, Sec 3.

b) Hydraulic piping, valves and accessories and hydraulic pumps are to be subjected to hydrostatic tests according to the relevant provisions of Ch 3, Sec 5, [19].

5.3.2 Shipboard tests

After installation on board the ship, the steering gear is to be subjected to the tests detailed in Pt A, Ch 1, App 1.

5.3.3 Sea trials

For the requirements of sea trials, refer to Pt A, Ch 1, App 1.

APPENDIX 1 PLASTIC PIPES

1 General

1.1 Application

1.1.1 These requirements are applicable to all piping systems with parts made of rigid plastic.

1.2 Use of plastic pipes

1.2.1 Plastic may be used in piping systems in accordance with the provisions of Ch 3, Sec 5, [2.1.4], provided the following requirements are complied with.

1.2.2 Plastic pipes are to be type approved by the Society.

1.3 Definitions

1.3.1 Plastic

Plastic includes both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and FRP (reinforced plastics pipes).

1.3.2 Piping systems

Piping systems include the pipes, fittings, joints, and any internal or external liners, coverings and coatings required to comply with the performance criteria.

1.3.3 Joints

Joints include all pipe assembling devices or methods, such as adhesive bonding, laminating, welding, etc.

1.3.4 Fittings

Fittings include bends, elbows, fabricated branch pieces, etc. made of plastic materials.

1.3.5 Nominal pressure

Nominal pressure is the maximum permissible working pressure which is to be determined in accordance with [2.2.3].

1.3.6 Fire endurance

Fire endurance is the capability of the piping system to perform its intended function, i.e. maintain its strength and integrity, for some predicted period of time while exposed to fire.

2 Design of plastic piping systems

2.1 General

2.1.1 Specification

The specification of the plastic piping is to be submitted in accordance with the provisions of Ch 3, Sec 5, [1.2.2]. It is to comply with a recognised national or international standard approved by the Society. In addition, the requirements stated below are to be complied with.

2.1.2 Marking

Plastic pipes and fittings are to be permanently marked with identification, including:

- pressure ratings
- the design standards that the pipe or fitting is manufactured in accordance with
- the material of which the pipe or fitting is made.

2.2 Strength

2.2.1 General

a) The piping is to have sufficient strength to take account of the most severe concomitant conditions of pressure, temperature, the weight of the piping itself and any static and dynamic loads imposed by the design or environment.

b) The strength of the pipes is to be determined at the maximum possible working temperature by the tests mentioned in [4.1.2].

2.2.2 Pipe thickness

Plastic pipes thickness is to be calculated using a maximum allowable stress not higher than 1/7 of the ultimate tensile strength of the material at the service temperature.

2.2.3 Permissible pressure

Piping systems are to be designed for a nominal pressure determined from the following conditions:

a) Internal pressure

The nominal internal pressure is not to exceed the smaller of:

- $P_{sth} / 4$
- $P_{lth} / 2,5$

where:

P_{sth} : Short-term hydrostatic test failure pressure, in MPa

P_{lth} : Long-term hydrostatic test failure pressure (> 100 000 hours), in MPa.

b) External pressure (to be considered for any installation subject to vacuum conditions inside the pipe or a head of liquid acting on the outside of the pipe)

The nominal external pressure is not to exceed $P_{col} / 3$, where:

P_{col} : Collapse pressure.

Note 1: The external pressure is the sum of the vacuum inside the pipe and the static pressure head outside the pipe.

c) The collapse pressure is not to be less than 0,3 MPa.

2.2.4 Permissible temperature

a) In general, plastic pipes are not to be used for media with a temperature above 60°C or below 0°C, unless satisfactory justification is provided to the Society.

b) The permissible working temperature range depends on the working pressure and is to be justified by appropriate tests.

c) The maximum permissible working temperature is to be at least 20°C lower than the minimum heat distortion temperature of the pipe material, determined according to ISO 75 method A or equivalent.

d) The minimum heat distortion temperature is not to be less than 80°C.

2.2.5 Axial strength

a) The sum of the longitudinal stresses due to pressure, weight and other loads is not to exceed the allowable stress in the longitudinal direction.

b) In the case of fibre reinforced plastic pipes, the sum of the longitudinal stresses is not to exceed half of the nominal circumferential stress derived from the nominal internal pressure condition (see [2.2.3]).

2.2.6 Impact resistance

Plastic pipes and joints are to have a minimum resistance to impact in accordance with a recognised national or international standard.

2.3 Requirements depending on service and/or location

2.3.1 Fire endurance

The requirements for fire endurance of plastic pipes and their associated fittings are given in Tab 1 for the various systems and locations where the pipes are used.

Specifically:

- a 60 min fire endurance test in dry conditions is to be carried out according to Appendix 1 of IMO Res. A.753(18), where indicated "L1" in Tab 1
- a 30 min fire endurance test in dry conditions is to be carried out according to Appendix 1 of IMO Res. A.753(18), where indicated "L2" in Tab 1
- a 30 min fire endurance test in wet conditions is to be carried out according to Appendix 1 of IMO Res. A.753(18), where indicated "L3" in Tab 1
- no fire endurance test is required, where indicated "0" in Tab 1
- a metallic material with a melting point greater than 925°C is to be used, where indicated "X" in Tab 1.

Note 1: "NA" means "not applicable".

2.3.2 Flame spread

a) All pipes, except those fitted on open decks and within tanks, cofferdams, pipe tunnels and ducts, are to have low spread characteristics not exceeding average values listed in IMO Resolution A.653(16). Other recognised national standards may also be referred to.

b) Surface flame characteristics are to be determined using the procedure given in IMO Res. A.653(16) with regard to the modifications due to the curvilinear pipe surfaces as listed in Appendix 3 of Res. A.753(18).

2.3.3 Fire protection coating

Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance level required, it is to meet the following requirements:

- the pipes are generally to be delivered from the manufacturer with the protective coating on
- the fire protection properties of the coating are not to be diminished when exposed to salt water, oil or bilge slops. It is to be demonstrated that the coating is resistant to products likely to come into contact with the piping
- in considering fire protection coatings, such characteristics as thermal expansion, resistance against vibrations and elasticity are to be taken into account
- the fire protection coatings are to have sufficient resistance to impact to retain their integrity.

2.3.4 Electrical conductivity

a) Piping systems conveying fluids with a conductivity less than 1000 pS/m (1 pS/m=10^{-9} siemens per metre), such as refined products and distillates, are to be made of conductive pipes.

b) Regardless of the fluid to be conveyed, plastic pipes passing through hazardous areas are to be electrically conductive.

c) Where electrical conductivity is to be ensured, the resistance of the pipes and fittings is not to exceed:

1×10^5 Ohm/m.

d) Where pipes and fittings are not homogeneously conductive, conductive layers are to be provided, suitably protected against the possibility of spark damage to the pipe wall.

2.4 Pipe and fitting connections

2.4.1 General

a) The strength of connections is not to be less than that of the piping system in which they are installed.

b) Pipes and fittings may be assembled using adhesive-bonded, welded, flanged or other joints.

c) When used for joint assembly, adhesives are to be suitable for providing a permanent seal between the pipes and fittings throughout the temperature and pressure range of the intended application.

d) Tightening of joints, where required, is to be performed in accordance with the manufacturer's instructions.

e) Procedures adopted for pipe and fitting connections are to be submitted to the Society for approval, prior to commencing the work.

Table 1: Fire endurance of piping systems

PIPING SYSTEM	LOCATION				
	Diesel engine room or equivalent **(1)**	Battery, torpedo room, other machinery spaces and pump rooms **(2)**	Fuel oil tanks **(3)**	Cofferdams, void spaces, pipe tunnels and ducts **(4)**	Accommodation, service and control spaces **(5)**
FLAMMABLE LIQUIDS (FLASH POINT > 60°C)					
Fuel oil	X	X	0	0	L1
Lubricating oil	X	X	NA	0	L1
Hydraulic oil	X	X	0	0	L1
SEA WATER (pipes not likely to withstand immersion pressure)					
Bilge main and branches	X	X	0	0	NA
Water spray	L1	L1	NA	0	X
Foam system	L1	L1	NA	0	L1
Cooling water, essential services	L3	L3	NA	0	NA
Non-essential systems	0	0	0	0	0
FRESH WATER					
Cooling water, essential services	L3	L3	0	0	L3
Condensate return	L3	L3	NA	0	0
Non-essential systems	0	0	0	0	0
SANITARY, DRAINS, SCUPPERS					
Deck drains (internal)	L1 **(6)**	L1 **(6)**	0	0	0
Sanitary drains (internal)	0	0	0	0	0
SOUNDING, AIR					
Water tanks, dry spaces	0	0	0	0	0
Oil tanks (flash point > 60°C)	X	X	0	0	X
MISCELLANEOUS					
Control air	L1 **(7)**	L1 **(7)**	0	0	L1 **(7)**
Service air (non-essential)	0	0	0	0	0

(1) Diesel engine room or equivalent are defined in Pt E, Ch 1, Sec 5, [1.3].
(2) As defined in Pt E, Ch 1, Sec 5, [1.3].
(3) All spaces used for fuel oil and trunks to such spaces.
(4) Empty spaces between two bulkheads separating two adjacent compartments.
(5) Accommodation spaces, service spaces and control stations are defined in Pt E, Ch 1, Sec 5, [1.3].
(6) For drains serving only the space concerned, "0" may replace "L1".
(7) When controlling functions are not required by the Rules, "0" may replace "L1".

2.4.2 Bonding of pipes and fittings

a) The procedure for making bonds is to be submitted to the Society for qualification. It is to include the following:
   - materials used
   - tools and fixtures
   - joint preparation requirements
   - cure temperature
   - dimensional requirements and tolerances
   - acceptance criteria for the test of the completed assembly.

b) When a change in the bonding procedure may affect the physical and mechanical properties of the joints, the procedure is to be requalified.

3 Arrangement and installation of plastic pipes

3.1 General

3.1.1 Plastic pipes and fittings are to be installed by the Shipyard in accordance with the Manufacturer's guidelines and taking account of the following provisions, as deemed necessary.

3.2 Supporting of the pipes

3.2.1

a) Selection and spacing of pipe supports in shipboard systems are to be determined as a function of allowable stresses and maximum deflection criteria.

b) The selection and spacing of pipe supports are to take into account the following data:
   - pipe dimensions
   - mechanical and physical properties of the pipe material
   - mass of pipe and contained fluid
   - external pressure
   - operating temperature
   - thermal expansion effects
   - load due to external forces
   - thrust forces
   - water hammer
   - vibrations
   - maximum accelerations to which the system may be subjected.

   Combinations of loads are also to be considered.

c) Support spacing is not to be greater than the pipe manufacturer's recommended spacing.

3.2.2 Each support is to evenly distribute the load of the pipe and its content over the full width of the support. Measures are to be taken to minimise wear of the pipes where they are in contact with the supports.

3.2.3 Heavy components in the piping system such as valves and expansion joints are to be independently supported.

3.3 Provision for expansion

3.3.1 Suitable provision is to be made in each pipeline to allow for relative movement between pipes made of plastic and the steel structure, having due regard to:

- the high difference in the coefficients of thermal expansion
- deformations of the ship's structure.

3.3.2 Calculations of the thermal expansions are to take into account the system working temperature and the temperature at which the assembly is performed.

3.4 External loads

3.4.1 When installing the piping, allowance is to be made for temporary point loads, where applicable. Such allowance is to include at least the force exerted by a load (person) of 100 kg at mid-span on any pipe of more than 100 mm nominal outside diameter.

3.4.2 Pipes are to be protected from mechanical damage where necessary.

3.5 Earthing

3.5.1 Where, in pursuance of [2.3.4], pipes are required to be electrically conductive, the resistance to earth from any point in the piping system is not to exceed 1×10^6 Ω.

3.5.2 Where provided, earthing wires are to be accessible for inspection.

3.6 Penetration of fire divisions and watertight bulkheads or decks

3.6.1 Where plastic pipes pass through "A" or "B" class divisions, arrangements are to be made to ensure that fire endurance is not impaired. These arrangements are to be tested in accordance with 'Recommendations for Fire Test Procedures for "A", "B" and "F" Bulkheads' (IMO Resolution A754 (18) as amended).

3.6.2 When plastic pipes pass through watertight bulkheads or decks, the watertight integrity of the bulkhead or deck is to be maintained. If the bulkhead or deck is also a fire division and destruction by fire of plastic pipes may cause the inflow of liquid from tanks, a metallic shut-off valve operable from above the freeboard deck is to be fitted at the bulkhead or deck.

3.7 Application of fire protection coatings

3.7.1 Where necessary for the required fire endurance as stated in [2.3.3], fire protection coatings are to be applied on the joints, after performing hydrostatic pressure tests of the piping system.

3.7.2 The fire protection coatings are to be applied in accordance with the manufacturer's recommendations, using a procedure approved in each case.

4 Certification, inspection and testing of plastic piping

4.1 Certification

4.1.1 Type approval

Plastic pipes and fittings are to be of a type approved by the Society for the intended use. For this purpose, the material tests required in [4.1.2] and, where applicable, the bonding qualification test detailed in [4.1.3] are to be performed.

4.1.2 Material tests

a) Tests are to be performed according to a procedure approved by the Society to determine, for each type of pipe and fitting, the following characteristics:
   - ultimate tensile strength
   - short-term and long-term design strength
   - collapse
   - impact resistance
   - fire endurance
   - low flame spread characteristics
   - electrical resistance (for electrically conductive pipes).

For the above tests, representative samples of pipes and fittings are to be selected to the satisfaction of the Society.

b) The ultimate tensile strength is to be determined by means of a hydrostatic test on pipe samples subjected to increasing pressure up to failure, the pressure being increased at such a rate that failure occurs in not less than 5 minutes. Such test is to be carried out under the standard conditions: atmospheric pressure equal to 100kPa, relative humidity 30%, environmental and carried fluid temperature 298 K (25°C).

The ultimate tensile strength is to be determined using the tangential stress based on the initial diameter of the pipe. Small deformations of the pipe sample during the test may be accepted.

c) Alternatively, hydrostatic test failure pressure and collapse pressure may be determined by a combination of tests and calculations, subject to the agreement of the Society.

d) After the impact resistance test, the specimen is to be subjected to hydrostatic pressure equal to 2,5 times the design pressure for at least 1 hour.

4.1.3 Bonding qualification test

a) A test assembly is to be fabricated in accordance with the procedure to be qualified. It is to consist of at least one pipe-to-pipe joint and one pipe-to-fitting joint.

b) When the test assembly has been cured, it is to be subjected to a hydrostatic test pressure at a safety factor of 2,5 times the design pressure of the test assembly, for not less than one hour. No leakage or separation of joints is allowed. The test is to be conducted so that the joint is loaded in both longitudinal and circumferential directions.

c) Selection of the pipes used for the test assembly is to be in accordance with the following:

- when the largest size to be joined is 200 mm nominal outside diameter or smaller, the test assembly is to be the largest piping size to be joined
- when the largest size to be joined is greater than 200 mm nominal outside diameter, the size of the test assembly is to be either 200 mm or 25% of the largest piping size to be joined, whichever is the greater.

4.2 Workshop tests

4.2.1 Each pipe and fitting is to be tested by the manufacturer at a hydrostatic pressure not less than 1,5 times the nominal pressure.

4.3 Testing after installation on board

4.3.1 Hydrostatic testing

a) Piping systems for essential systems are to be subjected to a test pressure of not less than 1,5 times the design pressure or 0,4 MPa, whichever is the greater.

b) Piping systems for non-essential services are to be checked for leakage under operational conditions.

4.3.2 Earthing test

For piping required to be electrically conductive, earthing is to be checked and random resistance testing is to be performed.

APPENDIX 2 CHECK OF THE SCANTLINGS OF CRANKSHAFTS FOR DIESEL ENGINES

1 General

1.1 Application

1.1.1

a) The requirements for the check of scantlings of crankshafts given in this Appendix apply to diesel engines as per Ch 3, Sec 2, [1.1.1], items a), b) and c), capable of continuous operation at their maximum continuous power P, (as defined in Ch 3, Sec 2, [1.3.2]), at the nominal maximum speed n.
Crankshafts which cannot satisfy these requirements will be subject to special consideration by the Society as far as detailed calculations or measurements can be submitted.
The following cases:

- surface treated fillets
- when fatigue parameter influences are tested, and
- when working stresses are measured,

will be also specially considered by the Society.

b) The requirements of this Appendix apply only to solid-forged and semi-built crankshafts of forged or cast steel, with one crank throw between two adjacent main bearings.

1.2 Documentation to be submitted

1.2.1 Required data for the check of the scantlings are indicated in the specific Society form as per Ch 3, Sec 2, Tab 1, item 1.

1.3 Principles of calculation

1.3.1 The scantlings of crankshafts as per this Appendix are based on an evaluation of safety against fatigue failure in the highly stressed areas.

The calculation is also based on the assumption that the areas exposed to highest stresses are:

- fillet transitions between the crankpin and web as well as between the journal and web
- outlets of crankpin oil bores.

When journal diameter is equal or larger than the crankpin one, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate documentation of fatigue safety may be required.

The engine manufacturer, where requested by the Society, is to submit documentation supporting his oil bore design.

Calculation of crankshaft strength consists initially in determining the nominal alternating bending and nominal alternating torsional stresses which, multiplied by the appropriate stress concentration factors using the theory of constant energy of distortion (Von Mises's criterion), result in an equivalent alternating stress (uni-axial stress). This equivalent alternating stress is then compared with the fatigue strength of the selected crankshaft material. This comparison will then show whether or not the crankshaft concerned is dimensioned adequately.

1.4 Symbols

1.4.1

B : Width of the web, in mm; see Fig 2

d_{BC} : Diameter of bore in crankpin, in mm; see Fig 2

d_{BJ} : Diameter of bore in journal, in mm; see Fig 2

d_C : Crankpin diameter, in mm; see Fig 2

d_J : Journal diameter, in mm; see Fig 2

D_E : The minimum value between:

- the outside diameter of web, in mm, or
- the value, in mm, equal to twice the minimum distance x between centre-line of journals and outer contour of web; see Fig 3

d_S : Shrink-fit diameter, in mm; see Fig 3

E : Pin eccentricity, in mm; see Fig 2

E_W : Value of the modulus of elasticity of the web material, in N/mm^2; see [7.2.2]

F : Area, in mm^2, related to cross-section of web, given by the following formula:

$F = B\ W$

K : Crankshaft manufacturing process factor; see [6.1.1], item a)

K_E : Empirical factor for the modification of the alternating bending stress, which considers to some extent the influence of adjacent cranks and bearing restraint, whose value may be taken as follows:

- $K_E = 0,8$ for 2-stroke engines
- $K_E = 1,0$ for 4-stroke engines

L_S : Axial length of the shrink-fit, in mm; see Fig 3

M_B : Bending moment in the web centre, in N·m

$M_{B,MAX}$: Maximum value of the bending moment M_B, in N·m

$M_{B,MIN}$: Minimum value of the bending moment M_B, in N·m

M_{BN} : Nominal alternating bending moment, in N·m; for the determination of M_{BN}, see [2.1.2] item b)

$M_{T,MAX}$: Maximum value of the torque, in N·m, with consideration of the mean torque

$M_{T,MIN}$: Minimum value of the torque, in N·m, with consideration of the mean torque

M_{TN} : Nominal alternating torque, in N·m, given by the following formula:

$$M_{TN} = \pm 0,5 \cdot (M_{T,MAX} - M_{T,MIN})$$

Q_1 : Acceptability factor for the crankpin fillet; see [8.1.1]

Q_2 : Acceptability factor for the journal fillet; see [8.1.1]

Q_{MAX} : Maximum value of the alternating shearing force Q, in N

Q_{MIN} : Minimum value of the alternating shearing force Q, in N

Q_N : Nominal alternating shearing force, in N; for the determination of Q_N, see [2.1.2], item c)

r_C : Fillet radius of crankpin, in mm; see Fig 2

r_J : Fillet radius of journal, in mm; see Fig 2

R_m : Value of the minimum specified tensile strength of crankshaft material, in N/mm^2

$R_{S,MIN}$: Specified value, in N/mm^2, of the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p\,0,2}$), of the crank web material

S : Pin overlap, in mm, (see Fig 2) whose value may be calculated by the following formula:

$$S = \frac{d_C + d_J}{2} - E$$

Where pins do not overlap, the negative value of S calculated by the above formula is to be considered

T_C : Recess of crankpin, in mm; see Fig 2

T_J : Recess of journal, in mm; see Fig 2

W : Axial web thickness, in mm; see Fig 2

W_{EQ} : Equatorial moment of resistance, in mm^3, related to cross-sectional area of web, whose value may be calculated as follows:

$$W_{EQ} = \frac{B \cdot W^2}{6}$$

W_{PC} : Value, in mm^3, of the polar moment of resistance related to cross-sectional area of crankpin; for the determination of W_{PC}; see [2.2.2]

W_{PJ} : Value, in mm^3, of the polar moment of resistance related to cross-sectional area of journal; for the determination of W_{PJ}; see [2.2.2]

y : Distance, in mm, between the adjacent generating lines of journal and pin connected to the same web; see Fig 3.

In general y is not to be less than 0,05 d_S.
Where y is less than 0,1 d_S, special consideration will be given by the Society in each case, to the effect of the stress due to the shrink on the fatigue strength of the web at the crankpin fillet

β_{BC} : Stress concentration factor for bending in crankpin fillet; for the determination of β_{BC}, see [3.1.2], item a)

β_{BJ} : Stress concentration factor for bending in journal fillet; for the determination of β_{BJ}, see [3.1.3], item a)

β_{QJ} : Stress concentration factor for shearing in journal fillet; for the determination of β_{QJ}, see [3.1.3], item b)

β_{TC} : Stress concentration factor for torsion in crankpin fillet; for the calculation of β_{Tc}, see [3.1.2], item b)

β_{TJ} : Stress concentration factor for torsion in journal fillet; for the calculation of β_{TJ}, see [3.1.3], item c)

$\sigma_{B,ADD}$: Additional bending stress, in N/mm^2, due to misalignment; see [4.1.1]

σ_{BN} : Nominal alternating bending stress, in N/mm^2; for the determination of σ_{BN}, see [2.1.2], item b)

σ_{BC} : Alternating bending stress in crankpin fillet, in N/mm^2; for the determination of σ_{BC}, see [2.1.3], item a)

σ_{BJ} : Alternating bending stress in journal fillet, in N/mm^2; for the determination of σ_{BJ}, see [2.1.3], item b)

σ'_E : Equivalent alternating stress in way of the crankpin fillet, in N/mm^2; for the determination of σ'_E see [5.2.1], item a)

σ''_E : Equivalent alternating stress in way of the journal fillet, in N/mm^2; for the determination of σ''_E see [5.2.1], item b)

$\sigma'_{F,ALL}$: Allowable alternating bending fatigue strength in way of the crankpin fillet, in N/mm^2; for the determination of $\sigma'_{F,ALL}$, see [6.1.1], item a)

$\sigma''_{F,ALL}$: Allowable alternating bending fatigue strength in way of the journal fillet, in N/mm^2; for the determination of $\sigma''_{F,ALL}$, see [6.1.1], item b)

σ_{QN} : Nominal alternating shearing stress, in N/mm^2; for the determination of σ_{QN}, see [2.1.2], item c)

τ_C : Alternating torsional stress in way of crankpin fillet, in N/mm^2; for the determination of τ_C, see [2.2.3], item a)

τ_J : Alternating torsional stress in way of journal fillet, in N/mm^2; for the determination of τ_J, see [2.2.3], item b)

τ_{NC} : Nominal alternating torsional stress referred to crankpin, in N/mm^2; for the determination of τ_{NC}, see [2.2.2]

τ_{NJ} : Nominal alternating torsional stress referred to journal, in N/mm^2; for the determination of τ_{NJ}, see [2.2.2]

d_{OB} : Diameter of oil bore in crankpin, in mm; see Fig 4

M_{BRO} : Bending moment of the radial component of the connecting-rod force, in Nm

M_{BTO} : Bending moment of the tangential component of the connecting-rod force, in Nm

σ_{BON} : Nominal alternating bending stress related to the crank, in N/mm^2

M_{BON} : Alternating bending moment, in Nm, calculated at the outlet of crankpin oil bore

Ψ : Angular position, in deg; see Fig 4

W_e : Section modulus related to cross-section of axially bored crankpin, in mm^3

σ_{BO} : Alternating bending stress in outlet of crankpin oil bore, in N/mm^2

γ_B : Stress concentration factor for bending in crankpin oil bore; see Article [3]

σ_{TO} : Alternating torsional stress in outlet of crankpin oil bore, in N/mm^2; for the determination of σ_{TO}, see [2.2.2], item c)

γ_T : Stress concentration factor for torsion in outlet of crankpin oil bore; see Article [3]

σ'''_E : Equivalent alternating stress in way of the crankpin outlet of oil bore, in N/mm^2; for the determination of σ'''_E, see [5.2.1], item c)

$\sigma'''_{F, ALL}$: Allowable alternating bending fatigue strength in way of the crankpin outlet of oil bore, in N/mm^2; for the determination of $\sigma'''_{F,ALL}$, see [6.1.1], item c)

Q_3 : Acceptability factor for the crankpin outlet of oil bore; see [8.1.1]

W_{red} : Reduced axial web thickness (see Fig 2), in mm, for two strokes engines with $T_c > r_c$:

$$W_{red} = W - (T_c - r_c)$$

2 Calculation of alternating stresses

2.1 Calculation of alternating stresses due to bending moments and shearing forces

2.1.1 Assumptions

The calculation of alternating stresses is based on the assumptions specified below.

a) The calculation is based on a statically determined system, so that only one single crank throw is considered with the journals supported in the centre of adjacent bearings and the throw subjected to gas and inertia forces. The bending length is taken as the length L3 between the centre of two adjacent main bearings (see Fig 1 (a) and Fig 1 (b)).

b) The nominal bending moment is taken as the bending moment in the crank web cross-section in the centre of the solid web (distance L1) based on a triangular bending moment load due to the radial components of the connecting rod force. For crank throws with two connecting rods acting upon one crankpin, the nominal bending moment is taken as a bending moment obtained by superimposing the two triangular bending moment loads due to the radial components of the connecting rod forces, according to phase.

c) The nominal alternating stresses due to bending moments and shearing forces are to be related to the cross-sectional area of the crank web, at the centre of the overlap S in cases of overlap of the pins and at the centre of the distance y between the adjacent generating lines of the two pins in cases of pins which do not overlap (see Fig 2 and Fig 3). Nominal mean bending stresses are neglected.

d) Bending acting in outlet of crankpin oil bore

The two relevant bending moments M_{BRO} and M_{BTO} (see definitions in [1.4.1]) are taken in the crankpin cross-section through the oil bore.

The alternating stresses due to these bending moments are to be related to the cross-sectional area of the axially bored crankpin. Mean bending stresses are neglected.

The nominal alternating bending stress related to the crankpin diameter, in N/mm^2, is as follows:

$$\sigma_{BON} = \pm 10^3 M_{BON} / W_e$$

where:

M_{BON} : Alternating bending moment calculated at the outlet of crankpin oil bore, in Nm, equal to:

$$M_{BON} = \pm 1/2 \, (M_{BOmax} - M_{BOmin})$$

with:

$$M_{BO} = M_{BTO} \cos \psi + M_{BRO} \sin \psi$$

W_e : Section modulus, in mm^3, related to the cross-section of axially bored crankpin:

$$W_e = \frac{\pi}{32} \frac{(d_C^4 - d_{BC}^4)}{d_C}$$

2.1.2 Calculation of nominal alternating bending and shearing stresses

a) As a rule the calculation is carried out in such a way that the individual radial forces acting upon the crank pin owing to gas and inertia forces will be calculated for all crank positions within one working cycle. A simplified calculation of the radial forces may be used at the discretion of the Society.

b) The bending moment M_B in the web centre is to be calculated by means of the radial forces variable in time within one working cycle, and taking into account the axial distance from the time curve as defined in the bearing centre to the acting position of the forces on the pin. The nominal alternating bending moment M_{BN} , in N·m, and, from this, the nominal alternating bending stress σ_{BN}, in N/mm^2, will then be calculated by the following formulae:

$$M_{BN} = \pm 0,5 \cdot (M_{B,MAX} - M_{B,MIN})$$

$$\sigma_{BN} = \pm \frac{M_{BN}}{W_{EQ}} \cdot K_E \cdot 10^3$$

In the case of V-type engines, the bending moments, progressively calculated for the various crank angles and due to the gas and inertia forces of the two cylinders acting on one crank throw, are to be superimposed according to phase, the differing designs of the connecting rods (forked connecting rod, articulated-type connecting rod or adjacent connecting rods) being taken into account.

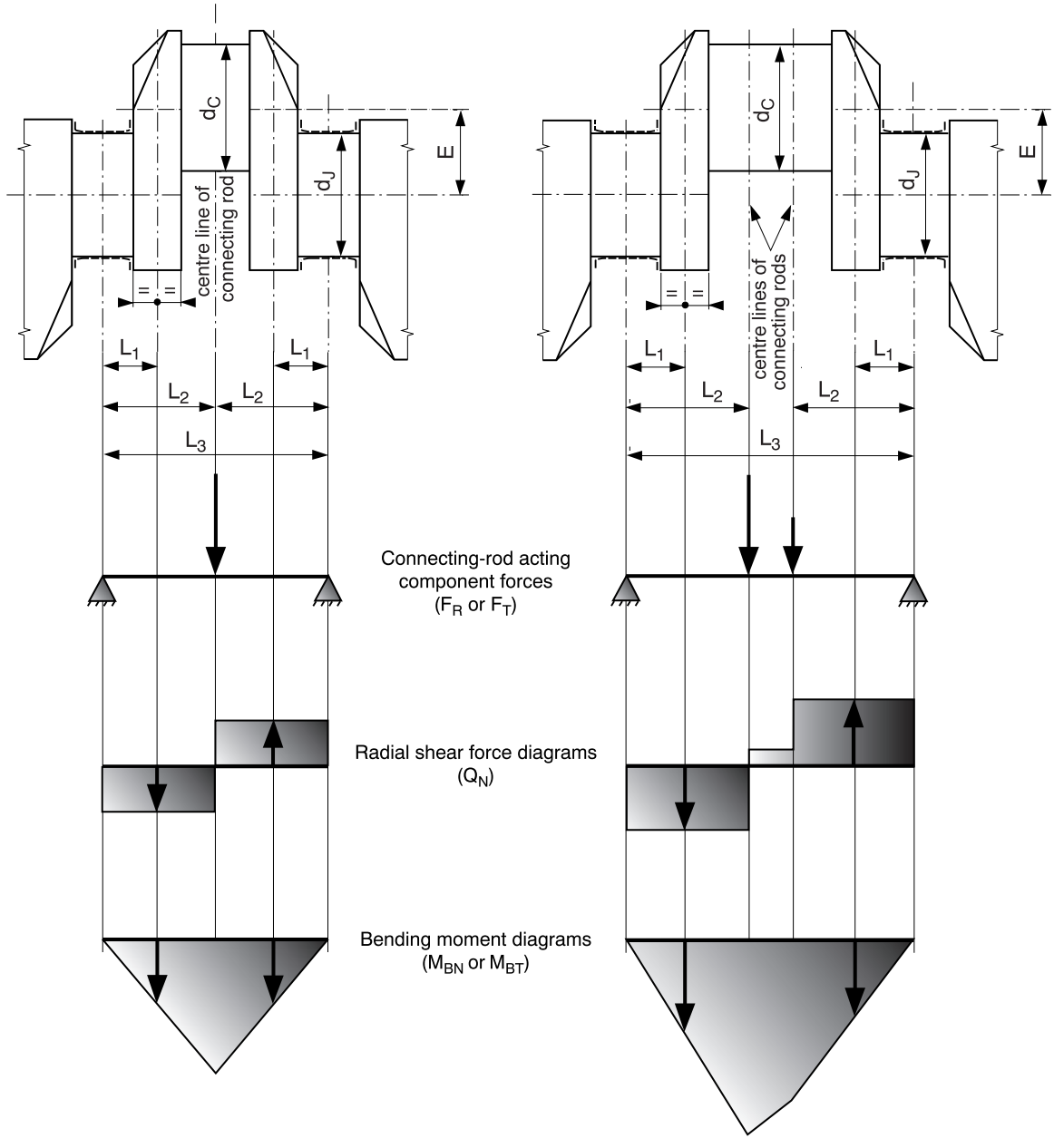
Where there are cranks of different geometrical configuration (e.g., asymmetric cranks) in one crankshaft, the calculation is to cover all crank variants.

c) The nominal alternating shearing force Q_N, in N, and, from this, the nominal alternating shearing stress σ_{QN}, in N/mm_2, may be calculated by the following formulae:

$$Q_N = \pm 0,5 \cdot (Q_{MAX} - Q_{MIN})$$

$$\sigma_{QN} = \pm \frac{Q_N}{F} \cdot K_E$$

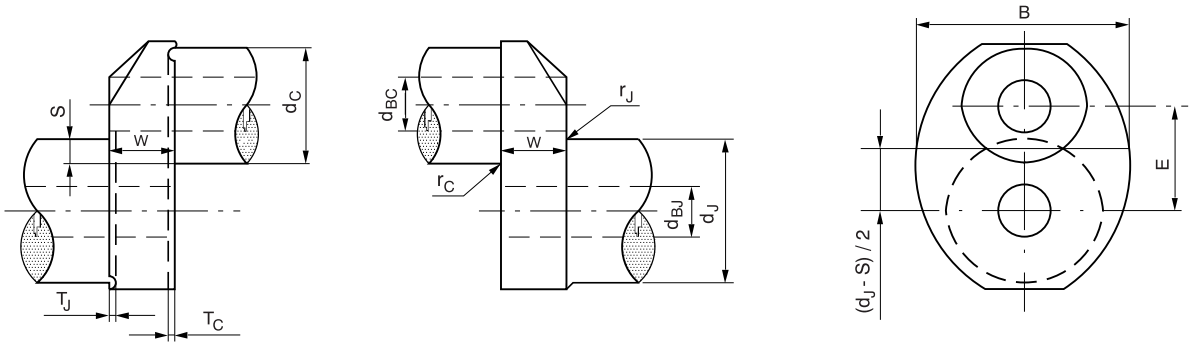
Figure 1: Crank throw of solid crankshaft



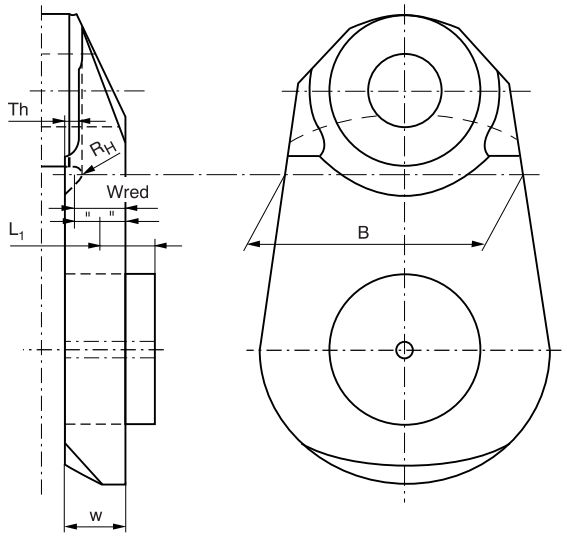
(a) Crank throw for engine with one connecting rod

(b) Crank throw for engine with two adjacent connecting rods

Figure 2: Crank dimensions necessary for the calculation of stress concentration factors



Overlapped crankshaft



Crankshaft without overlap

Figure 3: Crank throw of semi-built crankshaft

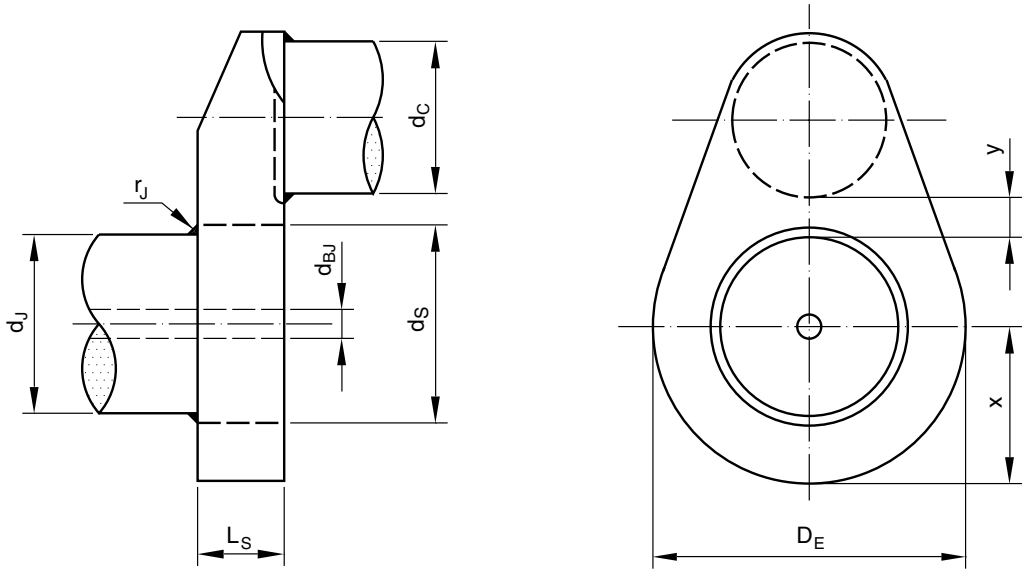
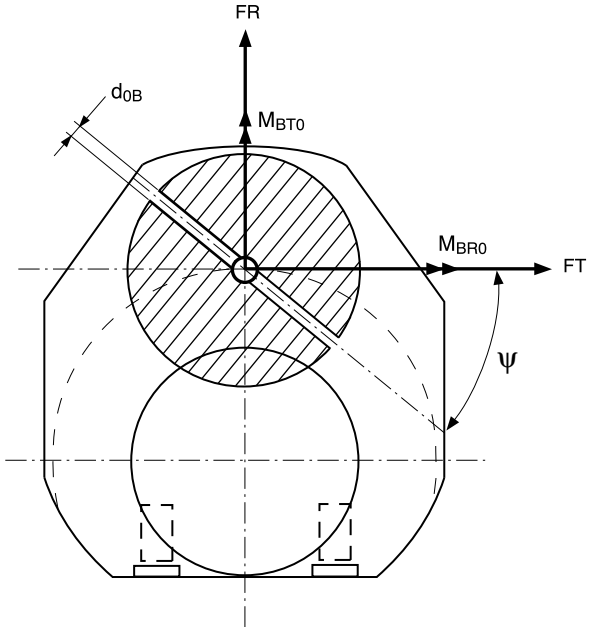


Figure 4 : Crankpin section through the oil bore



2.1.3 Calculation of alternating bending stresses in way of fillets and outlet of crankpin oil bore

The calculation of the alternating bending stresses is to be carried out in way of the crankpin fillet, the journal fillet and the outlet of the crankpin oil bore, as follows:

a) The alternating bending stress in crankpin fillet is to be taken equal to the value σ_{BC}, in N/mm^2, obtained by the following formula:

$$\sigma_{BC} = \pm (\beta_{BC} \cdot \sigma_{BN})$$

b) The alternating bending stress in journal fillet is to be taken equal to the value σ_{BJ}, in N/mm^2, obtained by the following formula:

$$\sigma_{BJ} = \pm (\beta_{BJ} \cdot \sigma_{BN} + \beta_{QJ} \cdot \sigma_{QN})$$

c) The alternating bending stress in outlet of crankpin oil bore is to be taken equal to the value σ_{BO}, in N/mm^2, obtained by the following formula:

$$\sigma_{BO} = \pm (\gamma_B \ \sigma_{BON})$$

where:

γ_B, σ_{BON} : As defined in [1.4.1].

2.2 Calculation of alternating torsional stresses

2.2.1 General

The calculation for nominal alternating torsional stresses is to be undertaken by the engine manufacturer according to the information contained in [2.2.2].

The maximum value obtained from such calculations will be used by the Society when determining the equivalent alternating stress according to the provisions of article [5].

In the absence of such a maximum value, the Society reserves the right to incorporate a fixed value in the calculation for the crankshaft dimensions, to be established at its discretion in each case.

In the event of the Society being entrusted to carry out a forced vibration calculation on behalf of the engine manufacturer to determine the torsional vibration stresses expected in the engine and where relevant in the shafting, the following data are to be submitted in addition to those required in [1.2.1]:

a) equivalent dynamic system of the engine, comprising:

   1) mass moment of inertia of every mass point, in kg·m^2

   2) inertialess torsional stiffnesses, in N·m/rad, of all crankshaft parts between two mass points

b) vibration dampers, specifying:

   1) type designation

   2) mass moments of inertia, in kg·m^2

   3) inertialessly torsional stiffnesses, in N·m/rad

   4) values of the damping coefficients, in N·m·s

c) flywheels, specifying:

   1) mass moment of inertia, in kg·m^2.

Where the whole propulsion system is to be considered, the following information is also to be submitted:

a) elastic couplings, specifying:

   1) dynamic characteristics and damping data, as well as the permissible value of alternating torque

b) gearing and shafting, specifying:

   1) shaft diameters of gear shafts, thrust shafts, intermediate shafts and propeller shafts, mass moments of inertia, in kg·m^2, of gearing or important mass points, gear ratios and, for gearboxes of complex type, the schematic gearing arrangement

c) propellers, specifying:

   1) propeller diameter

   2) number of blades

   3) pitch and developed area ratio

   4) mass moment of inertia of propeller in air and with entrained water, in kg·m^2 (for controllable pitch propellers both the values at full pitch and at zero pitch are to be specified)

   5) damping characteristics, if available and documented

d) natural frequencies with their relevant modes of vibration and the vector sums for the harmonics of the engine excitation

e) estimated torsional vibration stresses in all important elements of the system with particular reference to clearly defined resonance speeds of rotation and continuous operating ranges.

2.2.2 Calculation of nominal alternating torsional stresses

The maximum and minimum values of the alternating torques are to be ascertained for every mass point of the system and for the entire speed range by means of a harmonic synthesis of the alternating stresses due to the forced vibrations from the 1st order up to and including the 15th order for 2-stroke cycle engines, and from the 0,5th order up to and including the 12th order for 4-stroke cycle engines.

In performing this calculation, allowance is to be made for the dampings that exist in the system and for unfavourable conditions (e.g., misfiring in one of the cylinders).

The speed stages is to be selected for the forced vibration calculations in such a way that the transient response can be recorded with sufficient accuracy at various speeds.

The values received from such calculation are to be submitted to the Society for consideration.

The nominal alternating torsional stresses, referred to crankpin and journal, in every mass point which is essential to the assessment, may be taken equal to the values τ_{NC} and τ_{NJ}, in N/mm^2, calculated by the following formulae:

$$\tau_{NC} = \pm \frac{M_{TN}}{W_{PC}} \cdot 10^3$$

$$\tau_{NJ} = \pm \frac{M_{TN}}{W_{PJ}} \cdot 10^3$$

where:

a) For unbored crankpins or journals:

$$W_{PC} = \frac{\pi \cdot d_C^3}{16}$$

$$W_{PC} = \frac{\pi \cdot d_J^3}{16}$$

b) For bored crankpins or journals:

$$W_{PC} = \frac{\pi}{16} \cdot \frac{d_C^4 - d_{BC}^4}{d_C}$$

$$W_{PJ} = \frac{\pi}{16} \cdot \frac{d_J^4 - d_{BJ}^4}{d_C}$$

For the symbols d_C, d_J, d_{BC} and d_{BJ}, see [3.1.1] and Fig 2.

For the calculation of the polar moments of resistance W_{PC} and W_{PJ}, bored crankpins and journals having bore diameter not exceeding 0,3 times the outer diameter of crankpins or journals may be considered as unbored.

Bored crankpins and journals whose bore longitudinal axis does not coincide with the axis of the said crankpins and journals, will be considered by the Society in each case.

The assessment of the proposed crankshaft dimensions is based on the alternating torsional stress which, in conjunction with the associated bending stress, results in the lowest acceptability factor F_A, as specified in [8.1].

Where barred speed ranges are necessary, the alternating torsional stresses within these ranges are to be neglected in the calculation of the above acceptability factor.

Barred speed ranges are to be so arranged that satisfactory operation is possible despite their existence.

There are to be no barred speed ranges for values of the speed ratio $\lambda \geq 0,8$, λ being the ratio between the rotational speed considered and the rotational speed corresponding to the maximum continuous power.

The approval of the proposed crankshaft dimensions will be based on the installation having the lowest value of the above-mentioned acceptability factor.

Thus, for each installation, it is to be ensured by suitable calculation that the nominal alternating torsional stress accepted for the purpose of checking the crankshaft scantlings is not exceeded.

This calculation is to be submitted for assessment to the Society (see Ch 3, Sec 2).

2.2.3 Calculation of alternating torsional stresses in way of fillets and outlet of crankpin oil bore

The calculation of the alternating torsional stresses is to be carried out in way of the crankpin fillet, the journal fillet and the outlet of the crankpin oil bore, as follows:

a) The alternating torsional stress in way of crankpin fillet is to be taken equal to the value τ_C, in N/mm^2, given by the following formula:

$$\tau_C = \pm (\beta_{TC} \cdot \tau_{NC})$$

b) The alternating torsional stress in way of journal fillet is to be taken equal to the value τ_J, in N/mm^2, given by the following formula:

$$\tau_J = \pm (\beta_{TJ} \cdot \tau_{NJ})$$

c) The alternating torsional stress in way of outlet of crankpin oil bore is to be taken equal to the value σ_{TO}, in N/mm^2, given by the following formula:

$$\sigma_{TO} = \pm (\gamma_T \tau_{NC})$$

where:

γ_T, τ_{NC} : As defined in [1.4.1].

3 Calculation of stress concentration factors

3.1 General

3.1.1 The stress concentration factors for bending (β_{BC} and β_{BJ}) are defined as the ratio of the maximum value of the bending stress occurring in the fillets under bending load acting in the central cross-section of a crank, to the value of the nominal alternating bending stress related to the web cross-section.

The value of the above nominal stress is to be determined under the bending moment in the middle of the solid web.

The stress concentration factors for torsion (β_{TC} and β_{TJ}) are defined as the ratio of the maximum value of the torsional stress occurring under torsional load in the fillets to the value of the nominal alternating torsional stress related to the crankpin or journal cross-section, taking account of the relevant bores, if any.

The stress concentration factor for shearing β_{QJ} is defined as the ratio of the maximum value of the shear stress occurring in the journal fillet under bending load to the value of the nominal shear stress related to the web cross-section.

Where the above stress concentration factors cannot be obtained by reliable measurements, their values may be evaluated by means of the formulae in [3.1.2] and [3.1.3], which are applicable to crankpin fillets and journal fillets for solid-forged crankshafts, and to the crankpin fillets only for semi-built crankshafts.

Fig 2 shows the dimensions necessary for the calculation of the above-mentioned stress concentration factors.

For the calculation of stress concentration factors for bending, torsion and shearing, the related dimensions shown in Tab 1 will be applied.

Table 1 : Definitions

Crankpin fillets	Journal fillets
$r_1 = r_C / d_C$	$r_2 = r_J / d_C$
$s = S / d_C$	$s = S / d_C$
$w = W / d_C$	$w = W / d_C$
$b = B / d_C$	$b = B / d_C$
$d_1 = d_{BC} / d_C$	$d_2 = d_{BJ} / d_C$
$t_1 = T_C / d_C$	$t_2 = T_J / d_C$

The values of the stress concentration factors, calculated as follows, are valid for the following ranges of related dimensions for which investigations have been carried out:

$-0,50 \leq s \leq 0,70$

$0,20 \leq w \leq 0,80$

$1,20 \leq b \leq 2,20$

$0,03 \leq r_1 \leq 0,13$

$0,03 \leq r_2 \leq 0,13$

$0 \leq d_1 \leq 0,80$

$0 \leq d_2 \leq 0,80$

The factor f (t,s), which accounts for the influence of a recess in the web in way of the crankpin and journal fillets, is valid if the related dimensions t_1 and t_2 meet the following conditions:

$t_1 \leq r_1 \qquad t_2 \leq r_2$

and is to be applied for the values of the related dimension s within the range:

$-0,30 \leq s \leq 0,50$

3.1.2 Crankpin fillets

a) The value of the stress concentration factor for bending β_{BC} may be calculated by the following formula:

$$\beta_{BC} = 2,6914\ f_1(s,w)\ .\ f_1(w)\ .\ f_1(b)\ .\ f_1(r_1)\ .\ f_1(d_1)\ .\ f_1(d_2)\ .\ f_1(t,s)$$

where:

$f_1(s,w)$: $-4,1883 + 29,2004\ w - 77,5925\ w^2 + 91,9454\ w^3 - 40,0416\ w^4 + (1-s)\ (9,5440 - 58,3480\ w + 159,3415\ w^2 - 192,5846\ w^3 + 85,2916\ w^4) + (1-s)^2\ (-3,8399 + 25,0444\ w - 70,5571\ w^2 + 87,0328\ w^3 - 39,1832\ w^4)$

$f_1(w)$: $2,1790\ w^{0,7171}$

$f_1(b)$: $0,6840 - 0,0077\ b + 0,1473\ b^2$

$f_1(r_1)$: $0,2081\ r_1^{-0,5231}$

$f_1(d_1)$: $0,9978 + 0,3145\ d_1 - 1,524\ d_1^2 + 2,4147\ d_1^3$

$f_1(d_2)$: $0,9993 + 0,27\ d_2 - 1,0211\ d_2^2 + 0,5306\ d_2^3$

$f\ (t,s)$: $1 + (t_1 + t_2)\ (1,8 + 3,2\ s)$

b) The value of the stress concentration factor for torsion β_{TC} may be calculated by the following formula:

$$\beta_{TC} = 0,8\ f_2(r_1,s) \cdot f_2(b) \cdot f_2(w)$$

where:

$f_2(r_1,s)$: r_1^x with $x = -0,322 + 0,1015\ (1-s)$

$f_2(b)$: $7,8955 - 10,654\ b + 5,3482\ b^2 - 0,857\ b^3$

$f_2(w)$: $w^{-0,145}$

3.1.3 Journal fillets

a) The value of the stress concentration factor for bending β_{BJ} may be calculated by the following formula:

$$\beta_{BJ} = 2,7146\ f_3(s,w) \cdot f_3(w) \cdot f_3(b) \cdot f_3(r_2) \cdot f_3(d_1) \cdot f_3(d_2) \cdot f\ (t,s)$$

where:

$f_3(s,w)$: $-1,7625 + 2,9821\ w - 1,5276\ w^2 + (1-s)\ (5,1169 - 5,8089\ w + 3,1391\ w^2) + (1-s)^2\ (-2,1567 + 2,3297\ w - 1,2952\ w^2)$

$f_3(w)$: $2,2422\ w^{0,7548}$

$f_3(b)$: $0,5616 + 0,1197\ b + 0,1176\ b^2$

$f_3(r_2)$: $0,1908\ r_2^{-0,5568}$

$f_3(d_1)$: $1,0022 - 0,1903\ d_1 + 0,0073\ d_1^2$

$f_3(d_2)$: $1,0012 - 0,6441\ d_2 + 1,2265\ d_2^2$

$f\ (t,s)$: $1 + (t_1 + t_2)\ (1,8 + 3,2\ s)$

b) The value of the stress concentration factor for shearing β_{QJ} may be calculated by the following formula:

$$\beta_{QJ} = 3,0128\ f_4(s) \cdot f_4(w) \cdot f_4(b) \cdot f_4(r_2) \cdot f_4(d_1) \cdot f\ (t,s)$$

where:

$f_4(s)$: $0,4368 + 2,1630\ (1-s) - 1,5212\ (1-s)^2$

$f_4(w)$: $\dfrac{w}{0,0637 + 0,9369 \cdot w}$

$f_4(b)$: $-0,5 + b$

$f_4(r_2)$: $0,5331\ r_2^{-0,2038}$

$f_4(d_1)$: $0,9937 - 1,1949\ d_1 + 1,7373\ d_1^2$

$f\ (t,s)$: $1 + (t_1 + t_2)\ (1,8 + 3,2\ s)$

c) The value of the stress concentration factor for torsion β_{TJ} may be calculated by the following formulae:

- where $d_J = d_C$ and $r_J = r_C$:

  $\beta_{TJ} = \beta_{TC}$

- where $d_J \neq d_C$ and/or $r_J \neq r_C$:

  $\beta_{TJ} = 0,8\ f_2(r_1,s) \cdot f_2(b) \cdot f_2(w)$

  and $f_2(r_1,s)$, $f_2(b)$ and $f_2(w)$ are to be determined in accordance with [3.1.2], but taking $r_1 = r_J / d_J$ instead of $r_1 = r_C / d_C$ for the calculation of $f_2(r_1,s)$.

3.1.4 Outlet of crankpin oil bore

The value of the stress concentration factors for bending γ_B and torsion γ_T may be calculated by the following formulae:

$\gamma_B = 3 - 5,88\ d_{OB} + 34,6\ d_{OB}^2$

$\gamma_T = 4 - 6\ d_{OB} + 30\ d_{OB}^2$

with d_{OB} defined in [1.4.1].

4 Additional bending stresses

4.1

4.1.1 In addition to the alternating bending stresses in fillets (see [2.1.3]), further bending stresses due to misalignment, bedplate deformation and axial and bending vibrations are also to be considered.

The values of such additional bending stresses may be taken equal to the values $\sigma_{B,ADD}$, in N/mm², as shown in Tab 2.

Table 2 : Additional bending stresses

Type of engine	$\sigma_{B,ADD}$, in N/mm²
Crosshead engine	± 30
Trunk piston engine	± 10

5 Calculation of the equivalent alternating stress

5.1 General

5.1.1 The equivalent alternating stress is to be calculated for the crankpin fillet, the journal fillet as well as for the crankpin outlet of oil bore.

For this calculation the theory of constant energy of distortion (Von Mises's criterion) is to be used.

Here it is assumed that the maximum alternating bending stresses and maximum alternating torsional stresses within a crankshaft occur simultaneously and at the same point.

5.2 Equivalent alternating stresses

5.2.1 The equivalent alternating stresses are to be taken as the values σ'_E, σ''_E and σ'''_E calculated according to the following formulae:

a) The equivalent alternating stress in way of the crankpin fillet is to be taken equal to the value σ'_E, in N/mm², calculated by the following formula:

$$\sigma'_E = \pm[(\sigma_{BC} + \sigma_{B,ADD})^2 + 3\tau_C^2]^{0,5}$$

b) The equivalent alternating stress in way of the journal fillet is to be taken equal to the value σ''_E, in N/mm², calculated by the following formula:

$$\sigma''_E = \pm[(\sigma_{BJ} + \sigma_{B,ADD})^2 + 3\tau_J^2]^{0,5}$$

c) The equivalent alternating stress in way of the crankpin outlet of oil bore is to be taken equal to the value σ'''_E, in N/mm², calculated by the following formula:

$$\sigma'''_E = \pm\frac{1}{3}\sigma_{BO}\left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\gamma_T\tau_{NC}}{\sigma_{BO}}\right)^2}\right]$$

6 Calculation of the fatigue strength

6.1

6.1.1 The fatigue strength is to be understood as that value of alternating bending stress which a crankshaft can permanently withstand at the most highly stressed points of the fillets between webs and pins and at the crankpin oil bore outlets.

Where the fatigue strength for a crankshaft cannot be ascertained by reliable measurements, it may be taken equal to the values $\sigma'_{F,ALL}$, $\sigma''_{F,ALL}$ and $\sigma'''_{F,ALL}$ evaluated by means of the following formulae:

a) The value of the allowable alternating bending fatigue strength in way of the crankpin fillet may be taken equal to the value $\sigma'_{F,ALL}$, in N/mm², calculated by the following formula:

$$\sigma'_{F,ALL} = \pm\ KR'_m(0,264 + 1,073\,d_C^{-0,2} + R''_m + R'''_m r_C^{-0,5})$$

where:

K : Factor for different types of forged and cast steel crankshafts without surface treatment of pins, whose value may be taken as follows:

- 1,05 for continuous grain flow forged or drop-forged steel crankshafts
- 1,00 for free form forged steel crankshafts
- 0,93 for cast steel crankshafts

R'_m : $0,42 \cdot R_m + 39,3$

R''_m : $\dfrac{785 - R_m}{4900}$

R'''_m : $196 / R_m$

b) The value of the allowable alternating bending fatigue strength in way of the journal fillet may be taken equal to the value $\sigma''_{F,.ALL}$, in N/mm², calculated by the following formula:

$$\sigma''_{F,ALL} = \pm\ KR'_m(0,264 + 1,073\,d_J^{-0,2} + R''_m + R'''_m r_J^{-0,5})$$

c) The value of the allowable alternating bending fatigue strength in way of the crankpin outlet of oil bore may be taken equal to the value $\sigma'''_{F,ALL}$, in N/mm^2, calculated by the following formula:

$$\sigma'''_{F,ALL} = \pm K R'_m [0,264 + 1,073 d_c^{-0,2} + R''_m + R'''_m (d_{OB}/2)^{-0,5}]$$

For calculation of $\sigma'_{F,ALL}$ and $\sigma''_{F,ALL}$, the values of r_C and r_J are not to be taken less than 2 mm.

Where results of the fatigue tests conducted on full size crank throws or crankshafts whose pins have been subjected to surface treatment are not available, the factor K for crankshafts without surface treatment of pins is to be used.

In all cases the experimental values of fatigue strength carried out with full size crank throws or crankshafts is to be submitted to the Society for consideration.

The survival probability for fatigue strength values derived from testing is to be to the satisfaction of the Society and in principle not less than 80%.

7 Calculation of shrink-fit of semi-built crankshafts

7.1 General

7.1.1 Considering the radius of the transition r_J from the journal diameter d_J to the shrink diameter d_S, both the following equations are to be respected:

$r_J \geq 0,015\ d_J$

$r_J \geq 0,5\ (d_S - d_J)$

The actual oversize h of the shrink-fit must be within the limits h_{MIN} and h_{MAX} calculated in accordance with [7.2] and [7.3] or according to recognized standards.

7.2 Minimum required oversize of shrink-fit

7.2.1 The minimum oversize required for the shrink-fit is determined by the greater of the values calculated in accordance with [7.2.2] and [7.2.3].

7.2.2 The value of the minimum required oversize of the shrink-fit h_{MIN}, in mm, is to be not less than that calculated by the following formula for the crank throw with the absolute maximum torque $M_{T,MAX}$.

The above torque $M_{T,MAX}$, in N·m, corresponds to the maximum value of the torque for the various mass points of the crankshaft.

$$h_{MIN} = \frac{4 \cdot 10^3}{\pi \cdot \mu} \cdot \frac{s_F \cdot M_{T,MAX}}{E_W \cdot d_S \cdot L_S} \cdot f(Z)$$

where:

s_F : Safety factor against slipping; in no case is a value less than 2 to be taken

μ : Coefficient for static friction between the journal and web surfaces, to be taken equal to 0,20, if $L_S / d_S \geq 0,40$

$f(Z)$: $\dfrac{1 - Z_A^2 \cdot Z_S^2}{(1 - Z_A^2) \cdot (1 - Z_S^2)}$

Z_A : d_S / D_E

Z_S : d_{BJ} / d_S

7.2.3 In addition to the provisions of [7.2.2], the minimum required oversize value h_{MIN}, in mm, is not to be less than that calculated according to the following formula:

$$h_{MIN} = \frac{R_{S,MIN} \cdot d_S}{E_W}$$

7.3 Maximum permissible oversize of shrink-fit

7.3.1 The value of the maximum permissible oversize of shrink-fit is not to be exceeded the value h_{MAX}, in mm, calculated in accordance with the following formula:

$$h_{MAX} = \frac{R_{S,MIN} \cdot d_S}{E_W} + \frac{0,8 d_S}{1000}$$

This condition concerning the maximum permissible oversize serves to restrict the shrinkage induced mean stress in the journal fillet.

8 Acceptability criteria

8.1

8.1.1 In order for the proposed crankshaft scantlings to be acceptable, the equivalent alternating stresses, calculated both at crankpin and journal fillets, as well as at the crankpin outlet of oil bore, are to be such as to satisfy the following conditions:

$$Q_1 = \frac{\sigma'_{F,ALL}}{\sigma'_E} \geq 1,15$$

$$Q_2 = \frac{\sigma''_{F,ALL}}{\sigma''_E} \geq 1,15$$

$$Q_3 = \frac{\sigma'''_{F,ALL}}{\sigma'''_E} \geq 1,15$$

APPENDIX 3 REQUIREMENTS FOR DESIGN OF PRESSURE VESSELS

1 Design and construction - Scantlings of pressure parts

1.1 General

1.1.1 Application

a) In general, the formulae in the present Article do not take into account additional stresses imposed by effects other than pressure, such as stresses deriving from the static and dynamic weight of the pressure vessel and its content, external loads from connecting equipment and foundations, etc. For the purpose of the Rules, these additional loads may be neglected, provided it can reasonably be presumed that the actual average stresses of the vessel, considering all these additional loads, would not increase more than 10% with respect to the stresses calculated by the formulae in this Article.

b) Where it is necessary to take into account additional stresses, such as dynamic loads, the Society reserves the right to ask for additional requirements on a case-by-case basis.

c) A calculation shall be submitted for pressure vessels located outside pressure hull, taking into account at least situations where external pressure is maximum and internal one is minimum, and external pressure is minimum and internal one is maximum. This calculation is not necessary when:

- pressure vessel is metallic, and
- internal design pressure is more than external maximum pressure, and
- pressure vessel is hull is cylindrical with convex heads, or
- justification accepted by the Society.

1.1.2 Alternative requirements

When pressure parts are of an irregular shape, such as to make it impossible to check the scantlings by applying the formulae of this Article, the approval is to be based on other means, such as burst and/or deformation tests on a prototype or by another method agreed upon between the Manufacturer and the Society.

1.2 Materials

1.2.1 Materials for high temperatures

a) Materials for pressure parts having a design temperature exceeding the ambient temperature are to be selected by the Manufacturer and to have mechanical and metallurgical properties adequate for the design temperature. Their allowable stress limits are to be determined as a function of the temperature, as per [1.3.2].

b) When the design temperature of pressure parts exceeds 400°C, alloy steels are to be used. Other materials are subject of special consideration by the Society.

1.2.2 Materials for low temperatures

Materials for pressure parts having a design temperature below the ambient temperature are to have notch toughness properties suitable for the design temperature.

1.2.3 Cast iron

Cast iron is not to be used for:

a) class 1 and class 2 pressure vessels

b) class 3 pressure vessels with design pressure $p > 0,7$ MPa or product $p \cdot V > 1000$, where V is the internal volume of the pressure vessel in litres

c) Bolted covers and closures of pressure vessels having a design pressure $p > 1$ MPa, except for covers intended for boiler shells, for which [2.2.4] applies.

1.2.4 Valves and fittings for boilers

a) Ductile materials are to be used for valves and fittings intended to be mounted on boilers. The material is to have mechanical and metallurgical characteristics suitable for the design temperature and for the and other loads imposed during the operation.

b) Grey cast iron is not to be used for valves and fittings which are subject to dynamic loads, such as safety valves and blow-down valves, and in general for fittings and accessories having design pressure p exceeding 0,3 MPa and design temperature T exceeding 220°C.

c) Spheroidal cast iron is not to be used for parts having a design temperature T exceeding 350°C.

d) Bronze is not to be used for parts having design temperature T exceeding 220°C for normal bronzes and 260°C for bronzes suitable for high temperatures. Copper and aluminium brass are not to be used for fittings with design temperature T above 200°C and copper-nickel fittings with design temperature T exceeding 300°C.

1.2.5 Alternative materials

In the case of boilers or pressure vessels constructed in accordance with one of the standards considered acceptable by the Society as per Ch 3, Sec 3, [1.5], the material specifications are to be in compliance with the requirements of the standard used.

1.3 Permissible stresses

1.3.1 The permissible stresses K, in N/mm², for steels, to be used in the formulae of this Article, may be determined from Tab 1, Tab 2, Tab 3 and Tab 4, where R_m is the ultimate strength of the material, in N/mm². For intermediate values of the temperature, the value of K is to be obtained by linear interpolation.

Table 1 : Permissible stresses K for carbon steels intended for boilers

Carbon steel	Steel thickness	Values of K (N/mm²) for T (°C) equal to:							
		≤ 50°	100	150	200	250	300	350	400
R_m = 360 N/mm² Grade HA	t ≤ 15 mm	133	109	107	105	94	77	73	72
	15 mm < t ≤ 40 mm	128	106	105	101	90	77	73	72
	40 mm < t ≤ 60 mm	122	101	99	95	88	77	73	72
R_m = 360 N/mm² Grades HB, HD	t ≤ 15 mm	133	127	116	103	79	79	72	69
	15 mm < t ≤ 40 mm	133	122	114	102	79	79	72	69
	40 mm < t ≤ 60 mm	133	112	107	99	79	79	72	69
R_m = 410 N/mm² Grade HA	t ≤ 15 mm	152	132	130	126	112	94	89	86
	15 mm < t ≤ 40 mm	147	131	124	119	107	94	89	86
	40 mm < t ≤ 60 mm	141	120	117	113	105	94	89	86
R_m = 410 N/mm² Grades HB, HD	t ≤ 15 mm	152	147	135	121	107	95	88	84
	15 mm < t ≤ 40 mm	152	142	133	120	107	95	88	84
	40 mm < t ≤ 60 mm	152	134	127	117	107	95	88	84
R_m = 460 N/mm² Grades HB, HD	t ≤ 15 mm	170	164	154	139	124	111	104	99
	15 mm < t ≤ 40 mm	169	162	151	137	124	111	104	99
	40 mm < t ≤ 60 mm	162	157	147	136	124	111	104	99
R_m = 510 N/mm² Grades HB, HD	t ≤ 60 mm	170	170	169	159	147	134	125	112

Table 2 : Permissible stresses K for carbon steels intended for other pressure vessels

Carbon steel	Steel thickness	Values of K (N/mm²) for T (°C) equal to:							
		≤ 50°	100	150	200	250	300	350	400
R_m = 360 N/mm² Grade HA	t ≤ 15 mm	133	117	115	112	100	83	78	77
	15 mm < t ≤ 40 mm	133	114	113	108	96	83	78	77
	40 mm < t ≤ 60 mm	130	108	105	101	94	83	78	77
R_m = 360 N/mm² Grades HB, HD	t ≤ 15 mm	133	133	123	110	97	85	77	73
	15 mm < t ≤ 40 mm	133	131	122	109	97	85	77	73
	40 mm < t ≤ 60 mm	133	119	115	106	97	85	77	73
R_m = 410 N/mm² Grade HA	t ≤ 15 mm	152	141	139	134	120	100	95	92
	15 mm < t ≤40 mm	152	134	132	127	114	100	95	92
	40 mm < t ≤ 60 mm	150	128	121	112	112	100	95	92
R_m = 410 N/mm² Grades HB, HD	t ≤ 15 mm	152	152	144	129	114	101	94	89
	15 mm < t ≤ 40 mm	152	152	142	128	114	101	94	89
	40 mm < t ≤ 60 mm	152	143	139	125	114	101	94	89
R_m = 460 N/mm² Grades HB, HD	t ≤ 15 mm	170	170	165	149	132	118	111	105
	15 mm < t ≤ 40 mm	170	170	161	147	132	118	111	105
	40 mm < t ≤ 60 mm	170	167	157	145	132	118	111	105
R_m = 510 N/mm² Grades HB, HD	t ≤ 60 mm	189	189	180	170	157	143	133	120

Table 3 : Permissible stresses K for alloy steels intended for boilers

Alloy steel	Steel thickness	Values of K (N/mm²) for T (°C) equal to:														
		≤ 50	100	150	200	250	300	350	400	450	475	500	525	550	575	600
0,3Mo	t ≤ 60 mm	159	153	143	134	125	106	100	94	91	89	87	36			
1Cr 0,5Mo	t ≤ 60 mm	167	167	157	144	137	128	119	112	106	104	103	55	31	19	
2,25Cr 1Mo **(1)**	t ≤ 60 mm	170	167	157	147	144	137	131	125	119	115	112	61	41	30	22
2,25Cr 1Mo **(2)**	t ≤ 60 mm	170	167	164	161	159	147	141	130	128	125	122	61	41	30	22

(1) Normalised and tempered
(2) Normalised and tempered or quenched and tempered.

Table 4 : Permissible stresses K for alloy steels intended for other pressure vessels

Alloy steel	Steel thickness	Values of K (N/mm²) for T (°C) equal to:														
		≤ 50	100	150	200	250	300	350	400	450	475	500	525	550	575	600
0,3Mo	t ≤ 60 mm	159	159	153	143	133	113	107	100	97	95	93	38			
1Cr 0,5Mo	t ≤ 60 mm	167	167	167	154	146	137	127	119	113	111	110	59	33	20	
2,25Cr 1Mo **(1)**	t ≤ 60 mm	183	174	167	157	154	146	140	133	127	123	119	65	44	32	23
2,25Cr 1Mo **(2)**	t ≤ 60 mm	174	174	174	172	170	157	150	139	137	133	130	65	44	32	23

(1) Normalised and tempered
(2) Normalised and tempered or quenched and tempered.

1.3.2 Direct determination of permissible stress

The permissible stresses K, where not otherwise specified, may be taken as indicated below:

a) Steel

The permissible stress is to be the minimum of the values obtained by the following formulae:

$$K = \frac{R_{m,20}}{2,7}$$

$$K = \frac{R_{S,MIN,T}}{A}$$

$$K = \frac{S_A}{A}$$

where:

$R_{m,20}$: Minimum tensile strength at ambient temperature (20°C), in N/mm²

$R_{S,MIN,T}$: Minimum between R_{eH} and $R_{p\ 0,2}$ at the design temperature T, in N/mm²

S_A : Average stress to produce creep rupture in 100000 hours, in N/mm², at the design temperature T

A : Safety factor taken as follows, when reliability of $R_{S,MIN,T}$ and S_A values are proved to the Society's satisfaction:

- 1,6 for boilers and other steam generators
- 1,5 for other pressure vessels
- specially considered by the Society if average stress to produce creep rupture in more than 100000 hours is used instead of S_A.

In the case of steel castings, the permissible stress K calculated as above is to be decreased by 20%. Where steel castings are subjected to non-destructive tests, a smaller reduction up to 10% may be taken into consideration by the Society.

b) Spheroidal cast iron

The permissible stress is be to the minimum of the values obtained by the following formulae:

$$K = \frac{R_{m,20}}{4,8}$$

$$K = \frac{R_{S,MIN,T}}{3}$$

c) Grey cast iron

The permissible stress is obtained by the following formula:

$$K = \frac{R_{m,20}}{10}$$

d) Copper alloys

The permissible stress is obtained by the following formula:

$$K = \frac{R_{m,T}}{4}$$

where:

$R_{m,T}$: Minimum tensile strength at the design temperature T, in N/mm².

e) Aluminium and aluminium alloys

The permissible stress is to be the minimum of the values obtained by the following formulae:

$$K = \frac{R_{m,T}}{4}$$

$$K = \frac{R_{e,H}}{1,5}$$

where:

$R_{e,H}$: Minimum yield stress, in N/mm².

f) Additional conditions

- In special cases, the Society reserves the right to apply values of permissible stress K lower than those specified above, in particular for lifting appliance devices and steering gear devices.
- In the case of boilers or other steam generators, the permissible stress K is not to exceed 170 N/mm^2.
- For materials other than those listed above the permissible stress is to be agreed with the Society on a case by case basis.

1.4 Cylindrical, spherical and conical shells with circular cross-sections subject to internal pressure

1.4.1 Cylindrical shell thickness

a) The minimum thickness of cylindrical, spherical and conical shells with circular cross-sections is not to be less than the value t, in mm, calculated by one of the following formulae, as appropriate. Cylindrical tube plates pierced by a great number of tube holes are to have thickness calculated by the applicable formulae in [1.4.3], [1.4.4], [1.4.5] and [1.9.2].

b) The thicknesses obtained by the formulae in [1.4.3], [1.4.4] and [1.4.5] are "net" thicknesses, as they do not include any corrosion allowance. The thickness obtained by the above formulae is to be increased by 0,75 mm. See also [1.4.7].

1.4.2 Efficiency

a) The values of efficiency e to be used in the formulae in [1.4.3], [1.4.4] and [1.4.5] are indicated in Tab 5.

b) The manufacturer may propose a factor e lower than those indicated in Tab 5 where consistent with the factor used in the formulae of [1.4.3], [1.4.4] and [1.4.5] and with the provisions of specific requirements according to class as per [3.9], [3.10] or [3.11]. The proposed efficiency factor is to be agreed by the Society.

Table 5 : Efficiency e of unpierced shells

Case	e
Seamless shells	1,00
Shells of class 1 vessels **(1)**	1,00
Shells of class 2 vessels (with partial radiographic examination of butt-joints)	0,85
Shells of class 2 vessels with actual thickness less than or equal to 15 mm (without radiographic examination of butt-joints)	0,75
(1) In special cases the Society reserves the right to take a factor e < 1, depending on the welding procedure adopted for the welded joint.	

1.4.3 Cylindrical shells

a) When the ratio external diameter/inside diameter is equal to or less than 1,5, the minimum thickness of cylindrical shells is given by the following formula:

$$t = \frac{pD}{(2K - p)e}$$

where:

p : Design pressure, in MPa

D : Inside diameter of vessel, in mm

K : Permissible stress, in N/mm^2, obtained as specified in [1.3]

e : Efficiency of welded joint, the value of which is given in [1.4.2].

b) The minimum thickness of shells having ratio external diameter/inside diameter exceeding 1,5 is subject of special consideration.

1.4.4 Spherical shells

a) When the ratio external diameter/inside diameter is equal to or less than 1,5, the minimum thickness of spherical shells is given by the following formula:

$$t = \frac{pD}{(4K - p)e}$$

For the meaning of the symbols, see [1.4.3].

b) The minimum thickness of shells having ratio external diameter/inside diameter exceeding 1,5 is subject of special consideration.

1.4.5 Conical shells

a) The following formula applies to conical shells of thickness not exceeding 1/6 of the external diameter in way of the large end of the cone:

$$t = \frac{pD}{(2K - p)e \cdot \cos\varphi}$$

For the meaning of the symbols, see [1.4.3].

D is measured in way of the large end of the cone and φ is the angle of slope of the conical section of the shell to the pressure vessel axis (see Fig 1). When φ exceeds 75°, the shell thickness is to be taken as required for flat heads, see [1.7].

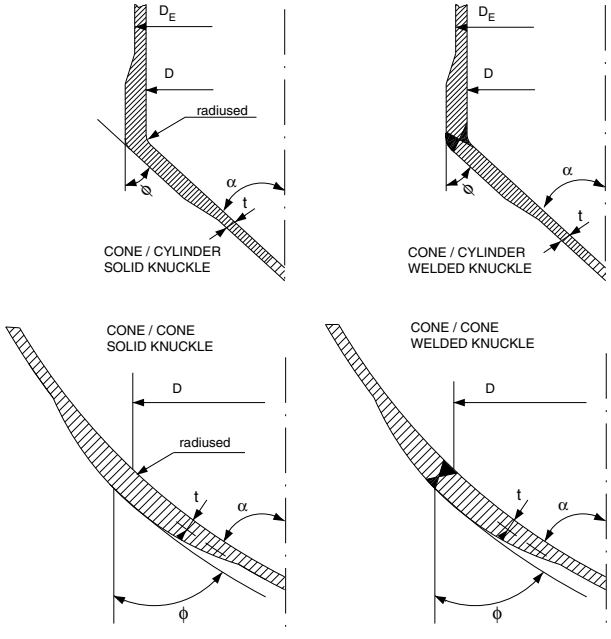
b) The minimum thickness of shells having thickness exceeding 1/6 of the external diameter in way of the large end of the cone is subject of special consideration.

c) Conical shells may be made of several ring sections of decreasing thickness. The minimum thickness of each section is to be obtained by the formula in a) using for D the maximum diameter of the considered section.

d) In general, the junction with a sharp angle between the conical shell and the cylindrical or other conical shell, having different angle of slope, is not allowed if the angle of the generating line of the shells to be assembled exceeds 30°.

e) The shell thickness in way of knuckles is subject of special consideration by the Society.

Figure 1 : Conic shells



1.4.6 Minimum thickness of shells

Irrespective of the value calculated by the formulae in [1.4.3], [1.4.4] or [1.4.5], the thickness t of shells is not to be less than one of the following values, as applicable:

- for pressure vessels: t = 3 + D/1500 mm
- for unpierced plates of boilers: t = 6,0 mm
- for boiler cylindrical tube plates: t = 9,5 mm.

No corrosion allowance needs to be added to the above values.

1.4.7 Corrosion allowance

The Society reserves the right to increase the corrosion allowance value in the case of vessels exposed to particular accelerating corrosion conditions. The Society may also consider the reduction of this factor where particular measures are taken to effectively reduce the corrosion rate of the vessel.

1.5 Dished heads subject to pressure on the concave (internal) side

1.5.1 Dished head for boiler headers

Dished heads for boiler headers are to be seamless.

1.5.2 Dished head profile

The following requirements are to be complied with for the determination of the profile of dished heads (see Fig 2, (a) and (b)).

a) Ellipsoidal heads:

$H \geq 0,2\ D$

where:

H : External depth of head, in mm, measured from the start of curvature at the base.

b) Torispherical heads:

$R_{IN} \leq D$

$r_{IN} \geq 0,1\ D$

$r_{IN} \geq 3\ t$

$H \geq 0,18\ D$

where:

R_{IN} : Internal radius of the spherical part, in mm

r_{IN} : Internal knuckle radius, in mm

H : External depth of head calculated by the following formula (see Fig 2 (b)):

$H = R_E - [(R_E - 0,5\ D) \cdot (R_E + 0,5\ D - 2\ r_E)]^{0,5}$

where:

R_E : External radius of the spherical part, in mm

r_E : External knuckle radius, in mm.

1.5.3 Required thickness of solid dished heads

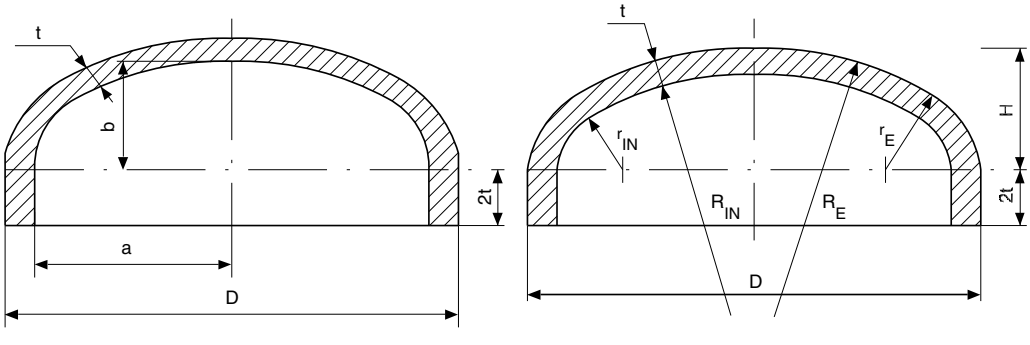
a) The minimum thickness of solid (not pierced) hemispherical, torispherical, or ellipsoidal unstayed dished heads, subject to pressure on the concave (internal) side, is to be not less than the value t, in mm, calculated by the following formula:

$$t = \frac{pDC}{2Ke}$$

where:

C : Shape factor, obtained from the graph in Fig 3, as a function of H/D and t/D.

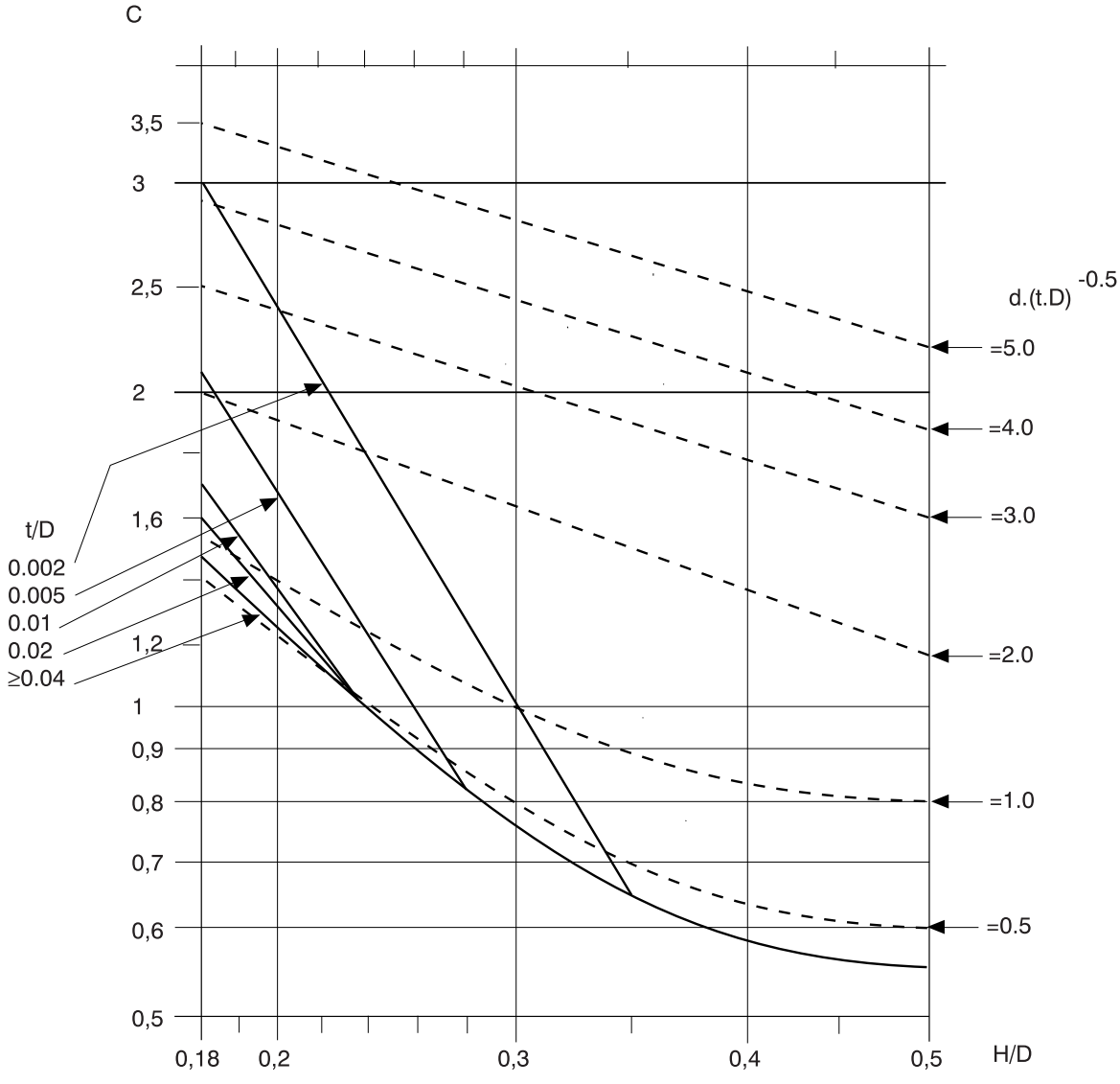
Figure 2 : Dished head profiles



(a) ELLIPSOIDAL HEAD

(b) TORISPHERICAL HEAD

Figure 3 : Shape factor C for dished heads



1.5.4 Composed torispherical heads

a) Torispherical heads may be constructed with welded elements of different thicknesses (see Fig 4).

b) Where a torispherical head is built in two sections, the thickness of the torispherical part is to be obtained by the formula in [1.5.3], while the thickness of the spherical part may be obtained by the formula in [1.4.4].

c) The spherical part may commence at a distance from the knuckle not less than:

$0,5 \cdot (R_{IN} \cdot t)^{0,5}$

where:

R_{IN} : Internal radius of the spherical part, in mm

t : Knuckle thickness, in mm.

1.5.5 Minimum thickness of dished heads

Irrespective of the values calculated in [1.5.2] and [1.5.3], the thickness t of dished heads is not to be less than:

- for normal pressure vessels: $3 + D_E / 1500$ mm
- for boiler pressure vessels: 6 mm.

No corrosion allowance needs to be added to the above values.

Figure 4 : Composed torispherical head

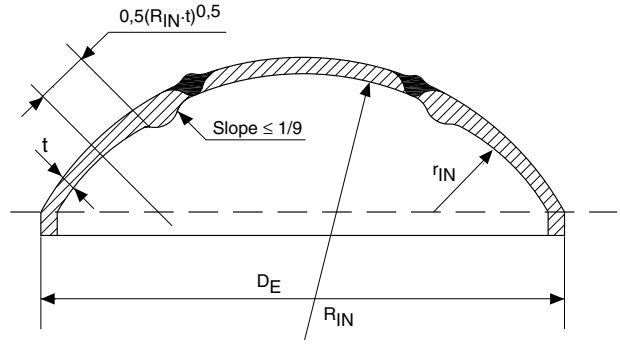
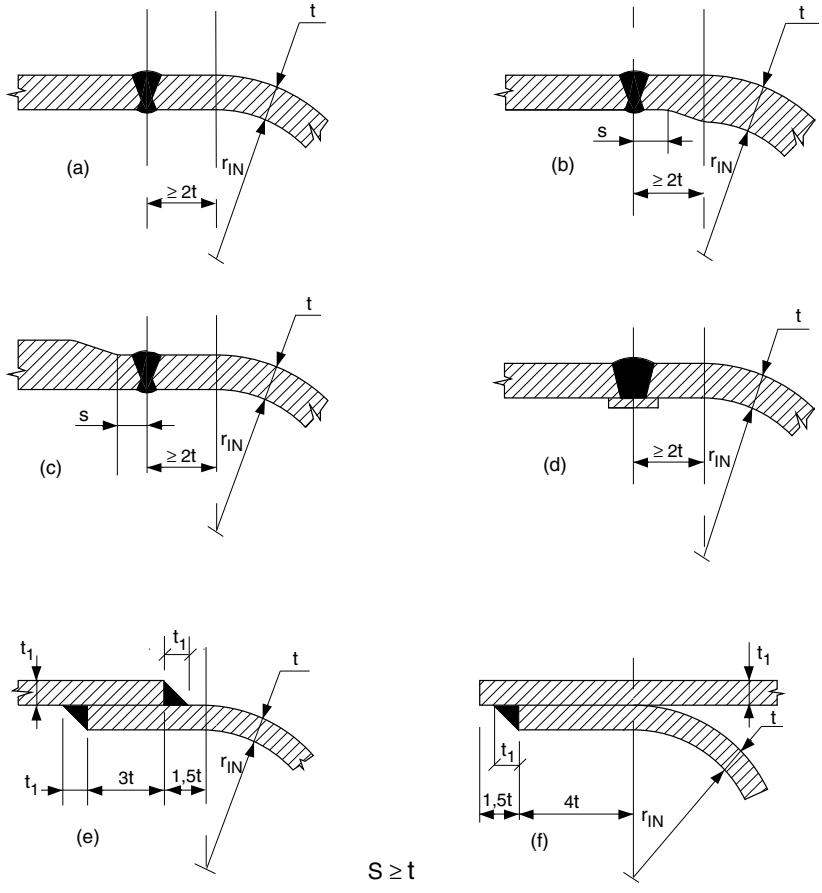


Figure 5 : Typical attachment of dished heads to cylindrical shells



Types shown in (a), (b) and (c) are acceptable for all pressure vessels.

Type shown in (d) is acceptable for class 2 and class 3 pressure vessels.

Types shown in (e) and (f) are acceptable for class 3 pressure vessels only.

1.5.6 Connection of heads to cylindrical shells

The heads are to be provided, at their base, with a cylindrical skirt not less than 2t in length and with a thickness in no case less than the Rule thickness of a cylindrical shell of the same diameter and the same material, calculated by the formula given in [1.4.3] using the same efficiency factor e adopted for calculation of the head thickness.

Fig 5 and Fig 6 show typical admissible attachments of dished ends to cylindrical shells.

In particular, hemispherical heads not provided with the above skirt are to be connected to the cylindrical shell if the latter is thicker than the head, as shown in Fig 5.

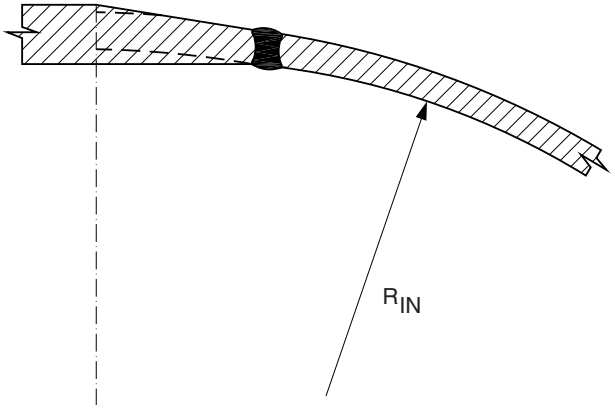
Other types of connections are subject to special consideration by the Society.

1.6 Dished heads subject to pressure on the convex (external) side

1.6.1 The calculation of the minimum thickness is to be performed according to a standard accepted by the Society.

In addition, the thickness of torispherical or ellipsoidal heads under external pressure is no to be less than 1,2 times the thickness required for a head of the same shape subject to internal pressure.

Figure 6 : Connection of hemispherical head to cylindrical shell



1.7 Flat heads

1.7.1 Unstayed flat head minimum thickness

a) The minimum thickness of unstayed flat heads is not to be less than the value t, in mm, calculated by the following formula:

$$t = D\left(\frac{100p}{CK}\right)^{0,5}$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm^2, obtained as specified in [1.3]

D : Diameter of the head, in mm. For circular section heads, the diameter D is to be measured as shown in Fig 7 and Fig 8 for various types of heads. For rectangular section heads, the equivalent value for D may be obtained from the following formula:

$$D = a\left[3,4 - 2,4\left(\frac{a}{b}\right)\right]^{0,5}$$

a and b being the smaller and larger side of the rectangle, respectively, in mm

C : The values given below, depending on the various types of heads shown in Fig 7 and Fig 8:

Fig 7(a) : C = 400 for circular heads

Fig 7(b) : C = 330 for circular heads

Fig 7(c) : C = 350 for circular heads

Fig 7(d) : C = 400 for circular heads and C = 250 for rectangular heads

Fig 7(e) : C = 350 for circular heads and C = 200 for rectangular heads

Fig 7(f) : C = 350 for circular heads

Fig 7(g) : C = 300 for circular heads

Fig 7(h) : C = 350 for circular heads and C = 200 for rectangular heads

Fig 8(i) : C = 350 for circular heads and C = 200 for rectangular heads

Fig 8(j) : C = 200 for circular heads

Fig 8(k) : C = 330 for circular heads

Fig 8(l) : C = 300 for circular heads

Fig 8(m) : C = 300 for circular heads

Fig 8(n) : C = 400 for circular heads

Fig 8(o) : C = value obtained from the following formula, for circular heads:

$$C = \frac{100}{0,3 + \frac{1,9Fh}{pD^3}}$$

where:

h : Radial distance, in mm, from the pitch centre diameter of bolts to the circumference of diameter D, as shown in Fig 8(o)

F : Total bolt load, in N, to be taken as the greater of the following values F_1 and F_2:

$F_1 = 0,785\ D\ p\ (D + m\ b)$

$F_2 = 9,81\ y\ D\ b$

with:

b : Effective half contact width of the gasket, in mm, calculated as follows:

$b = 0,5\ N$ for $N \leq 13$ mm, and

$b = 1,8\ N^{0,5}$ for $N > 13$ mm

where N is the geometric contact width of the gasket, in mm, as indicated in Fig 8(o)

m, y : Adimensional coefficients, whose values are given in Tab 6, depending on the type of gasket.

The adoption of one of the above-mentioned heads is subject to the Society's approval depending upon its use. Types of heads not shown in Fig 7 and Fig 8 are to be the subject of special consideration by the Society.

b) The thickness obtained by the formulae in a) is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1 mm. See also [1.4.7].

Table 6 : Coefficients m and y

Type of gasket	m	y
Self-sealing, metal or rubber (e.g. O-ring)	0	0
Rubber with cotton fabric	10	0,88
Rubber with reinforcing fabric with or without metal wire:		
• 3 layers	18	4,85
• 2 layers	20	6,4
• 1 layer	22	8,2
Synthetic fibre with suitable binders:		
• 3,0 mm thick	16	3,5
• 1,5 mm thick	22	8,2
Organic fibre	14	2,4
Metal spiral lined with synthetic fibre:		
• carbon steel	20	6,4
• stainless steel	24	9,9
Synthetic fibre with plain metal lining:		
• copper	28	14,0
• iron	30	16,8
• stainless steel	30	20,0
Solid metal:		
• copper	38	28,7
• iron	44	39,8
• stainless steel	52	57,5

Figure 7 : Types of unstayed flat heads (1)

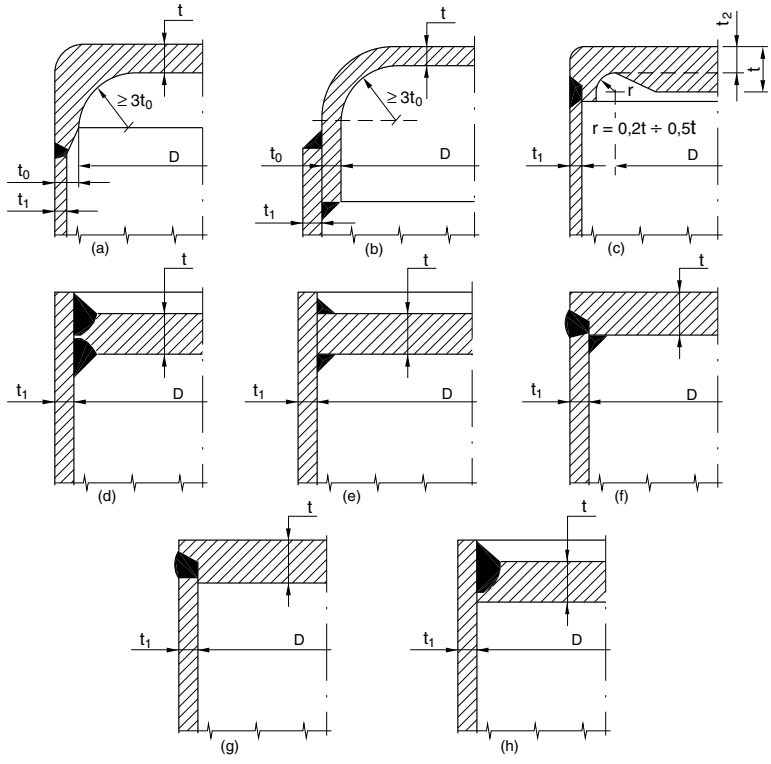
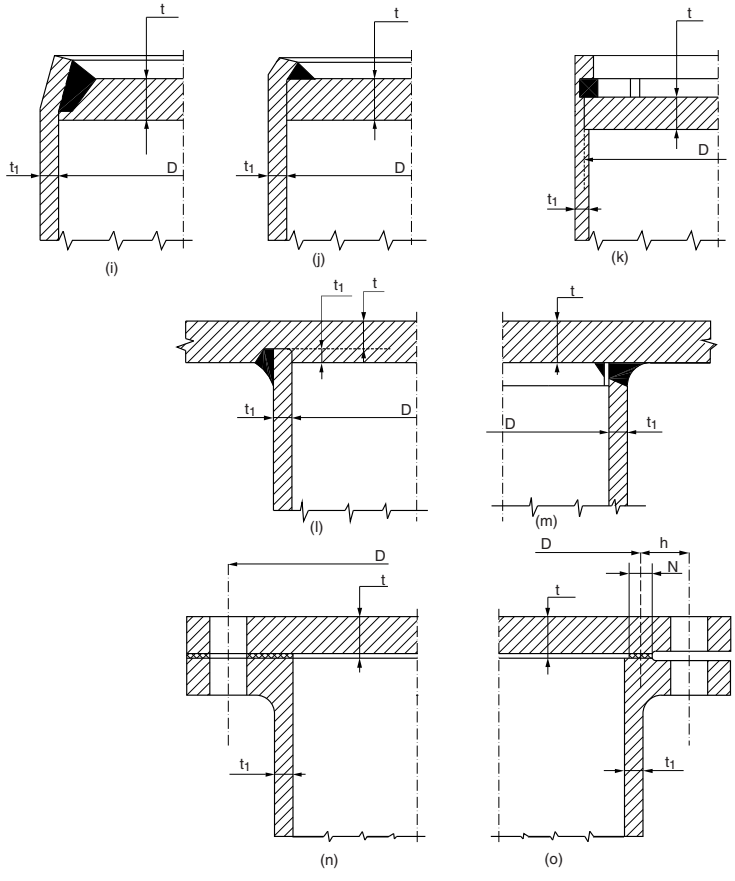


Figure 8 : Types of unstayed flat heads (2)



1.7.2 Stayed flat head minimum thickness

For the minimum thickness of stayed flat heads, see [1.12.3].

1.8 Openings and branches (nozzles)

1.8.1 Nozzles thickness

a) The thickness e_b, in mm, of nozzles attached to shells and headers of boilers is not to be less than:

$$e_b = \frac{d_E}{25} + 2,5$$

where d_E is the outside diameter of nozzle, in mm.

The thickness of the nozzle is, however, to be not less than the thickness required for the piping system attached to the vessel shell calculated at the vessel design pressure, and need not to be greater than the thickness of the shell to which it is connected.

b) The thickness of the nozzle attached to shells and headers of other pressure vessels is not to be less than the thickness required for the piping system attached to the vessel shell calculated at the vessel design pressure, and need not be greater than the thickness of the shell to which it is connected.

c) Where a branch is connected by screwing, the thickness of the nozzle is to be measured at the root of the thread.

1.8.2 Nozzle connection to vessel shell

a) In general, the axis of the nozzle is not to form an angle greater than 15° with the normal to the shell.

b) Fig 30, Fig 31, Fig 32 and Fig 33 show some typical acceptable connections of nozzles to shells. Other types of connections are to be considered by the Society on a case by case basis.

1.8.3 Openings in shells

a) In general, the largest dimensions of the openings in shells are not to exceed:

- for shells up to 1500 mm in diameter D_E:

  1/2 D_E, but not more than 500 mm

- for shells over 1500 mm in diameter D_E:

  1/3 D_E, but not more than 1000 mm,

where D_E is the vessel external diameter, in mm.

Greater values may be considered by the Society on a case by case basis.

b) In general, in oval or elliptical openings the ratio major diameter/minor diameter is not to exceed 2.

1.8.4 Openings compensation in cylindrical shells

a) Compensation methods

For cylindrical shells with openings, the efficiency of the main body is to be satisfied by one of the following methods:

- by increasing the wall thickness of main body compared with that of the cylindrical shell without opening: see Fig 9
- by branches which have been provided with a wall thickness of that required on account of the internal pressure: see Fig 10 and Fig 11
- by reinforcing pads or rings analogous to increasing the wall thickness: see Fig 12 and Fig 13
- by a combination of previous reinforcement.

b) Definitions

Effective lengths ℓ_{rs} required for calculation of efficiency and of compensations is to be taken as:

$$\ell_{rs} = \min(\sqrt{Dt_a}, \ell_{s1})$$

where:

D : Outside diameter, in mm

t_a : Available thickness, in mm

ℓ_{s1} : Transition length, in mm, according to Fig 9 and Fig 10.

Figure 9 : Reinforcement by increasing the wall thickness of the main body with opening

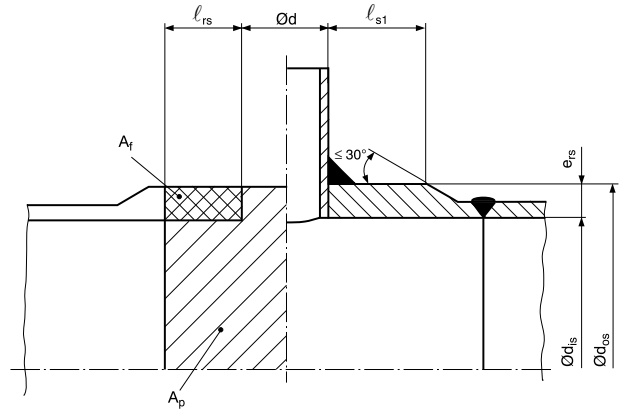


Figure 10 : Reinforcement by set-through and full penetration welded branch

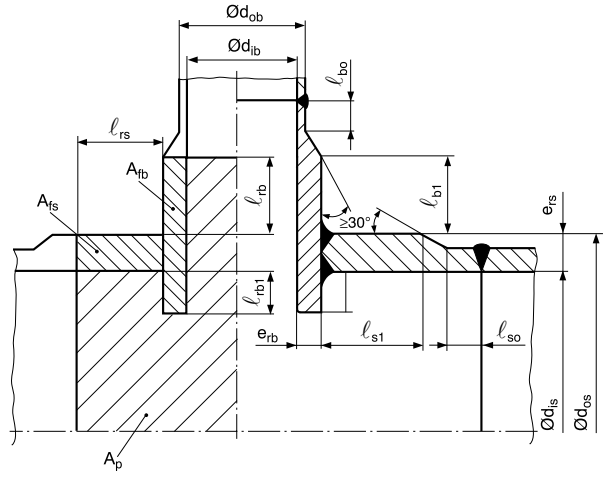


Figure 11 : Reinforcement by welded on branch

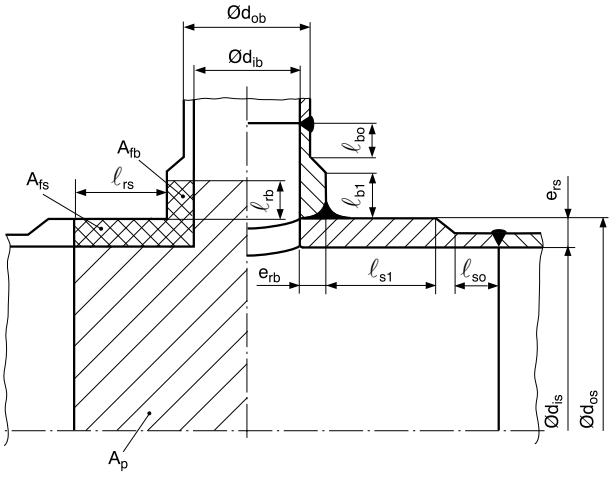
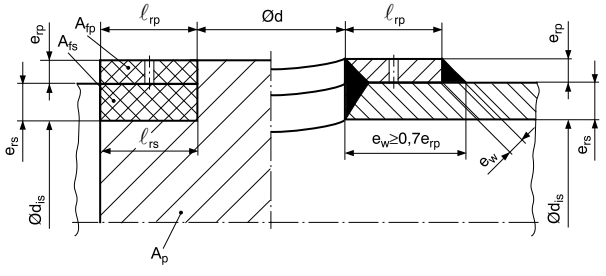


Figure 12 : Opening with reinforcing pad



c) Basic calculation

The required wall thickness without allowance of a cylindrical shell is determined with the following formula (see [1.4.3]):

$$t = \frac{pD}{(2K - p)e}$$

With the available thickness t_a, we obtain the available efficiency e_a and the maximum diameter d_{obmax} of an unreinforced opening when the average stress of the main body is equal to the permissible stress K:

$$e_a = \frac{pD_i}{(2K - p)t_a}$$

$$d_{obmax} = 2\left[\frac{\ell_{rs}}{e_a} - \ell_{rs}\right]$$

where:

D_i : Internal diameter of the main body, in mm.

d) Isolated opening reinforcement

The reinforcement of isolated openings as indicated in Fig 9 to Fig 13 are to be in respect with:

$$\frac{A_p}{A_f} \leq \frac{K}{p} - 0,5$$

where:

K : Permissible stress in the shell, in N/mm^2

A_f : Total area of cross section (wall and branch and pad)

A_p : Total area under pressure p.

In Fig 9 to Fig 13, ℓ_{rs}, ℓ_{rb} and ℓ_{rbi} are effective lengths for calculation of efficiency and compensation, equal to:

- for shell:

$$\ell_{rs} = \min(\sqrt{(D + e_{rs})e_{rs}}, \ell_{s1})$$

- for external branch projection:

$$\ell_{rb} = \min(\sqrt{(d_{ib} + e_{rb})e_{rb}}, \ell_{b1})$$

- for internal branch projection:

$$\ell_{rbi} = \min(0,5\sqrt{(d_{ib} + e_{rb})e_{rb}}, \ell_{b2})$$

e) Condition of isolated openings

- Full case

Adjacent openings are to be treated as isolated openings if the centre distance P_ϕ, in accordance with Fig 16, is not less than:

$$\frac{\left(\frac{d_{ib1}}{2} + e_{rb1}\right)}{\cos\Psi_1} + \frac{\left(\frac{d_{ib2}}{2} + e_{rb2}\right)}{\cos\Psi_2} + 2\sqrt{(d_{is} + e_{rs})e_{rs}}$$

For variable definition see Fig 14 and Fig 15.

- Simplification

  - For openings without branch:

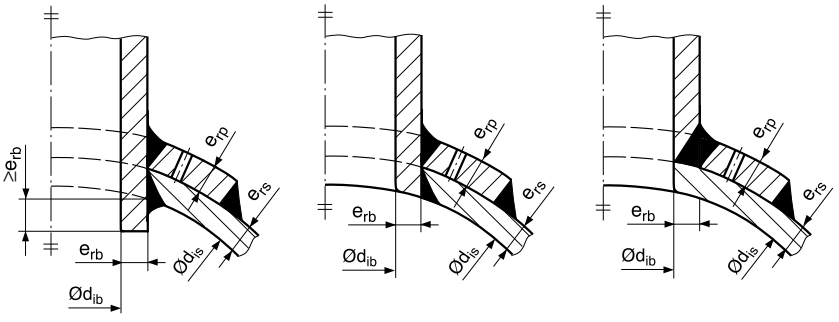
    $e_{rb} = 0$ and $\Psi = 0$

  - For openings with nozzles perpendicular to shell:

    The openings are to be treated as isolated openings if the centre distance P_ϕ in accordance with Fig 16 is not less than:

$$\left(\frac{d_{ib1}}{2} + e_{rb1}\right) + \left(\frac{d_{ib2}}{2} + e_{rb2}\right) + 2\sqrt{(d_{is} + e_{rs})e_{rs}}$$

Figure 13 : Opening with reinforcing pad and full penetration branch



a) set through welded branch b) set in welded branch c) set on welded branch

Figure 14 : Angle definition for cylindrical shell with oblique branch

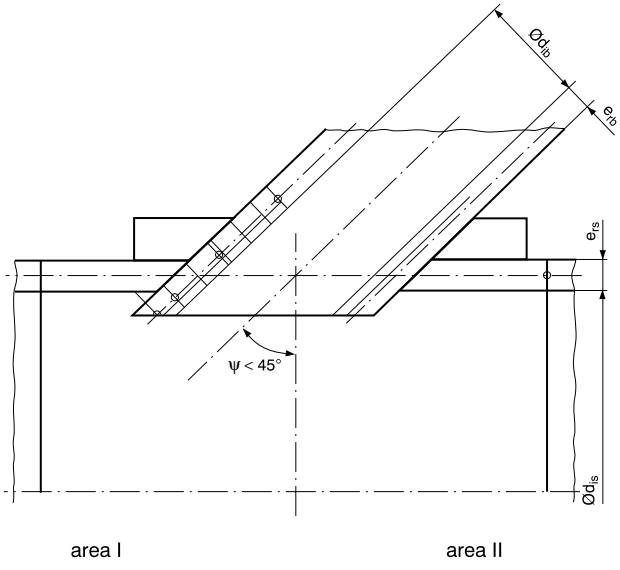
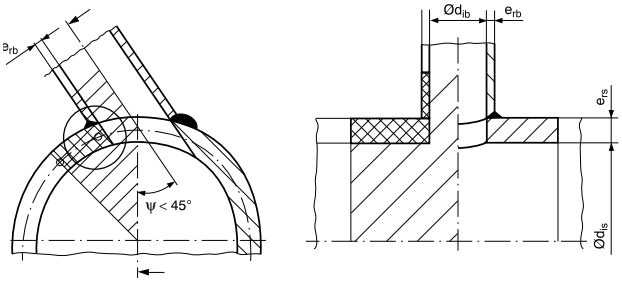


Figure 15 : Angle definition for cylindrical shell with non-radial branch



f) Adjacent openings

Where the condition of isolated openings is not fulfilled, the compensation is to be calculated, using Fig 16, as per the following formula:

$$\frac{A_p}{A_f} \leq \frac{K}{p} - 0,5$$

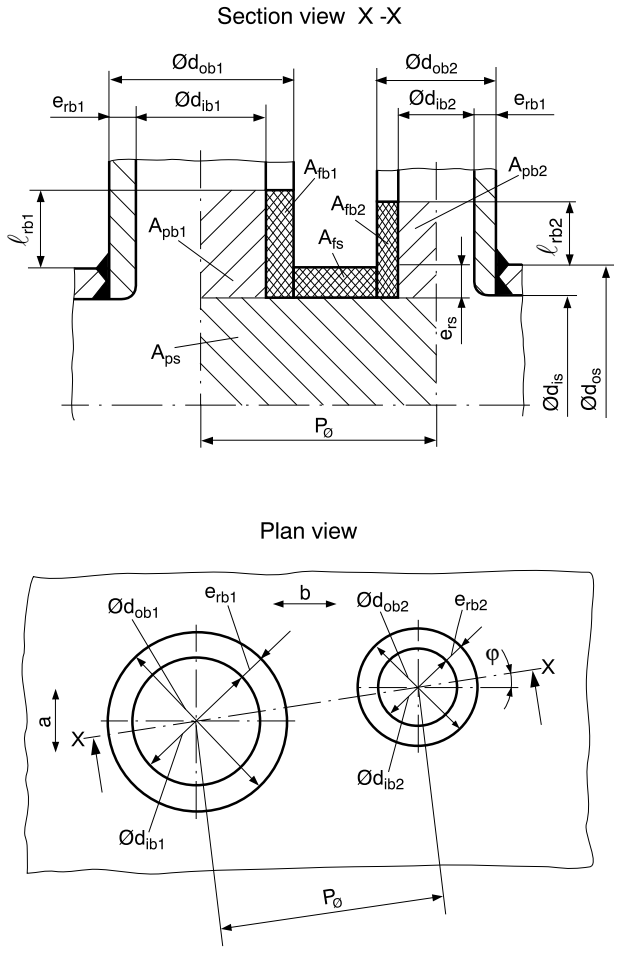
1.8.5 Openings in dished heads

a) The openings in dished heads may be circular, elliptical or oval.

b) The largest diameter of the non-compensated opening is not to exceed one half of the external diameter of the head.

c) The opening is to be so situated that its projection, or its reinforcement projection in the case of compensated openings, is completely contained inside a circle having its centre at the centre of the head and a diameter of 0,8 D, D being the external diameter of the head (see Fig 17). However, a small reinforced opening for drainage may be accepted outside the indicated area.

Figure 16 : Load diagram for cylindrical shell with adjacent branches



a : Circumferential direction
b : Longitudinal direction.

d) In the case of non-compensated openings (for this purpose, flanged openings are also to be considered as non-compensated), the head thickness is not to be less than that calculated by the formula in [1.5.3] using the greatest of the shape factors C obtained from the graph in Fig 3 as a function of:

H / D and t / D, or

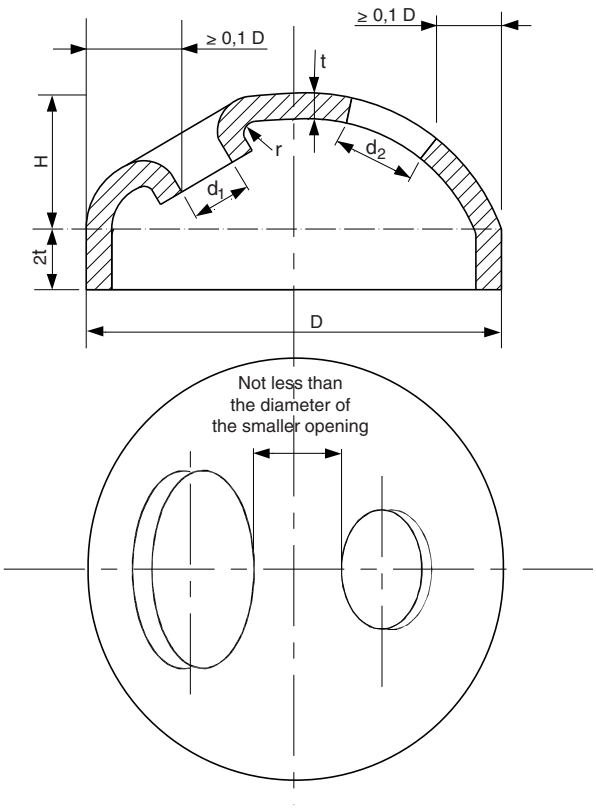
H / D and $d \cdot (t \cdot D)^{-0,5}$,

where d is the diameter of the largest non-compensated opening in the head, in mm. For oval and elliptical openings, d is the width of the opening in way of its major axis.

e) In all cases the diameter D of the head base, the head thickness t and the diameter d of the largest non-compensated opening are to be such as to meet the following requirements:

- the position of non-compensated openings in the heads is to be as shown in Fig 17
- for flanged openings, the radius r of the flanging (see Fig 17) is not to be less than 25 mm
- the thickness of the flanged part may be less than the rule thickness.

Figure 17 : Openings on dished heads



1.8.6 Opening compensation in dished heads

a) Where openings are cut in dished heads and the proposed thickness of the head is less than that calculated by the formula in [1.5.3], the openings are to be compensated.

b) Fig 30, Fig 31, Fig 32 and Fig 33 show typical connections of nozzles and compensating rings.

c) The opening is considered sufficiently compensated when the head thickness t is not less than that calculated in accordance with [1.5.3] and using the shape factor C obtained from the graph in Fig 3, using:

$$\left(d - \frac{A}{t}\right) \cdot (t \cdot D)^{-0,5} \quad \text{instead of} \quad d \cdot (t \cdot D)^{-0,5}$$

where:

A : Area, in mm^2, of the total transverse section of the compensating parts

t : Actual thickness of the head, in mm, in the zone of the opening under consideration.

d) When A / t > d, the coefficient C is to be determined using the curve corresponding to the value:

$d \cdot (t \cdot D)^{-0,5} = 0$

e) If necessary, calculations are to be repeated.

1.8.7 Compensation criteria

In the evaluation of the area A, the following is also to be taken into consideration:

a) The material that may be considered for compensating an opening is that located around the opening up to a distance l from the edge of the opening. The distance l, in mm, is the lesser obtained from the following formulae:

$l = 0,5\ d$

$l = (2 \cdot R_{IN} \cdot t)^{0,5}$

where:

d : Diameter of the opening, in mm

R_{IN} : Internal radius of the spherical part, in mm, in the case of hemispherical or torispherical heads

In the case of ellipsoidal heads, R_{IN} is to be calculated by the following formula:

$$R_{IN} = \frac{[a^4 - x^4(a^2 - b^2)]^{3/2}}{a^4 b}$$

where (see Fig 2 (a):

a : Half the major axis of the elliptical meridian section of the head, in mm

b : Half the minor axis of the above section, in mm

x : Distance between the centre of the hole and the rotation axis of the shell, in mm.

b) In the case of nozzles or pads welded in the hole, the section corresponding to the thickness in excess of that required is to be considered for the part which is subject to pressure and for a depth h, in mm, both on the external and internal sides of the head, not greater than:

$(d_B \cdot t_B)^{0,5}$

where:

d_B : Diameter of the opening, in mm

t_B : Thickness of the pad or nozzle, in mm.

c) The area of the welding connecting nozzle and pad reinforcements may be considered as a compensating section.

d) If the material of reinforcement pads, nozzles and collars has a permissible stress lower than that of the head material, the area A, to be taken for calculation of the coefficient C, is to be reduced proportionally.

1.8.8 Openings in flat end plates

The maximum diameter of an unreinforced opening in a flat end plate is to be determined from the equation:

$$d_{max} = 8 e_{rh} \left[1,5 \frac{e_{rh}^2}{e_{ch}^2} - 1\right]$$

where:

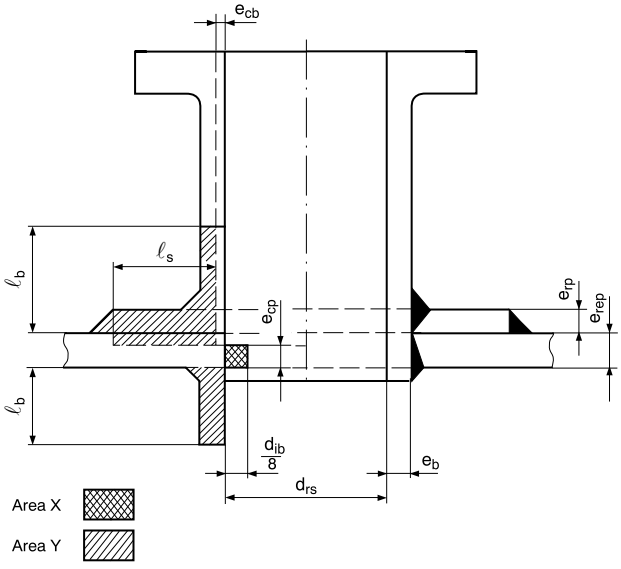
e_{rh} : Actual thickness of the flat end, in mm

e_{ch} : Required calculated thickness of the flat end, in mm.

1.8.9 Opening compensation in flat end plate

Reinforcement of branch openings is to be achieved by taking account of locally disposed material, including the attachment welds, in excess of the minimum requirements for end plate and branch thickness as shown in Fig 18. The branch thickness is to be increased where required. Compensation is to be considered adequate when the compensating area Y is equal to or greater than the area X requiring compensation.

Figure 18 : Compensation for branch in flat end plate



e_{cp} : Thickness calculated in accordance with equation in [2.8.1] for the part under consideration

e_{cb} : Thickness calculated taking efficiency = 1

ℓ_b : The smaller of the two values:
$2{,}5\ e_{rep}$ and $(2{,}5\ e_b + e_{rp})$

ℓ_s : The greater of the two values:
$(e_{rep} + 75)$ and $(d_{ib} / 4)$

Area Y is not to be less than area X.

Area X is to be obtained by multiplying 25% of the inside radius of the branch by the thickness of the flat end plate, calculated for the part of the end plate under consideration.

Area Y is to be measured in a plane through the axis of the branch parallel to the surface of the flat end plate, and is to be calculated as follows:

a) For that part of the branch which projects outside the boiler, calculate the full sectional area of the branch up to a distance ℓ_b from the actual outer surface of the flat end plate and deduct from it the sectional area that the branch would have within the same distance if its thickness were calculated in accordance with equation given in [1.4.3]

Note 1: The compensating plate is required only in cases where area Y would otherwise be less than area X.

b) Add to it the full sectional area of that part of the branch that projects inside the boiler (if any) up to a distance ℓ_b from the inside surface of the flat end plate

c) Add to it the sectional area of the fillet welds

d) Add to it the area obtained by multiplying the difference between the actual flat end plate thickness and its thickness calculated for the part of the end plate under consideration by the length ℓ_s

e) Add to it the area of the compensating plate (if any) within the limits of reinforcement shown in Fig 18.

Where material having a lower allowable stress than that of the flat end plate is taken as compensation, its effective area is to be reduced in the ratio of the allowable stresses at the calculation temperature. No credit is to be taken for the additional strength of material having a higher allowable stress than that of the flat end plate

Welds attaching branches and compensating plates are to be capable of transmitting the full strength of the reinforcing area and all other loadings to which they may be subjected.

1.8.10 Covers

a) Circular, oval and elliptical inspection openings are to be provided with steel covers. Inspection openings with a diameter not exceeding 150 mm may be closed by blind flanges.

b) The thickness of the opening covers is not to be less than the value t, in mm, given by the following formula:

$$t = 1{,}22 \cdot a \cdot \left(\frac{pC}{K}\right)^{0,5}$$

where:

a : The minor axis of the oval or elliptical opening, measured at half width of gasket, in mm

b : The major axis of the oval or elliptical opening, measured at half width of the gasket, in mm

C : Coefficient in Tab 7 as a function of the ratio b/a of the axes of the oval or elliptical opening, as defined above. For intermediate values of the ratio b/a, the value of C is to be obtained by linear interpolation.

For circular openings the diameter d, in mm, is to be used in the above formula instead of a.

c) The thickness obtained by the formula in item a) is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1 mm for classification purpose. See also [1.4.7].

Table 7 : Coefficient C for oval or elliptical covers

b/a	1,00	1,05	1,10	1,15	1,20	1,25	1,30	1,40	1,50	1,60
C	0,206	0,220	0,235	0,247	0,259	0,271	0,282	0,302	0,321	0,333
b/a	1,70	1,80	1,90	2,00	2,50	3,00	3,50	4,00	4,50	5,00
C	0,344	0,356	0,368	0,379	0,406	0,433	0,449	0,465	0,473	0,480

Table 8 : Coefficient m

d/s	0,30	0,35	0,40	0,45	0,50	0,55	0,60	0,65	0,70	0,75	0,80
m	0,137	0,175	0,220	0,274	0,342	0,438	0,560	0,740	1,010	1,420	2,060

1.9 Regular pattern openings - Tube holes

1.9.1 Definition

Openings may be considered as regular pattern openings when not less than three non isolated openings are disposed in regularly staggered rows in longitudinal or circular direction of a shell.

In such a case, instead of a direct calculation of the compensation of openings, the thickness of the shell could be calculated by application of applicable formulae given in [1.4], [1.5] with a reduced efficiency e as indicated in [1.9.2] and [1.9.3].

This requirement apply for pressure vessels and for boiler.

1.9.2 Efficiency factor of tube holes in cylindrical tube plates

The efficiency factor e of pipe holes in cylindrical shells pierced by tube holes is to be determined by direct calculation or by another suitable method accepted by the Society. In the case of cylindrical holes of constant diameter and radial axis, the efficiency factor e may be determined by the following formula (see Fig 19):

$$e = \frac{1}{\frac{s}{s-d} \cdot (1 - (0,5 \cdot \sin^2\alpha)) + m \cdot \sin 2\alpha}$$

where:

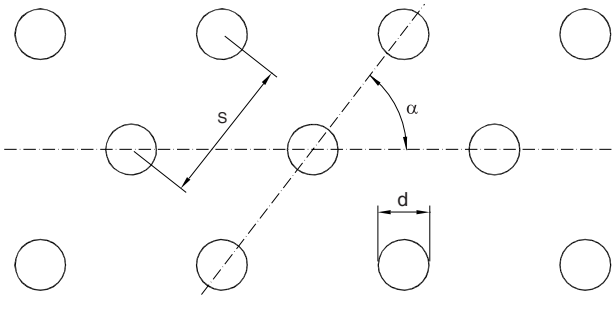
s : Pitch of the hole row considered, in mm

d : Diameter of holes, in mm. The hole diameter d may be reduced by the amount Y/e_{cp} where Y is the compensating area, in mm^2, of nozzle and welds and e_{cp} the calculated unpierced shell thickness, see [1.8.9] and Fig 18

α : Angle between the axis of hole row considered and the axis of the cylinder ($\alpha = 0°$ if the hole row is parallel to the cylinder generating line; $\alpha = 90°$ for circumferential hole row)

m : Coefficient depending upon the ratio d/s, as obtained from Tab 8. For intermediate values of d/s, the value of m is to be obtained by linear interpolation.

Figure 19 : Hole pattern in cylindrical shells



The value of e actually used is to be the smallest calculated value for either longitudinal, diagonal or circumferential rows of holes.

1.9.3 Welded shells with tube holes and efficiency factor of different hole patterns

Where shells have welding butts and/or different groups of hole patterns, the value to be assumed for the efficiency e in the formulae is the minimum of the values calculated separately for each type of welding (as per [1.4.2]) and for each configuration of holes (as per [1.9.1]).

1.9.4 Rectangular section headers

a) For seamless type headers of rectangular section design, the wall thickness t, in mm, in way of corner fillets and the thickness t_1, in mm, of any drilled wall is not to be less than those given by the following formulae, as appropriate (see Fig 20):

$$t = \left(\frac{100pM_1}{K}\right)^{0,5}$$

$$t_1 = \left(\frac{100pM_2}{eK}\right)^{0,5}$$

where (see also Fig 20):

t : Wall thickness at the corners, in mm

t_1 : Thickness of drilled wall, in mm

p : Design pressure, in MPa

K : Permissible stress, in N/mm^2, obtained as specified in [1.3]

a : Internal half width of the header, in a direction parallel to the wall under consideration, in mm

b : Internal half width of the header, in a direction normal to the wall under consideration, in mm

c : Distance between the axis of the hole row considered and the centreline of the header wall, in mm

e : Efficiency factor of holes in the wall, determined by the following formulae:

$$e = \frac{s-d}{s} \quad \text{for } d < a$$

$$e = \frac{s-0,67d}{s} \quad \text{for } a \le d < 1,3a$$

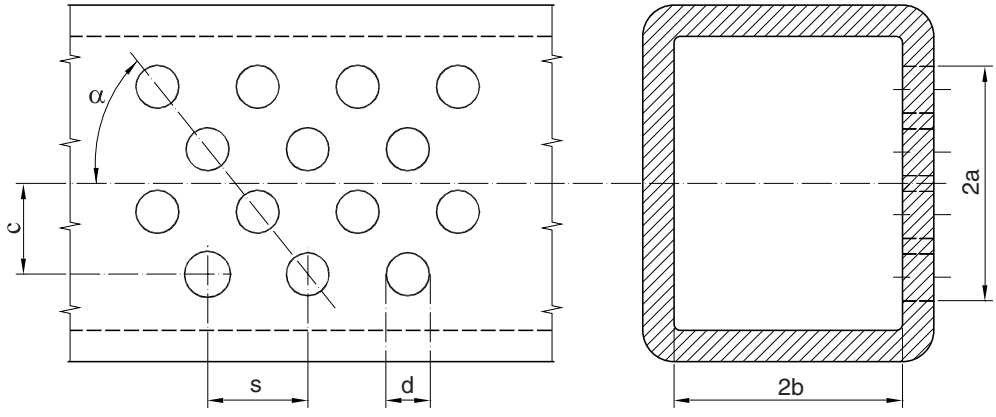
$$e = \frac{s-0,33d}{s} \quad \text{for } d \ge 1,3a$$

with:

s : Pitch of the holes, in mm, of the longitudinal or diagonal row under consideration. For a staggered pattern of holes, the pitch of the diagonal row is to be considered

d : Diameter of the holes, in mm

Figure 20 : Rectangular section headers



M_1 : Coefficient to be calculated by the following formula:

$$M_1 = \frac{a^2 + b^2 - ab}{50}$$

M_2 : Coefficient (to be taken always positive) to be calculated by one of the following formulae, as appropriate:

- for a non-staggered pattern of holes:

$$M_2 = \frac{b^2 - \frac{1}{2}a^2 - ab + \frac{3}{2}c^2}{50}$$

- for a staggered pattern of holes:

$$M_2 = \frac{b^2 - \frac{1}{2}a^2 - ab}{50}\cos\alpha$$

where α is the angle between the axis of the diagonal row of the holes under consideration and the axis of the header, in the case of a staggered pattern of holes.

b) The thickness obtained by the formulae in a) is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1,5 mm. See also [1.4.7].

1.10 Water tubes, superheaters and economiser tubes of boilers

1.10.1

a) The thickness of tubes of evaporating parts, economisers and superheaters exposed to gases which are subject to internal pressure is not to be less than the value t given by the following formula:

$$t = \frac{pd}{2K + p} + 0,3$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm², obtained as specified in [1.3]

d : Outside diameter of tube, in mm.

However, irrespective of the value calculated by the formulae in item a), the thickness t of tubes is not to be less than the values given in Tab 9.

b) The values of t determined by the above-mentioned formula are to be considered as theoretical values for straight tubes, not taking account of the manufacturing tolerance. Where the tubes are not sized precision tubes, the thickness calculated by the formula in item a) is to be increased by 12,5% to take into account the manufacturing tolerance. For bent tubes, the thickness of the thinner part in way of the bend is not to be less than that given by the formula.

c) Whenever abnormal corrosion and erosion may occur during service, the corrosion constant of 0,3 in the formula may be increased to the satisfaction of the Society.

Table 9 : Minimum thickness of water tubes

Outside diameter, in mm	Minimum thickness in mm of tubes subject to internal pressure of cylindrical boilers and water tube boilers having the feed water system	
	Closed type, if equipped with suitable devices for reducing the oxygen concentration in the water	Open type, not equipped with suitable devices for reducing the oxygen concentration in the water
< 38	1,8	2,9
38 - 48,3	2,0	2,9
51 - 63,5	2,4	2,9
70	2,6	3,2
76,1 - 88,9	2,9	3,2
101,6 - 127	3,6	–

1.11 Additional requirements for fired pressure vessels

1.11.1 Insulation for headers and combustion chambers

Those parts of headers and/or combustion chambers which are not protected by tubes and are exposed to radiant heat or to high temperature gases are to be covered by suitable insulating material.

1.11.2 Connections of tubes to drums and tube plates

Tubes are to be adequately secured to drums and/or tube plates by expansion, welding or other appropriate procedure.

a) Where the tubes are secured by expanding or equivalent process, the height of the shoulder bearing the tube, measured parallel to the tube axis, is to be at least 1/5 of the hole diameter, but not less than 9 mm for tubes normal to the tube plate or 13 mm for tubes angled to the tube plate. The tubes ends are not to project over the other face of the tube plate more than 6 mm.

b) The tube ends intended to be expanded are to be partially annealed when the tubes have not been annealed by the manufacturer.

1.12 Additional requirements for vertical boilers and fire tube boilers

1.12.1 General

The scantlings of the shells of vertical boilers and fire tube boilers are to be determined in accordance with [1.4].

1.12.2 Ends of vertical boilers

a) The minimum thickness of the dished ends forming the upper part of vertical boilers and subject to pressure on their concave face is to be determined in accordance with [1.5].

b) When the end is supported in its centre by an uptake, the minimum thickness t, in mm, is to be calculated with the following formula:

$$t = 0,77 \cdot \frac{pR_I}{K}$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm^2, obtained as specified in [1.3]

R_I : Radius of curvature at the centre of the end measured internally. R_I is not to exceed the external diameter of the shell.

c) The thickness obtained by the formula in item b) is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 0,7 mm. See also [1.4.7].

d) For ends supported by an uptake at their centre, the corner radius measured internally is not to be less than 4 times the end thickness or 65 mm, whichever is the lesser and the inside radius of curvature on the flange to uptake is not to be less than twice the end thickness or 25 mm, whichever is the lesser.

1.12.3 Supported flat head

a) Breathing space

- Stays are to give breathing space around the furnace tube connections and tube nests and equally divide the unstayed areas. Breathing space between furnace tube and tube nests are to be a minimum of 50 mm or 5% of the shell outside diameter, whichever is the larger, but need not be more than 100 mm.
- Breathing space between furnace tube and shell depends on the thickness of the plate of the type of end and of the dimensions of the boiler but is to be not less than 50 mm or, for bowling hoop furnaces tubes, not less than 75 mm.

b) The thickness of stayed flat heads, or of heads supported by flanges, is not to be less than the value t, in mm, given by the following formula:

$$t = D\left[\frac{100p}{CC_1K(1 + C_2B^2)}\right]^{0,5}$$

where:

B : Ratio of the thickness of the large washer or doubler, where fitted, to the thickness of the plate:

$B = t_1 / t$

The value of B is to be taken between 0,67 and 1,00

K : Permissible stress, in N/mm^2, obtained as specified in [1.3]

C : C = 1 when the plate is not exposed to flame

C = 0,88 when the plate is exposed to flame

C_1 : C_1 = 462 when the plate is supported by welded stays

C_1 = 704 for plates supported by flanges or equivalent

C_2 : C_2 = 0 when no doublers are fitted

C_2 = 0,85 when a complete doubling plate is fitted, adequately joined to the base plate.

The value of D is to be in accordance with the following provisions:

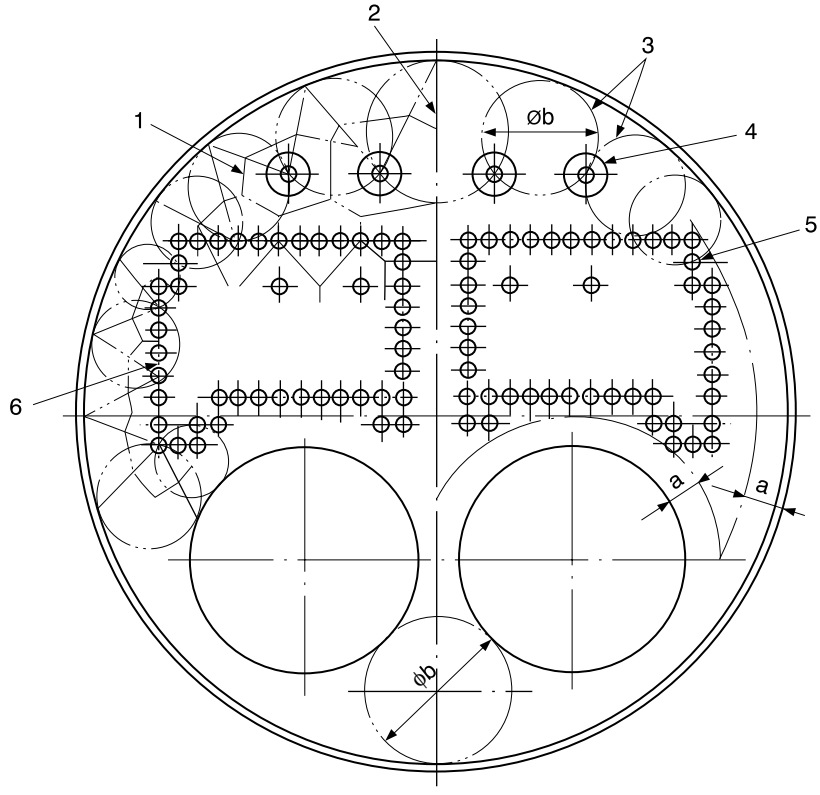
1) In the parts of the flat heads between the stays:
   - D = diameter, in mm, of the largest circle which can be drawn through the centre of at least three stays without enclosing any other stay, where the stays are not evenly spaced (see Fig 21), or
   - $D = (a^2 + b^2)^{0,5}$ where the stays are evenly spaced, considering the most unfavourable condition, where:

     a : Distance between two adjacent rows of stays, in mm

     b : Pitch of stays in the same row, in mm

2) In the parts of the flat heads between the stays and the boundaries, where flat heads are generally supported by flanges or shapes, or connected to other parts of the boiler:
   - D = diameter, in mm, of the largest circle which can be drawn through not less than three points of support (stay centres or points of tangency of the circle with the contour line). To this end, the contour of the part under consideration is to be drawn at the beginning of the flanging or connection curve if its inside radius does not exceed 2,5 times the thickness of the plate, or, where such radius is greater, at the above-mentioned distance (of 2,5 times the thickness of the plate) from the ideal intersection with other surfaces (see Fig 21).

Figure 21 :



Key:

1 : Boundaries of areas supported by individual stays

2 : To establish the area supported by bar stays or stay tubes in boundary rows, the boundary of the loaded area is to terminate at the centre of the associated main circle

3 : Main circles, diameter b

4 : Bar stays

5 : Stay tubes

6 : Termination of boundary areas where stay tubes are situated in the boundary rows only.

c) When applying the formulae for calculation of thickness of heads covered by this sub-article, the position of plates in the most unfavourable condition is to be considered.

d) Where various types of supports are provided, the value of C_1 should be the arithmetic mean of the values of C_1 appropriate to each type of support.

e) The thickness obtained by the formulae in a), is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1 mm. See also [1.4.7].

1.12.4 Flat tube plates

a) Flat tube plates in tube bundles

The thickness of the parts of flat tube plates contained in the tube bundle and supported by stay tubes is not to be less than the value t, in mm, given by the following formula:

$$t = s\left(\frac{p}{2,8K}\right)^{0,5}$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm^2, obtained as specified in [1.3]

s : Pitch of stay tubes, taken as the greatest mean pitch of the stay tubes supporting a quadrilateral portion of the plate, in mm.

Moreover the spacing of tube holes (diameter d) is to be such that the minimum width, in mm, of any ligament between the tube holes is to be not less than:

- for expanded tubes:

  (0,125 d + 12,5) mm

- for welded tubes:

  - for gas entry temperatures greater than 800°C:

    (0,125 d + 9) mm, but need not exceed 15 mm

  - for gas entry temperatures less than or equal to 800°C:

    (0,125 d + 7) mm, but need not exceed 15 mm.

Moreover the calculated thickness of tube plates is to be not less than the following:

- 12 mm where the tubes are expanded into the tube plate when the diameter of the tube hole does not exceed 50 mm, or 14 mm when the diameter of the tube hole is greater than 50 mm, or
- 6 mm where the tubes are attached to the tube plate by welding only.

b) Flat tube plates of combustion chamber in vertical boilers

Where tube plates contained in the tube bundle are simultaneously subject to compression due to the pressure in the combustion chamber, their thickness, as well as complying with the requirements in item a) is not to be less than the value t, in mm, given by the following formula:

$$t = \frac{pls_1}{1{,}78(s_1 - d)K}$$

where:

l : Depth of the combustion chamber, in mm

s_1 : Horizontal pitch of tubes, in mm

d : Inside diameter of plain tubes, in mm.

For the meaning of other symbols, see item a).

c) Tube plates outside tube bundles

For those parts of tube plates which are outside the tube bundle, the formula in [1.13.3] is to be applied, using the following coefficients C_1 and C_2:

$C_1 = 390$

$C_2 = 0{,}55$

Doublers are only permitted where the tube plate does not form part of a combustion chamber.

d) Tube plates not supported by stays

Flat tube plates which are not supported by stay tubes (e.g. in heat exchangers), are subject of special consideration by the Society (see also [1.14]).

e) Stay and stay tube scantling

- The diameter of solid stays of circular cross-section is not to be less than the value d calculated by the following formula:

$$d = \left(\frac{pA}{K}\right)^{0,5}$$

where:

d : Minimum diameter, in mm, of the stay throughout its length

A : Area supported by the stay, in mm^2

K : $K = R_m / 7$

R_m : Minimum ultimate tensile strength of the stay material, in N/mm^2.

The cross section of tube stays is to be equivalent to that of a solid stay supporting the same area, whose diameter is calculated by the above formula.

Stays which are not perpendicular to the supported surface are to be of an adequately increased diameter depending on the component of the force normal to the plate.

- Where articulated stays are used, articulation details are to be designed assuming a safety factor for articulated elements not less than 5 with respect to the value of R_m and a wear allowance of 2 mm.

The articulation is to be of the fork type and the clearance of the pin in respect of the holes is not to exceed 1,5 mm. The pin is to bear against the jaws of the fork and its cross-sectional area is not to be less than 80% of the cross-sectional area of the stay. The width of material around the holes is not to be less than 13 mm.

- Where stays are flanged for joining to the plate, the thickness of the flange is not to be less than one half the diameter of the stay.
- For welded connections of stays to tube plates, see Fig 37.

f) Stay and stay tubes construction

- In general, doublers are not to be fitted in plates exposed to flame.
- As far as possible, stays are to be fitted perpendicularly to the supported surface.
- Long stays in double front boilers and, in general, stays exceeding 5 m in length, are to be supported at mid-length.
- Where the ends of stay tubes are of increased thickness, the excess material is to be obtained by forging and not by depositing material by means of welding.
- After forging, the ends of stay tubes are to be stress relieved.

g) Gusset stays

Tube plate may be supported by gussets stays with full penetration welds to plate and shell.

The general shape and the scantling are to be in accordance with a standard accepted by the Society.

h) Girders

Where tops of combustion chambers, or similar structures, are supported by girders of rectangular section associated with stays, the thickness of the single girder or the aggregate thickness of all girders, at mid-length, is not to be less than the value t determined by the appropriate formula below, depending upon the number of stays:

- in case of an odd number of stays:

$$t = \frac{pL(L - s)l}{0{,}25R_m a^2} \cdot \frac{n + 1}{n}$$

- in case of an even number of stays:

$$t = \frac{pL(L - s)l}{0{,}25R_m a^2} \cdot \frac{n + 2}{n + 1}$$

where:

p : Design pressure, in MPa

a : Depth of the girder plate at mid-length, in mm

L : Length of girder between supports, in mm

s : Pitch of stays, in mm

n : Number of stays on the girder

l : Distance between centres of girders, in mm

R_m : Minimum ultimate tensile strength of the material used for the plates, in N/mm^2.

The above formulae refer to the normal arrangement where:

- the stays are regularly distributed over the length L
- the distance from the supports of the outer stays does not exceed the uniform pitch s
- when the tops of the combustion chambers are connected to the sides with curved parts with an external radius less than 0,5 l, the distance of end girders from the inner part of the side surface does not exceed l
- when the curvature radius mentioned under item just above exceeds 0,5 l, the distance of the end girders from the beginning of the connection does not exceed 0,5 l.

In other cases a direct calculation is to be made using a safety factor not less than 5, with respect to the minimum value of the tensile strength R_m.

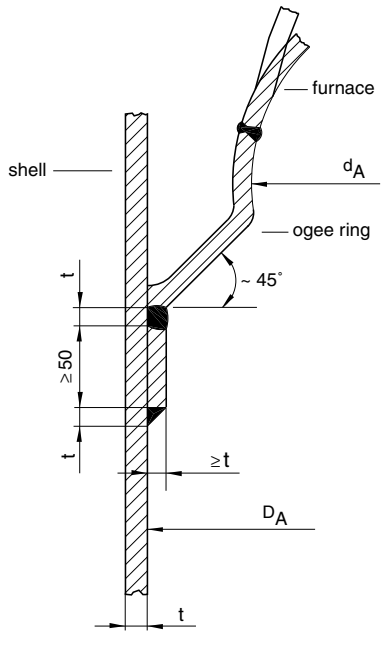
i) Ogee rings

The thickness of ogee rings connecting the furnaces to the shell in vertical auxiliary boilers (see Fig 22), where the latter support the weight of the water above the furnace, is not to be less than the value t, in mm, given by the following formula:

$$t = [1{,}02 \cdot 10^{-3} \cdot pD_A \cdot (D_A - d_A)]^{0,5} + 1$$

where:

Figure 22 : Ogee ring



p : Design pressure, in MPa

D_A : Inside diameter of boiler shell, in mm

d_A : Inside diameter of the lower part of the furnace where it joins the ogee ring, in mm.

1.12.5 Fire tubes

a) The thickness of fire tubes subject to external pressure in cylindrical boilers is not to be less than the value t, in mm, calculated by the following formula:

$$t = \frac{pd}{0{,}15R_m} + 1{,}8$$

where:

p : Design pressure, in MPa

d : Outside diameter of tube, in mm

R_m : Minimum ultimate tensile strength of the tube material, in N/mm^2.

The minimum acceptable thickness is given in Tab 10.

b) The values of t determined by the above-mentioned formula are to be considered as theoretical values for straight tubes, not taking account of the manufacturing tolerance. Where the tubes are not sized precision tubes, the thickness calculated by the formula in item a) is to be increased by 12,5% to take into account the manufacturing tolerance. In the case of bent tubes, the thickness of the thinner part in way of the bend is not to be less than that given by the above formula.

c) Whenever abnormal corrosion and erosion may occur during service the corrosion constant of 1,8 in the formula may be increased to the satisfaction of the Society.

Table 10 : Minimum thickness of fire tubes

Nominal outside diameter	Lowest nominal thickness t
d ≤ 88,9	3,00
88,9 < d ≤ 114,3	3,15
114,3 < d ≤139,7	3,50
139,7 < d ≤168,3	3,99

1.12.6 Furnaces general points

a) Thermal design of furnace tubes.

The heat input for a given furnace tube inside diameter is not to exceed a value compatible with the chosen design temperature. Burners with a fixed firing rate are not to be used for heat inputs exceeding 1 MW per furnace tube.

b) The minimum thickness of furnaces is to be calculated for elastic buckling and plastic deformation in accordance with the requirements of a Standard for pressure vessels subject to external pressure accepted by the Society.

c) However, the minimum thicknesses of furnaces and cylindrical ends of combustion chambers of fire tube boilers are to be not less than the value t given by the appropriate formulae in [1.12.7], [1.12.8] and [1.12.9].

d) The thickness of furnaces is not to be less than 8 mm for plain furnace and 10 mm for corrugated furnace and the stays are to be spaced such that the thickness does not exceed 22 mm.

e) All the thicknesses obtained for furnaces by the formulae in [1.12.7], [1.12.8], [1.12.9] and [1.12.4] are "net" thicknesses, as they do not include any corrosion allowance. The thicknesses obtained by the above formulae are to be increased by 1 mm. See also [1.4.7].

1.12.7 Plain furnace tubes

a) Plain furnace tube

The minimum thickness t of plain cylindrical furnaces is to be not less than the greater value, in mm, obtained from the following formulae:

$$t = \frac{B}{2}\left[1 + \sqrt{1 + \frac{0,12D \cdot u}{(1 + 5D/L)B}}\right]$$

$$t = D^{0,6}[(LS_2p)/(2,6E)]^{0,4}$$

where:

$$B = \frac{pDS_1}{2R_{S,MIN,T}(1 + 0,1D/L)}$$

S_1 : Safety factor, equal to 2,5

L : Unstayed length of furnace, in mm

u : Departure from circularity, in %, equal to:

$$u = \frac{2(D_{max} - D_{min})}{D_{max} + D_{min}} \times 100$$

u is to be taken as 1,5% for plain furnace tubes

S_2 : Safety factor for buckling, equal to:

- 3 for u ≤1,5%
- 4 for 1,5% < u ≤ 2%

E : Elastic modulus, in MPa, at design temperature T, in °C, and equal to:

$E = 208800 - 93,4 \cdot T$

b) Stiffeners

Stiffeners welded to furnaces tubes according to a standard accepted by the Society may be considered as providing effective stiffening (reduction of L in upper formulae).

1.12.8 Corrugated furnace tubes

The minimum thickness of corrugated furnace tubes, in mm, is to be determined by:

$$t = \frac{pD_E}{0,26R_m}$$

where:

D_E : External diameter of the furnace, in mm, measured at the bottom of the corrugation.

This formula apply for Fox and Morisson type furnaces tubes. The scantling of furnaces of other types and the use of stiffeners are to be especially considered by the Society.

1.12.9 Hemispherical furnaces

The minimum thickness t, in mm, of hemispherical furnaces is not to be less than the value given by the following equation:

$$t = \frac{pD_E}{120}$$

1.13 Bottles containing pressurised gases

1.13.1 General

a) The following requirements apply to bottles intended to contain pressurised and/or liquefied gases at ambient temperature, made by seamless manufacturing processes.

b) In general, such bottles are to have an outside diameter not exceeding 420 mm, a length not exceeding 2000 mm and capacity not exceeding 150 litres (see also [2.3.1]).

c) For bottles exceeding the above capacity and dimensions, the following requirements may be applied at the discretion of the Society.

1.13.2 Cylindrical shell

The wall thickness of the cylindrical shell is not to be less than the value t, in mm, determined by the following formula:

$$t = \frac{p_H D_E}{2K + p_H}$$

where:

p_H : Hydrostatic test pressure, in MPa. This pressure is to be taken as 1,5 times the setting pressure of the safety valves with the following exceptions:

- for CO_2 bottles, p_H = 25 MPa
- for refrigerants, the value of hydrostatic test pressure is given in Pt F, Ch 1, Sec 1

D_E : Outside diameter of tube, in mm

$K = R_{S,MIN} / 1,3$

$R_{S,MIN}$: Value of the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p\,0,2}$), at the ambient temperature, in N/mm^2. In no case is the value $R_{S,MIN}$ to exceed:

- 0,75 R_m for normalised steels
- 0,90 R_m for quenched and tempered steels.

1.13.3 Dished heads

Dished ends are to comply with the following requirements:

a) hemispherical ends: the thickness of the ends is to be not less than the thickness calculated for spherical shells in accordance with [1.4.4]

b) convex ends: see Fig 23

c) concave base ends: see Fig 24

d) ends with openings: see Fig 25

e) other types of ends are to be specially considered by the Society.

Figure 23 : Dished convex ends

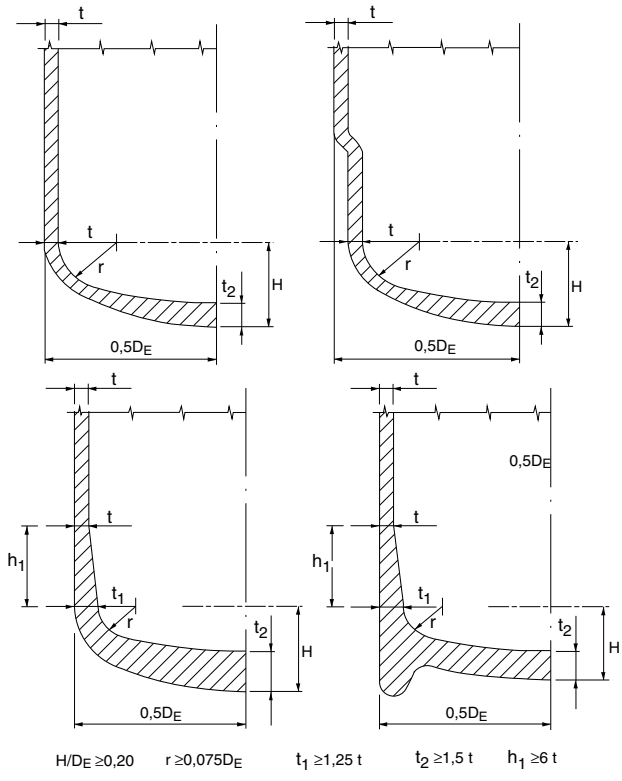
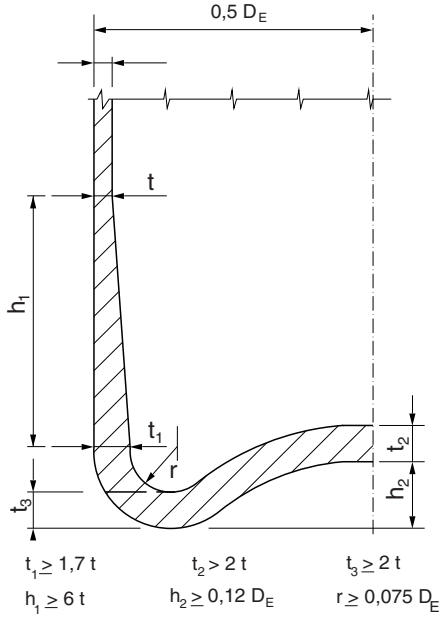


Figure 24 : Dished concave ends



1.14 Heat exchangers

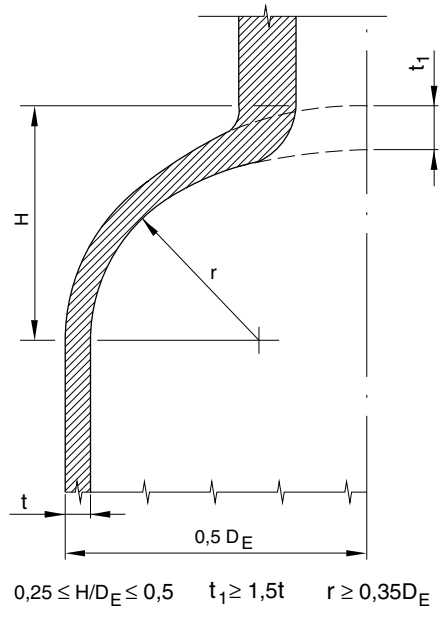
1.14.1 Scantlings

a) Vessels are to be designed in accordance with the applicable requirements stated in [1.4] and [1.5].

b) Tubes are to be designed in accordance with [1.10.1].

c) Tube plates are to be designed in accordance with a standard accepted by the Society.

Figure 25 : Heads with openings



2 Design and construction - Equipment

2.1 All pressure vessels

2.1.1 Drainage

a) Each air pressure vessel is to be fitted with a drainage device allowing the evacuation of any oil or water accumulated in the vessel. Common drain for a group of air pressure vessels as defined in Ch 3, Sec 5, [11.1.1] is allowed.

b) Drainage devices are also to be fitted on other vessels, in particular steam vessels, in which condensation water is likely to accumulate.

2.2 Boilers and steam generators

2.2.1 Safety valve arrangement

a) Every steam boiler and every steam generator with a total heating surface of 50 m^2 and above is to be provided with not less than two spring loaded safety valves of adequate capacity. For steam boilers and steam generators having heating surface less than 50 m^2, only one safety valve need be fitted.

b) Where a superheater is an integral part of the boiler, at least one safety valve is to be located on the steam drum and at least one at the superheater outlet. The valves fitted at the superheater outlet may be considered as part of the boiler safety valves required in item a), provided that their capacity does not account for more than 25% of the total capacity required in [2.2.2], unless specially considered by the Society.

c) Where fitted, superheaters which may be shut-off from the boiler are to be provided with at least one safety valve; such valve(s) cannot be considered as part of the boiler safety valves required in item a).

d) In the case of boilers fitted with a separate steam accumulator, safety valves may be fitted on the accumulator if no shut-off is provided between it and the boiler and if the connecting pipe is of a size sufficient to allow the whole steam production to pass through, without increasing the boiler pressure more than 10% above the design pressure.

2.2.2 Relieving capacity of safety valves

a) The relieving capacity of each safety valve Q, in kg/h, is to be determined by the appropriate formula below in order that:

$Q \geq W$

- saturated steam:

$$Q = \frac{C \cdot A \cdot (10 \cdot P + 1.05)}{100}$$

- superheated steam:

$$Q = \frac{C \cdot A \cdot (10 \cdot P + 1.05)}{100} \times \sqrt{\frac{v}{v_S}}$$

where:

W : Maximum steam production, in kg/h, as defined by the maximum power of the heating equipment; otherwise the value of W is to be based on evaporating capacities (referring to evaporating surfaces of the boiler concerned) less than the following:

- 14 kg/(m²·h) for exhaust gas heated boilers
- 29 kg/(m²·h) for oil fired boilers
- 60 kg/(m²·h) for water walls of oil fired boilers

A : Aggregate area, in mm², of the orifices in way of the seat of the valve, deducting the obstructions corresponding to the guides and the conformation of the valve in full lift position

p : Maximum working pressure of the boiler or other steam generator, in MPa. For superheated steam safety valves, P is to be the pressure at the superheater outlet

C : Coefficient with the following values:

- 4,8 for ordinary safety valves, i.e. where the valve lift is at least 1/24 of the internal diameter of the seat
- 10 for high lift safety valves, i.e. where the valve lift is at least 1/12 of the internal diameter of the seat
- 20 for full lift safety valves, i.e. where the valve lift is at least 1/4 of the internal diameter of the valve

Higher values of coefficient C may be admitted for safety valves of approved type and having undergone, in the presence of the Surveyor or according to a procedure considered as equivalent by the Society, capacity tests with conditions of pressure and temperature comparable to those of the plant considered. In such a case, coefficient C is to be, as a rule, taken as 90% of the resulting value from the capacity test

v : Specific volume of saturated steam at the pressure corresponding to the superheater outlet

v_S : Specific volume of superheated steam at the temperature corresponding to the superheater outlet.

b) When the safety valves are fitted at the superheater outlet. Their relieving capacity is to be such that, during the discharge of safety valves, a sufficient quantity of steam is circulated through the superheater to avoid damage.

c) The orifice diameter in way of the safety valves seat is not to be less than 40 mm. Where only one safety valve need be fitted, the orifice minimum diameter is not to be less than 50 mm. Valves of large relieving capacity with 15 mm minimum diameter may be accepted for boilers with steam production not exceeding 2000 kg/h.

d) Independently of the above requirements, the aggregate capacity of the safety valves is to be such as to discharge all the steam that can be generated without causing a transient pressure rise of more than 10% over the design pressure.

2.2.3 Miscellaneous safety valve requirements

a) Safety valves operated by pilot valves

The arrangement on the superheater of large relieving capacity safety valves, operated by pilot valves fitted in the saturated steam drum, is to be specially considered by the Society.

b) Safety valve setting

- safety valves are to be set under steam in the presence of the Surveyor to a pressure not higher than 1,03 times the design pressure
- safety valves are to be so constructed that their setting may not be increased in service and their spring may not be expelled in the event of failure. In addition, safety valves are to be provided with simple means of lifting the plug from its seat from a safe position in the boiler or engine room
- where safety valves are provided with means for regulating their relieving capacity, they are to be so fitted that their setting cannot be modified when the valves are removed for surveys.

c) Safety valve fitting on boiler

- the safety valves of a boiler are to be directly connected to the boiler and separated from other valve bodies
- where it is not possible to fit the safety valves directly on the superheater headers, they are to be mounted on a strong nozzle fitted as close as practicable to the superheater outlet. The cross-sectional area for passage of steam through restricted orifices of the nozzles is not to be less than 1/2 the aggregate area of the valves, calculated with the formulae of [1.3.2] when $C \leq 10$, and not less than the aggregate area of the valves when $C > 10$

- safety valve bodies are to be fitted with drain pipes of a diameter not less than 20 mm for double valves, and not less than 12 mm for single valves, leading to the bilge or to the hot well. Valves or cocks are not to be fitted on drain pipes.

d) Exhaust pipes

- the minimum cross-sectional area of the exhaust pipes of safety valves which have not been experimentally tested is not to be less than C times the aggregate area A
- the cross-sectional area of the exhaust manifold of safety valves is to be not less than the sum of the areas of the individual exhaust pipes connected to it
- silencers fitted on exhaust manifolds are to have a free passage area not less than that of the manifolds
- the strength of exhaust manifolds and pipes and associated silencers is to be such that they can withstand the maximum pressure to which they may be subjected, which is to be assumed not less than 1/4 of the safety valve setting pressure
- in the case that the discharges from two or more valves are led to the same exhaust manifold, provision is to be made to avoid the back pressure from the valve which is discharging influencing the other valves
- exhaust manifolds are to be led to a place where crew has no access when ship is afloat or diving. On dry dock, when access is possible where exhaust end is located, safety procedures shall be implemented in order to guarantee that no access shall be allowed when steam installation is started. In case of opening of safety valves, suitable means shall be provided in order to maintain pressure in adequate range according to structural behaviour of bulkheads.
- They are to be adequately supported and fitted with suitable expansion joints or other means so that their weight does not place an unacceptable load on the safety valve bodies.

e) Steam generator heated by steam

Steam heated steam generators are also to be protected against possible damage resulting from failure of the heating coils. In this case, the area of safety valves calculated as stated in [2.2.2] may need to be increased to the satisfaction of the Society, unless suitable devices limiting the flow of steam in the heating coils are provided.

2.2.4 Other requirements

Access arrangement

a) Boilers are to be provided with openings in sufficient number and size to permit internal examination, cleaning and maintenance operations. In general, all pressure vessels which are part of a boiler with inside diameter exceeding 1200 mm, and those with inside diameter exceeding 800 mm and length exceeding 2000 mm, are to be provided with access manholes.

b) Manholes are to be provided in suitable locations in the shells, headers, domes, and steam and water drums, as applicable. The "net" (actual hole) dimension of elliptical or similar manholes is to be not less than 300mm x 400mm. The "net" diameter of circular manholes (actual hole) cannot be less than 400 mm. The edges of manholes are to be adequately strengthened to provide compensation for vessel openings in accordance with [1.8.4], [1.8.6] and [1.8.9], as applicable.

c) In pressure vessels which are part of a boiler and are not covered by the requirement in item a) above, or where an access manhole cannot be fitted, at least the following openings are to be provided, as far as practicable:

- head holes
  minimum dimensions: 220mm x 320mm
  (320 mm diameter if circular)
- handholes
  minimum dimensions: 87mm x 103mm
- sight holes
  minimum diameter: 50 mm.

d) Sight holes may only be provided when the arrangement of manholes, head holes, or handholes is impracticable.

e) Covers for manholes and other openings are to be made of ductile steel, dished or welded steel plates or other approved design. Grey cast iron may be used only for small openings, such as handholes and sight holes, provided the design pressure p does not exceed 1 MPa and the design temperature T does not exceed 220°C.

f) Covers are to be of self-closing internal type. Small opening covers of other type may be accepted by the Society on a case by case basis.

g) Covers of the internal type are to have a spigot passing through the opening. The clearance between the spigot and the edge of the opening is to be uniform for the whole periphery of the opening and is not to exceed 1,5 mm.

h) Closing devices of internal type covers, having dimensions not exceeding 180mm x 230mm, may be fitted with a single fastening bolt or stud. Larger closing devices are to be fitted with at least two bolts or studs.

i) Covers are to be designed so as to prevent the dislocation of the required gasket by the internal pressure. Only continuous ring gaskets may be used for packing.

Fittings

a) In general, cocks and valves are to be designed in accordance with the requirements in Ch 3, Sec 5, [2.7.2]

b) Cocks, valves and other fittings are to be connected directly or as close as possible to the boiler shell.

c) Cocks and valves for boilers are to be arranged in such a way that it can be easily seen when they are open or closed and so that their closing is obtained by a clockwise rotation of the actuating mechanism.

Boiler burners

Burners are to be arranged so that they cannot be withdrawn unless the fuel supply to the burners is cut off.

Allowable water levels

a) In general, for water tube boilers the lowest permissible water level is just above the top row of tubes when the water is cold. Where the boiler is designed not to have fully submerged tubes, when the water is cold, the lowest allowable level indicated by the manufacturer is to be indicated on the drawings and submitted to the Society for consideration.

b) For fire tube boilers with combustion chamber integral with the boiler, the minimum allowable level is to be at least 50 mm above the highest part of the combustion chamber.

c) For vertical fire tube boilers the minimum allowable level is 1/2 of the length of the tubes above the lower tube sheet.

Steam outlets

a) Each boiler steam outlet, if not serving safety valves, integral superheaters and other appliances which are to have permanent steam supply during boiler operation, is to be fitted with an isolating valve secured either directly to the boiler shell or to a standpipe of substantial thickness, as short as possible, and secured directly to the boiler shell.

b) The number of auxiliary steam outlets is to be reduced to a minimum for each boiler.

c) Where several boilers supply steam to common mains, the arrangement of valves is to be such that it is possible to positively isolate each boiler for inspection and maintenance. In addition, for water tube boilers, non-return devices are to be fitted on the steam outlets of each boiler.

d) Where steam is used for essential auxiliaries (such as steam operated electric generators, etc.) and when several boilers are fitted on board, it is to be possible to supply steam to these auxiliaries with any one of these boilers out of operation.

e) Each steam stop valve exceeding 150 mm nominal diameter is to be fitted with a bypass valve.

Feed check valves

a) Each fired boiler supplying steam to essential services is to be fitted with at least two feed check valves connected to two separate feed lines. For unfired steam generators a single feed check valve may be allowed.

b) Feed check valves are to be secured directly to the boiler or to an integral economiser. Water inlets are to be separated. Where, however, feed check valves are secured to an economiser, a single water inlet may be allowed provided that each feed line can be isolated without stopping the supply of feed water to the boiler.

c) Where the economisers may be bypassed and cut off from the boiler, they are to be fitted with pressure-limiting type valves, unless the arrangement is such that excessive pressure cannot occur in the economiser when cut off.

d) Feed check valves are to be fitted with control devices operable from the stokehold floor or from another appropriate location. In addition, for water tube boilers, at least one of the feed check valves is to be arranged so as to permit automatic control of the water level in the boiler.

e) Provision is to be made to prevent the feed water from getting in direct contact with the heated surfaces inside the boiler and to reduce, as far as possible and necessary, the thermal stresses in the walls.

Drains

Each superheater, whether or not integral with the boiler, is to be fitted with cocks or valves so arranged that it is possible to drain it completely.

Water sample

a) Every boiler is to be provided with means to supervise and control the quality of the feed water. Suitable arrangements are to be provided to preclude, as far as practicable, the entry of oil or other contaminants which may adversely affect the boiler.

b) For this purpose, boilers are to be fitted with at least one water sample cock or valve. This device is not to be connected to the water level standpipes.

c) Suitable inlets for water additives are to be provided in each boiler.

Marking of boilers

a) Each boiler is to be fitted with a permanently attached plate made of non-corrosive metal, with indication of the following information, in addition to the identification marks (name of manufacturer, year and serial number):

- the design pressure
- the design temperature
- the test pressure and the date of the test.

b) Markings may be directly stamped on the vessel if this does not produce notches having an adverse influence on its behaviour in service.

c) For lagged vessels, these markings are also to appear on a similar plate fitted above the lagging.

2.3 Special types of pressure vessels

2.3.1 Seamless pressure vessels (bottles)

Each bottle is to be marked with the following information:

- name or trade name of the manufacturer
- serial number
- type of gas
- capacity
- test pressure
- empty weight
- test stamp.

2.3.2 Steam condensers

a) The water chambers and steam spaces are to be fitted with doors for inspection and cleaning.

b) Where necessary, suitable diaphragms are to be fitted for supporting tubes.

c) Condenser tubes are to be removable.

d) High speed steam flow, where present, is to be prevented from directly striking the tubes by means of suitable baffles.

e) Suitable precautions are to be taken in order to avoid corrosion on the circulating water side and to provide an efficient grounding.

2.4 Other pressure vessels

2.4.1 Safety valves arrangement

a) General

- Taking into consideration exception mentioned in Ch 3, Sec 3, [1.1.2], pressure vessels which are part of a system are to be provided with safety valves, or equivalent devices, if they are liable to be isolated from the system safety devices. This provision is also to be made in all cases in which the vessel pressure can rise, for any reason, above the design pressure.
- Safety devices ensuring protection of pressure vessels in normal service are to be rated to operate before the pressure exceeds the maximum working pressure by more than 5%
- where two or more pressure vessels are interconnected by a piping system of adequate size so that no branch of piping may be shut off, it is sufficient to provide them with one safety valve and one pressure gauge only.

b) Heat exchangers

Special attention is to be paid to the protection against overpressure of vessels, such as heat exchangers, which have parts that are designed for a pressure which is below that to which they might be subjected in the case of rupture of the tubular bundles or coils contained therein and that have been designed for a higher pressure.

2.4.2 Other requirements

a) Access arrangement

The access requirements for boilers stated in [2.2.4] are also applicable for other pressure vessels.

b) Corrosion protection

Vessels and equipment containing media that might lead to accelerated corrosion are to be suitably protected.

c) Marking

- Each pressure vessel is to be fitted with a permanently attached plate made of non-corrosive metal, with indication of the following information, in addition to the identification marks (name of manufacturer, year and serial number):
  - the design pressure
  - the design temperature
  - the test pressure and the date of the test.
- Markings may be directly stamped on the vessel if this does not produce notches having an adverse influence on its behaviour in service.
- For smaller pressure vessels the indication of the design pressure only may be sufficient.

3 Design and construction - Fabrication and welding

3.1 General

3.1.1 Base materials

a) These requirements apply to boilers and pressure vessels made of steel of weldable quality.

b) Fabrication and welding of vessels made of other materials are to be the subject of special consideration.

3.1.2 Welding

a) Weldings are to be performed in accordance with welding procedures approved by the Society.

b) Manual and semi-automatic welding is to be performed by welders qualified by the Society.

c) The conditions under which the welding procedures, welding equipment and welders operate are to correspond to those specified in the relevant approvals or qualifications.

d) Both ordinary and special electric arc welding processes are covered in the following requirements.

3.1.3 Cutting of plates

a) Plates are to be cut by flame cutting, mechanical machining or a combination of both processes. For plates having a thickness less than 25 mm, cold shearing is admitted provided that the sheared edge is removed by machining or grinding for a distance of at least one quarter of the plate thickness with a minimum of 3 mm.

b) For flame cutting of alloy steel plates, preheating is to be carried out if necessary.

c) The edges of cut plates are to be examined for laminations, cracks or any other defect detrimental to their use.

3.1.4 Forming of plates

a) The forming processes are to be such as not to impair the quality of the material. The Society reserves the right to require the execution of tests to demonstrate the suitability of the processes adopted. Forming by hammering is not allowed.

b) Unless otherwise justified, cold formed shells are to undergo an appropriate heat treatment if the ratio of internal diameter after forming to plate thickness is less than 20. This heat treatment may be carried out after welding.

c) Before or after welding, hot formed plates are to be normalised or subjected to another treatment suitable for their steel grade, if hot forming has not been carried out within an adequate temperature range.

d) Plates which have been previously butt-welded may be formed under the following conditions:

- Hot forming

  After forming, the welded joints are to be subjected to X-ray examination or equivalent. In addition, mechanical tests of a sample weld subjected to the same heat treatment are to be carried out.

- Cold forming

  Cold forming is only allowed for plates having a thickness not exceeding:

  - 20 mm for steels having minimum ultimate tensile strength R_m between 360 N/mm^2 and 410 N/mm^2
  - 15 mm for steels having R_m between 460 N/mm^2 and 510 N/mm^2 as well as for steels 0,3Mo, 1Mn0,5Mo, 1Mn0,5MoV and 0,5Cr0,5Mo.

  Cold forming is not allowed for steels 1Cr0,5Mo and 2,25Cr1Mo.

- Weld reinforcements are to be carefully ground smooth prior to forming.
- A proper heat treatment is to be carried out after forming, if the ratio of internal diameter to thickness is less than 36, for steels: 460 N/mm^2, 510 N/mm^2, 0,3Mo, 1Mn0,5Mo, 1Mn0,5MoV and 0,5Cr0,5Mo.
- After forming, the joints are to be subjected to X-ray examination or equivalent and to a magnetic particle or liquid penetrant test.
- Refer to Fig 26 for definition of thickness to be taken in account.

3.2 Welding design

3.2.1 Main welded joints

a) All joints of class 1 and 2 pressure parts of boilers and pressure vessels are to be butt-welded, with the exception of welding connecting flat heads or tube sheets to shells, for which partial penetration welds or fillet welds may be accepted.

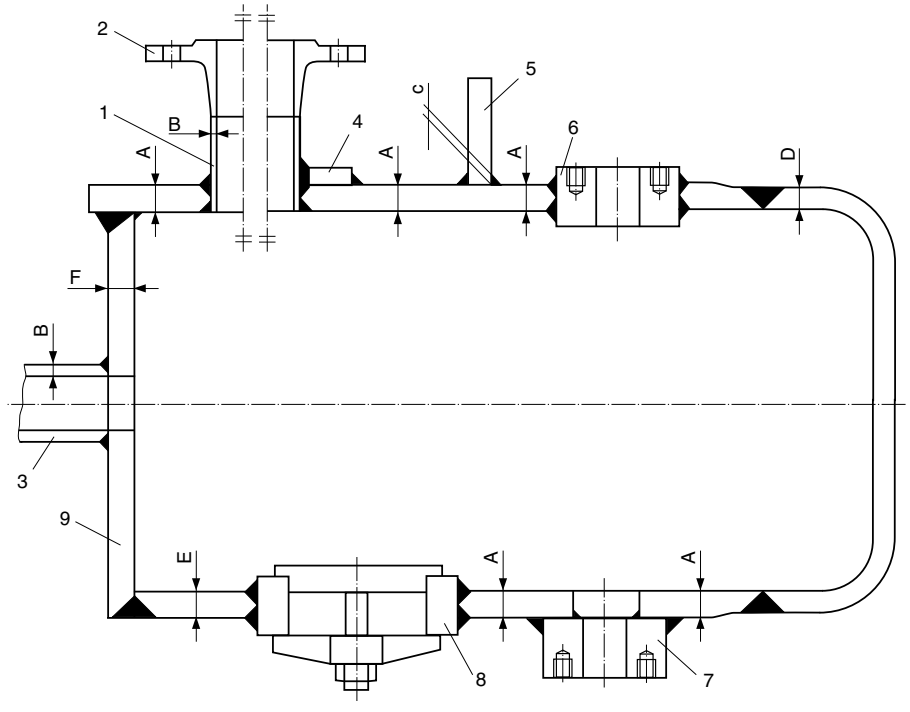
Fig 26 shows examples of acceptable welding for class 1 and 2 pressure vessels.

b) Joints of class 3 pressure vessels are also subject to the requirement in a), however connection of dished heads to shells by lap welds may be accepted. Fig 27 shows some acceptable details of circumferential lap welds for class 3 pressure vessels.

3.2.2 Shell longitudinal and circumferential welds

Longitudinal and circumferential joints are to be welded from both sides of the plate. Welding from one side may be allowed only when there is evidence that the welding process permits a complete penetration and a sound weld root. If a backing strip is used, it is to be removed after welding and prior to any non-destructive examination. However, the backing strip may be retained in circumferential joints of class 2 vessels, having a thickness not exceeding 15 mm, and of class 3 vessels, provided that the material of the backing strip is such as not to adversely affect the weld.

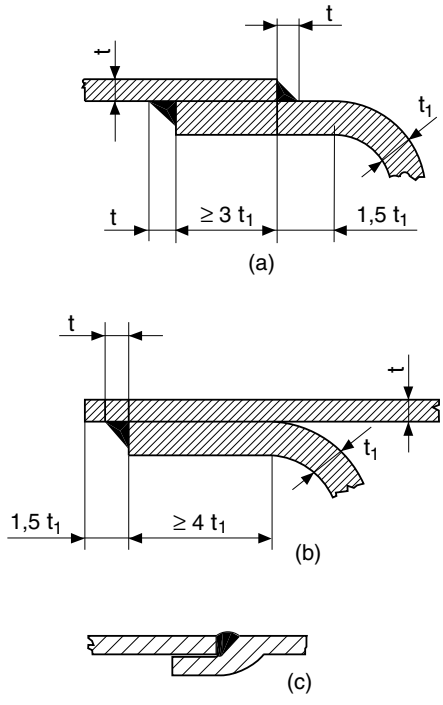
Figure 26 : Example of acceptable joints and thickness to be considered for forming and post-weld heat treatment



Key

1 : Nozzle (set in); **2** : Flange; **3** : Nozzle (set on); **4** : Reinforcing plate; **5** : Non-pressure part; **6** : Pad (set in); **7** : Pad (set on); **8** : Manhole frame; **9** : Flat plate.

Figure 27 : Example of acceptable lap-joints



Details (b) and (c) may be used only for pressure vessels having internal diameter less than 600mm.

3.2.3 Plates of unequal thickness

a) If plates of unequal thickness are butt-welded and the difference between thicknesses is more than 3 mm, the thicker plate is to be smoothly tapered for a length equal to at least four times the offset, including the width of the weld. For longitudinal joints the tapering is to be made symmetrically on both sides of the plate in order to obtain alignment of middle lines.

b) If the joint is to undergo radiographic examination, the thickness of the thicker plate is to be reduced to that of the thinner plate next to the joint and for a length of at least 30 mm.

3.2.4 Dished heads

a) For connection of a hemispherical end with a cylindrical shell, the joint is to be arranged in a plane parallel to that of the largest circle perpendicular to the axis of the shell and at such a distance from this plane that the tapering of the shell made as indicated in [1.5.6] is wholly in the hemisphere.

b) For torispherical ends made of parts assembled by welding, no welded joint is normally admitted along a parallel in the knuckle nor at a distance less than 50 mm from the beginning of the knuckle.

3.2.5 Welding location

The location of main welded joints is to be chosen so that these joints are not submitted to appreciable bending stresses.

Figure 28 : Types of joints for unstayed flat heads (1)

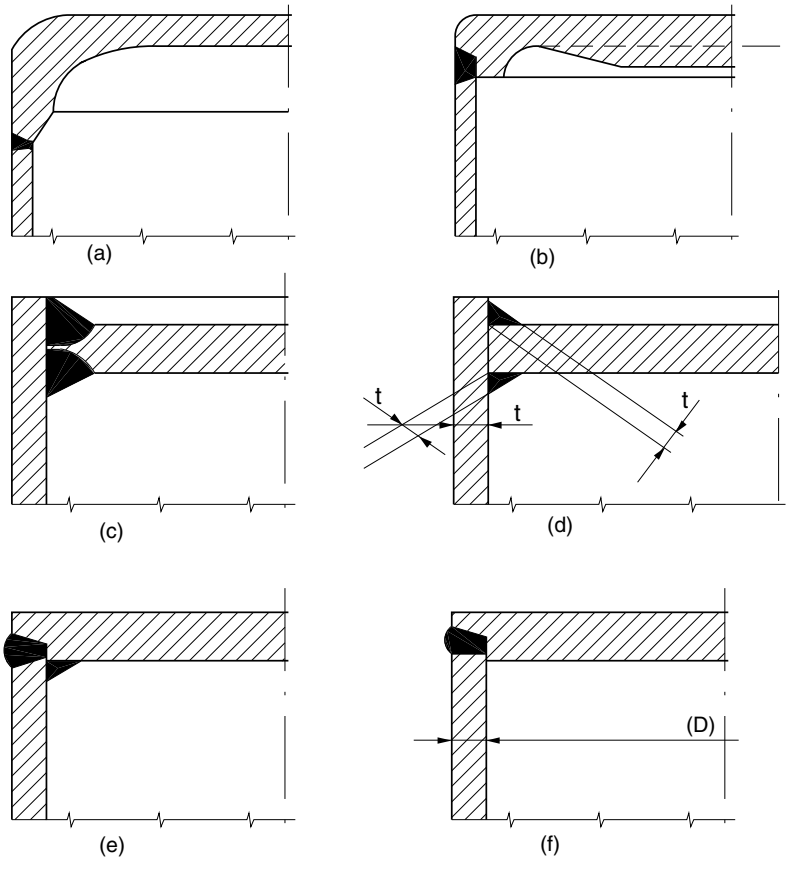
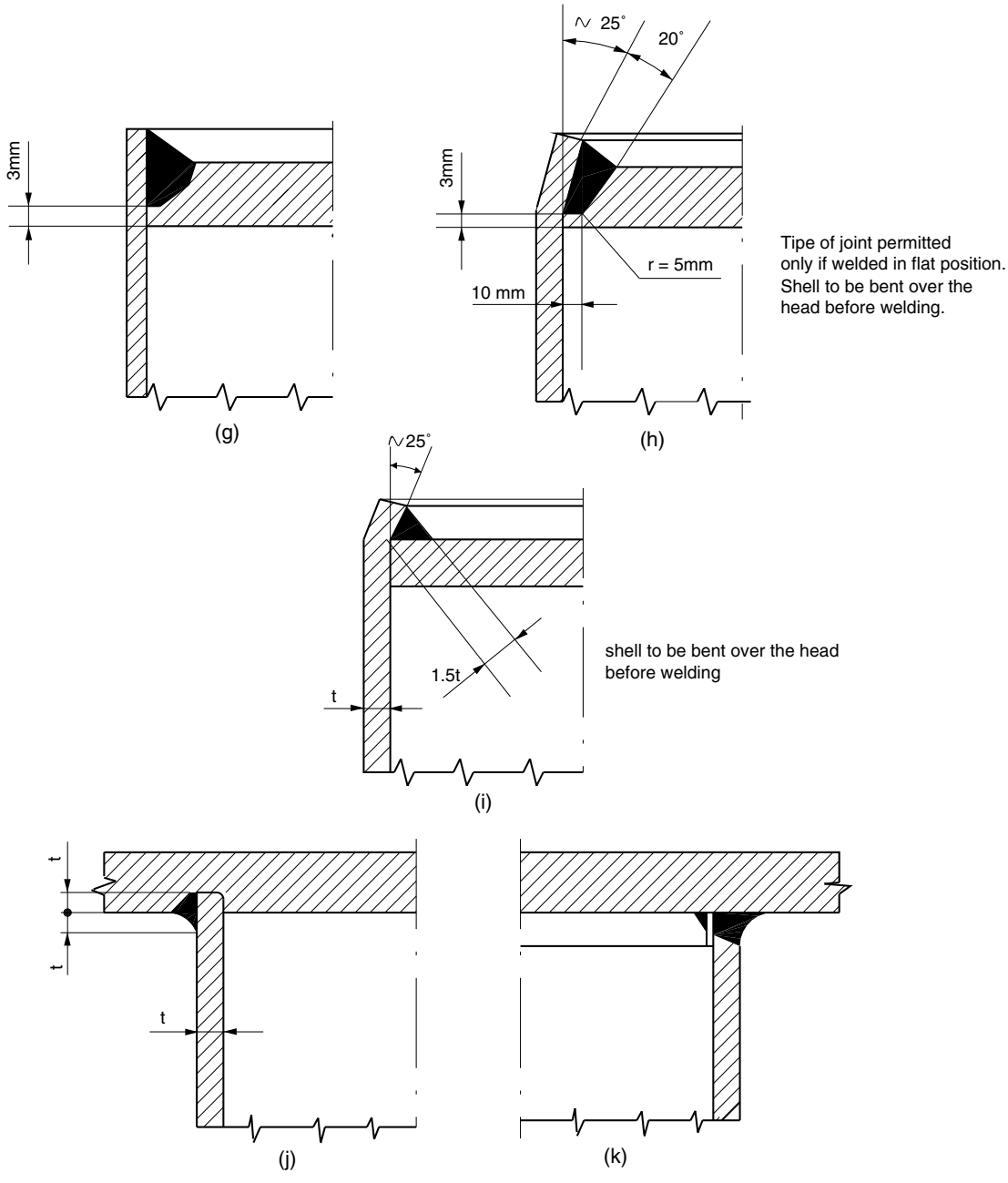


Figure 29 : Types of joints for unstayed flat heads (2)



3.2.6 Accessories and nozzles

a) Attachment of accessories by welds crossing main welds or located near such welds is to be avoided; where this is impracticable, welds for attachment of accessories are to completely cross the main welds rather than stop abruptly on or near them.

b) Openings crossing main joints or located near main joints are also to be avoided as far as possible.

c) Doubling plates for attachment of accessories such as fixing lugs or supports are to be of sufficient size to ensure an adequate distribution of loads on pressure parts; such doubling plates are to have well rounded corners. Attachment of accessories such as ladders and platforms directly on the walls of vessels such that they restrain their free contraction or expansion is to be avoided.

d) Welded connections of nozzles and other fittings, either with or without local compensation, are to be of a suitable type, size and preparation in accordance with the approved plans.

3.2.7 Connections of stays to tube plates

a) Where stays are welded, the cross-sectional area of the weld is to be at least 1,25 times the cross-section of the stay.

b) The cross-sectional area of the end welding of welded stay tubes is to be not less than 1,25 times the cross-sectional area of the stay tube.

Figure 30 : Types of joints for nozzles and reinforced rings (1)

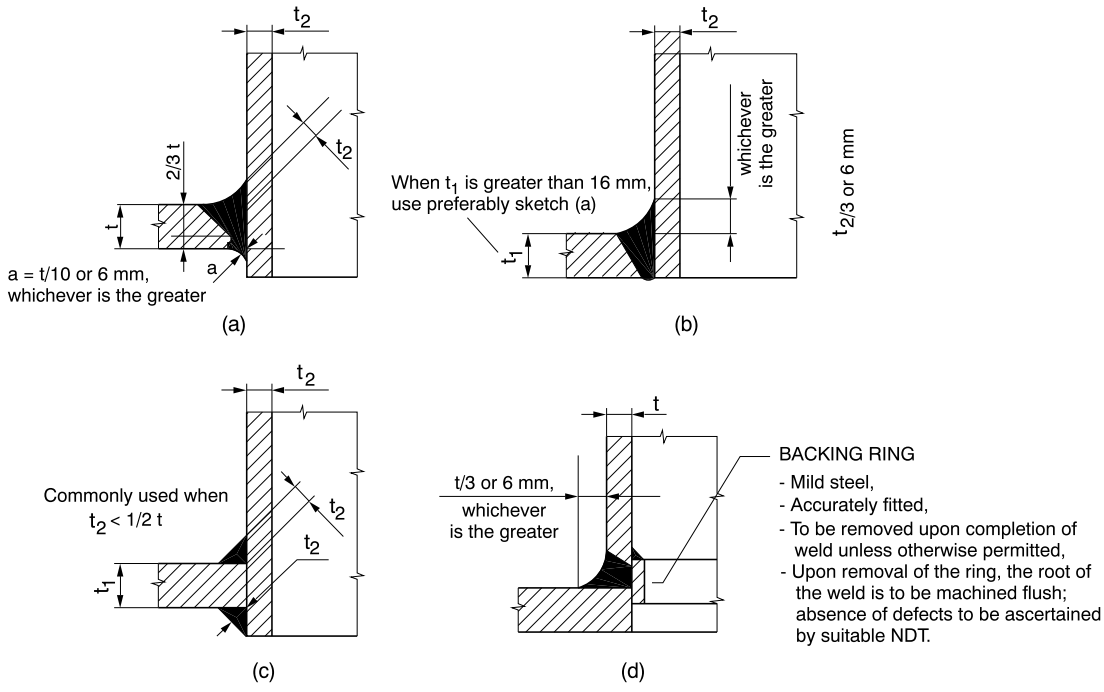
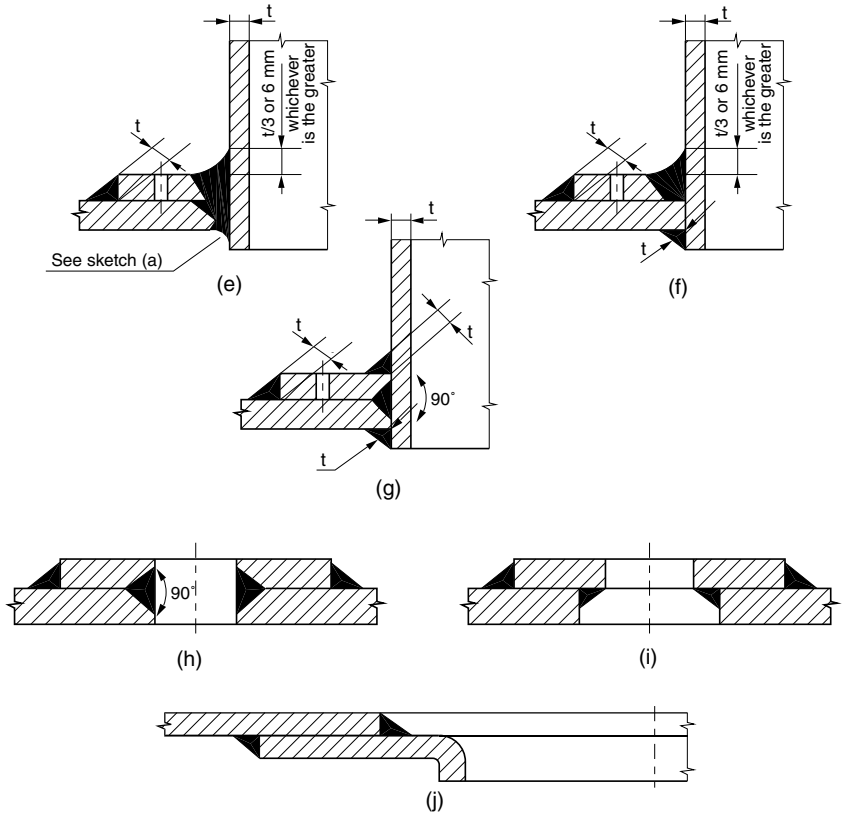


Figure 31 : Types of joints for nozzles and reinforcing rings (2)



3.2.8 Types of welding

Fig 28, Fig 29, Fig 30, Fig 31, Fig 32, Fig 33, Fig 34, Fig 35, Fig 36 and Fig 37 indicate the type and size of weldings of typical pressure vessel connections. Any alternative type of welding or size is to be the subject of special consideration by the Society.

Figure 32 : Types of joints for nozzles and reinforcing rings (3)

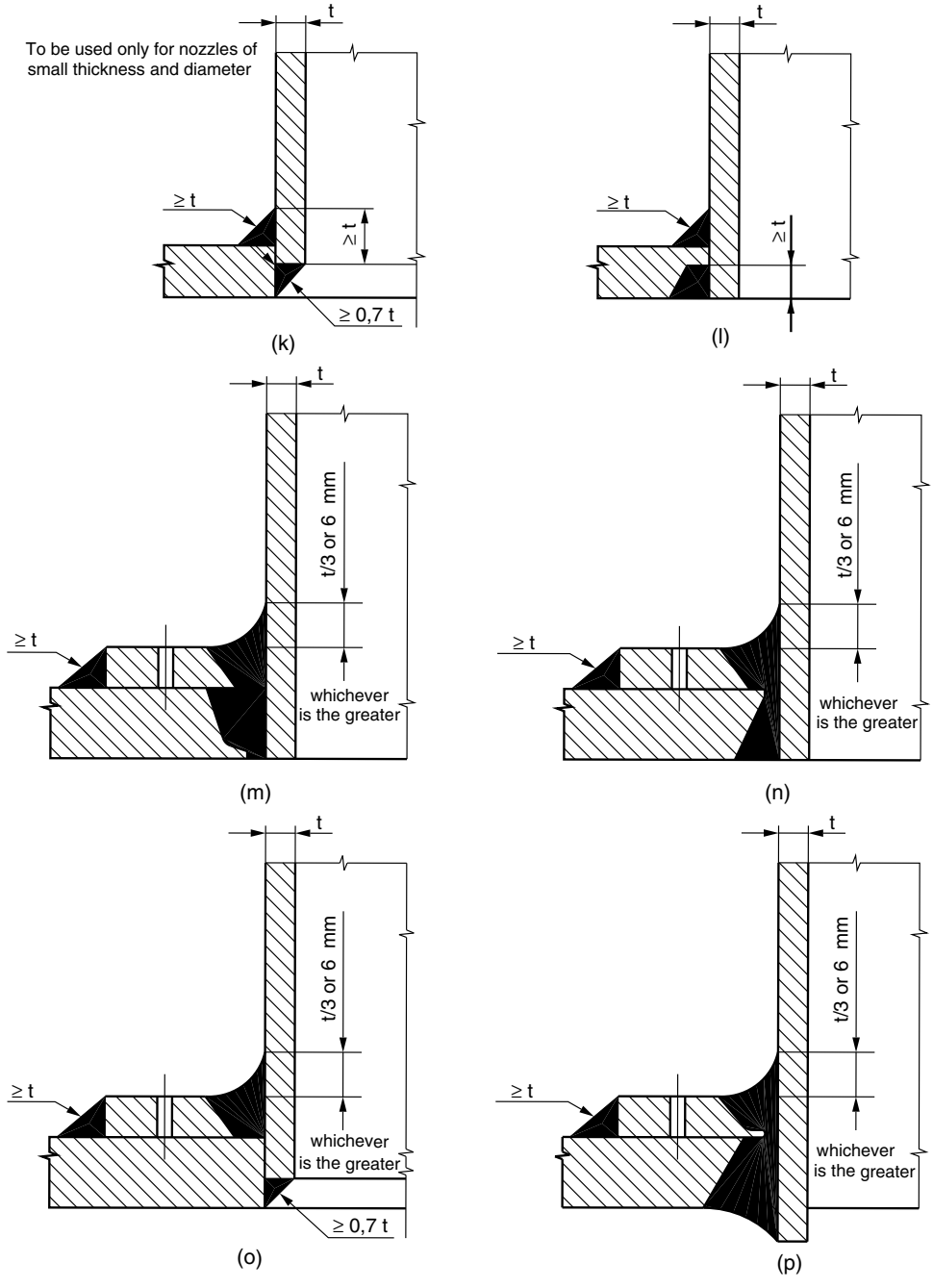
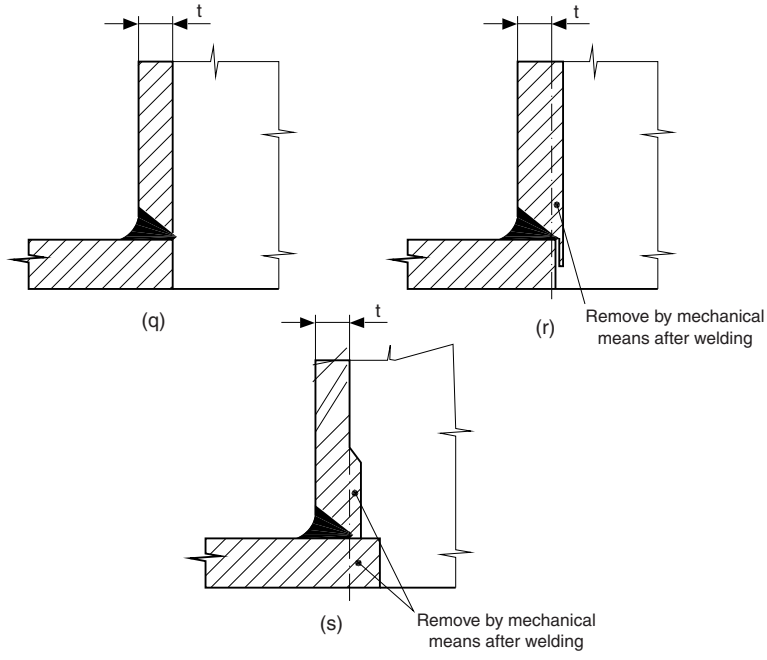


Figure 33 : Types of joints for nozzles (4)



Note: Where preparations of Fig 33 are carried out, the shell is to be carefully inspected to ascertain the absence of lamination.

Figure 34 : Types of joints for flanges to nozzles

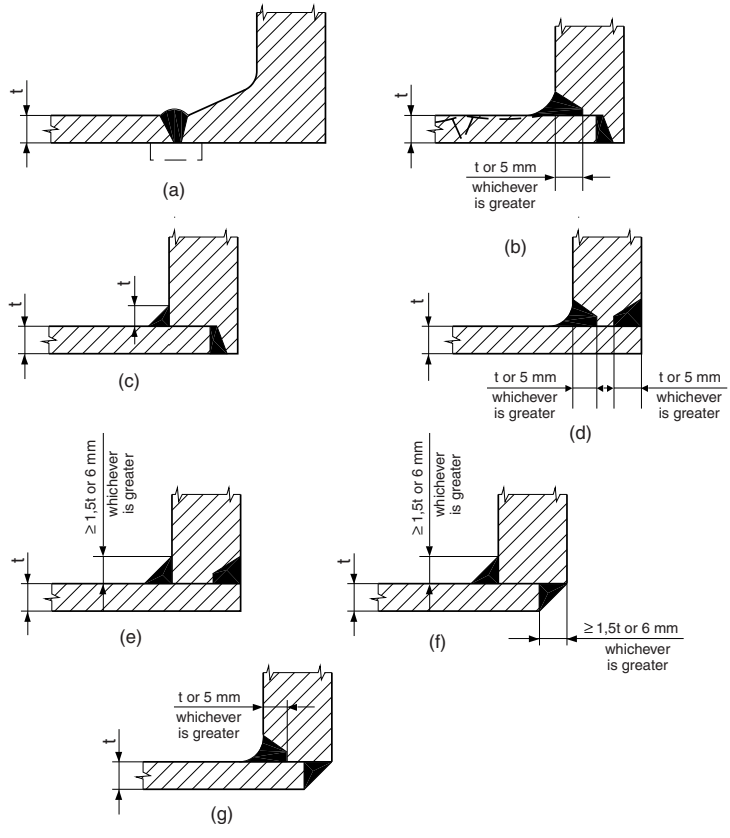


Figure 35 : Types of joints for tubesheets to shell (1)

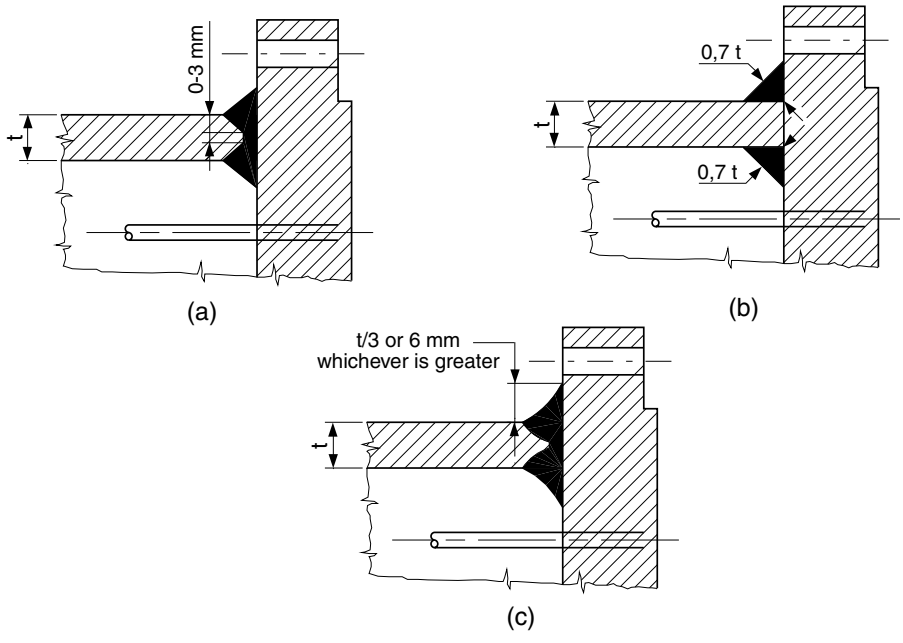


Figure 36 : Types of joints for tubesheets to shells (2)

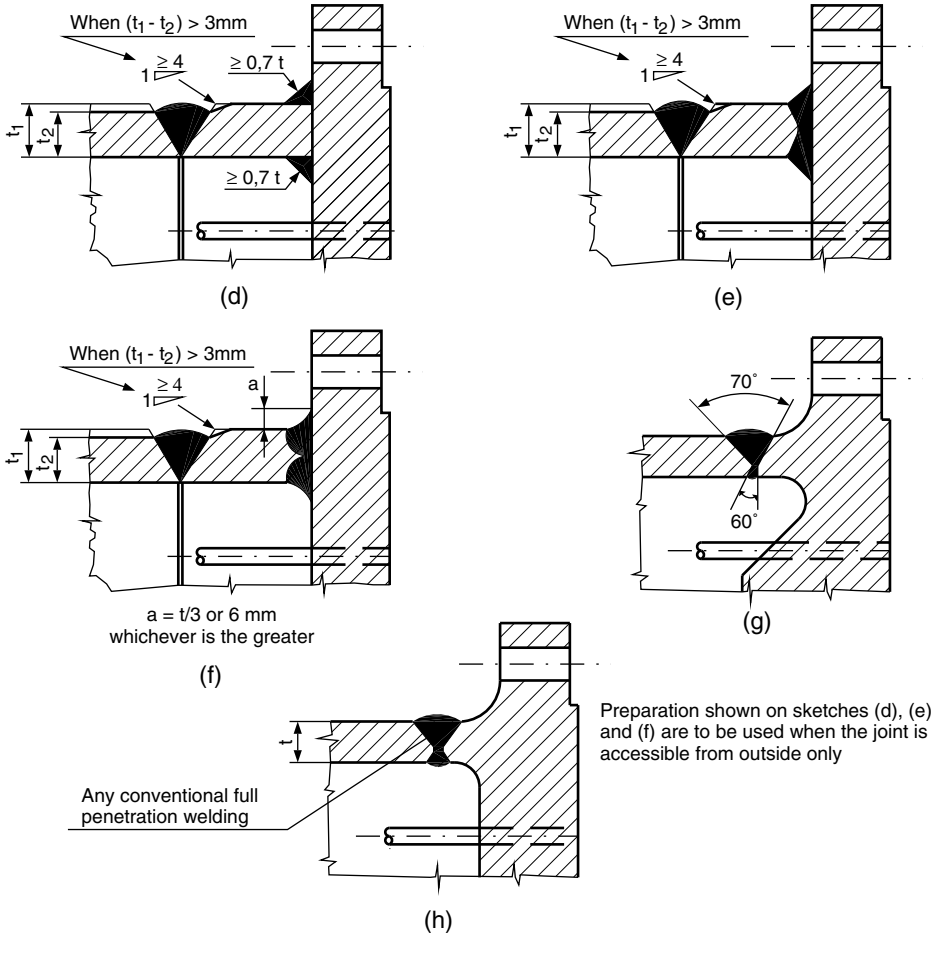
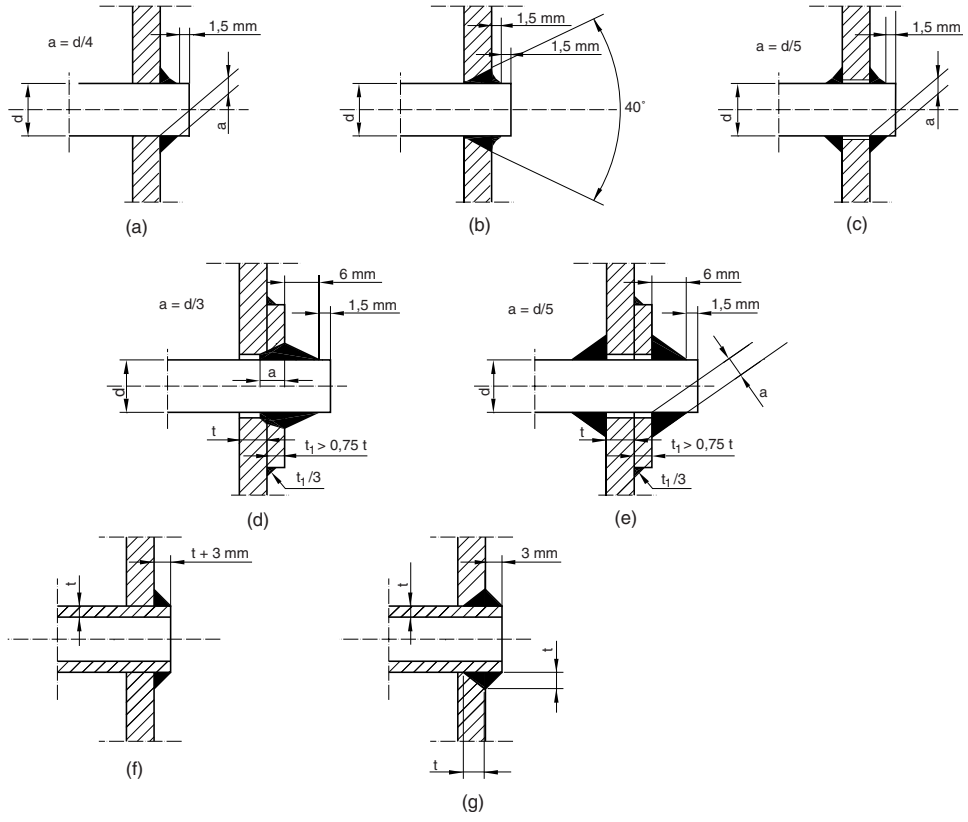


Figure 37 : Type of joints for stays and stay tubes



3.3 Miscellaneous requirements for fabrication and welding

3.3.1 Welding position

a) As far as possible, welding is to be carried out in the downhand horizontal position and arrangements are to be foreseen so that this can be applied in the case of circumferential joints.

b) When welding cannot be performed in this position, tests for qualification of the welding process and the welders are to take account thereof.

3.3.2 Cleaning of parts to be welded

a) Parts to be welded are, for a distance of at least 25 mm from the welding edges, to be carefully cleaned in order to remove any foreign matter such as rust, scale, oil, grease and paint.

b) If the weld metal is to be deposited on a previously welded surface, all slag or oxide is to be removed to prevent inclusions.

3.3.3 Protection against adverse weather conditions

a) Welding of pressure vessels is to be done in a sheltered position free from draughts and protected from cold and rain.

b) Unless special justification is provided, no welding is to be performed if the temperature of the base metal is less than 0°C.

3.3.4 Interruption in welding

If, for any reason, welding is stopped, care is to be taken on restarting to obtain a complete fusion.

3.3.5 Backing weld

When a backing weld is foreseen, it is to be carried out after suitable chiseling or chipping at the root of the first weld, unless the welding process applied does not call for such an operation.

3.3.6 Appearance of welded joints

a) Welded joints are to have a smooth surface without under-thickness; their connection with the plate surface is to be gradual without undercutting or similar defects.

b) The weld reinforcement of butt welds, on each side of the plate, is not to exceed the following thickness:

- 2,5 mm for plates having a thickness not exceeding 12 mm
- 3 mm for plates having a thickness greater than 12 mm but less than 25 mm
- 5 mm for plates having a thickness at least equal to 25 mm.

3.4 Preparation of parts to be welded

3.4.1 Preparation of edges for welding

a) Grooves and other preparations of edges for welding are to be made by machining, chipping or grinding. Flame cutting may also be used provided that the zones damaged by this operation are removed by machining, chipping or grinding. For alloy steel plates, preheating is to be provided, if needed, for flame cutting.

b) Edges prepared are to be carefully examined to check that there are no defects detrimental to welding.

3.4.2 Abutting of parts to be welded

a) Abutting of parts to be welded is to be such that surface misalignment of plates does not exceed:

- 10% of the thickness of the plate with a maximum of 3 mm for longitudinal joints
- 10% of the thickness of the plate plus 1 mm with a maximum of 4 mm for circumferential joints.

b) For longitudinal joints, middle lines are to be in alignment within 10% of the thickness of the thinner plate with a maximum of 3 mm.

c) Plates to be welded are to be suitably retained in position in order to limit deformation during welding. The arrangements are to be such as to avoid modification of the relative position of parts to be welded and misalignment, after welding, exceeding the limits indicated above.

d) Temporary welds for abutting are to be carried out so that there is no risk of damage to vessel shells. Such welds are to be carefully removed after welding of the vessel and before any heat treatment. Non-destructive testing of the corresponding zones of the shell may be required by the Surveyor if considered necessary.

e) Accessories such as doubling plates, brackets and stiffeners are to be suitable for the surface to which they are to be attached.

3.5 Tolerances after construction

3.5.1 General

The sizes and shape of vessels are to be checked after welding for compliance with the design taking into account the tolerances given below. The Society reserves the right to stipulate smaller values for these tolerances for vessels subjected to special loads.

Any defect in shape is to be gradual and there is to be no flat area in way of welded joints.

Measurements are to be taken on the surface of the parent plate and not on the weld or other raised part.

3.5.2 Straightness

The straightness of cylindrical shells is to be such that their deviation from the straight line does not exceed 0,6% of their length, with a maximum of 15 mm for each 5 m of length.

3.5.3 Out-of-roundness

a) Out-of-roundness of cylindrical shells is to be measured either when set up on end or when laid flat on their sides; in the second case, measures of diameters are to be repeated after turning the shell through 90° about its axis and out-of-roundness is to be calculated from the average of the two measures of each diameter.

b) For any transverse section, the difference between the maximum and minimum diameters is not to exceed 1% of the nominal diameter D with a maximum of:

(D + 1250) / 200, D being expressed in mm.

For large pressure vessels, this limit may be increased by a maximum of 0,2% of the internal diameter of the vessel. Any possible out-of-roundness within the above limit is to be gradual and there are to be no localised deformations in way of the welded joints.

3.5.4 Irregularities

Irregularities in profile of cylindrical shells, checked by a 20° gauge, are not to exceed 5% of the thickness of the plate plus 3 mm. This value may be increased by 25% if the length of the irregularity does not exceed one quarter of the distance between two circumferential seams, with a maximum of 1 mm.

3.6 Preheating

3.6.1

a) Preheating, to be effectively maintained during the welding operation, may be required by the Society when deemed necessary in relation to a number of circumstances, such as the type of steel, thickness of the base material, welding procedure and technique, type of restraint, and heat treatment after welding, if any.

b) The preheating temperature is to be determined accordingly. However, a preheating temperature of approximately 150°C is required for 0,5Mo or 1Cr0,5Mo type steel, and approximately 250°C for 2,25Cr1Mo type steel.

c) These requirements also apply to welding of nozzles, fittings, steam pipes and other pipes subject to severe conditions.

3.7 Post-weld heat treatment

3.7.1 General

a) When post-weld heat treatment of a vessel is to be carried out, such treatment is to consist of:

- heating the vessel slowly and uniformly up to a temperature suitable for the grade of steel
- maintaining this temperature for a duration determined in relation to the actual thickness t_A of the vessel and the grade of steel
- slowly cooling the vessel in the furnace down to a temperature not exceeding 400°C, with subsequent cooling allowed out of the furnace in still air.

b) As far as possible, vessels are to be heat treated in a single operation. However, when the sizes of the vessels are such that heat treatment requires several operations, care is to be taken such that all the parts of the vessels undergo heat treatment in a satisfactory manner. In particular, a cylindrical vessel of great length may be treated in sections in a furnace if the overlap of the heated sections is at least 1500 mm and if parts outside the furnace are lagged to limit the temperature gradient to an acceptable value.

3.7.2 Thermal stress relieving

Upon completion of all welding, including connections of nozzles, doublers and fittings, pressure vessels of classes 1 and 2, boilers and associated parts are to be subjected to an effective stress relieving heat treatment in the following cases:

- Pressure vessels of classes 1 and 2 containing fluids at a temperature not less than the ambient temperature, where the thickness exceeds that indicated in Tab 11
- Boilers and steam generators for thicknesses higher than 20 mm or, depending upon the type of steel, for lower thicknesses as required for class 1 pressure vessels.

Applications at temperatures less than the ambient temperature and/or steels other than those indicated above are to be the subject of special consideration by the Society.

Stress relieving heat treatment is not to be required when the minimum temperature of the fluid is at least 30°C higher than the KV-notch impact test temperature specified for the steel; this difference in temperature is also to be complied with for welded joints (both in heat-affected zones and in weld metal).

Table 11 : Thermal stress relieving

Grade	Thickness (mm) above which post-weld heat treatment is required	
	Boilers	Unfired pressure vessels
R_m = 360 N/mm² Grade HA R_m = 410 N/mm² Grade HA	14,5	14,5
R_m = 360 N/mm² Grade HB R_m = 410 N/mm² Grade HB	20,0	30,0
R_m = 360 N/mm² Grade HD R_m = 410 N/mm² Grade HD	20,0	38,0
R_m = 460 N/mm² Grade HB R_m = 510 N/mm² Grade HB	20,0	25,0
R_m = 460 N/mm² Grade HD R_m = 510 N/mm² Grade HD	20,0	35,0
0,3Mo 1Mn 0,5Mo 1Mn 0,5MoV 0,5Cr 0,5Mo	20,0	20,0
1Cr 0,5Mo 2,25Cr 1Mo	ALL	ALL

Pressure vessels and pipes of class 3 and associated parts are not required to be stress relieved, except in specific cases.

3.7.3 Heat treatment procedure

The temperature of the furnace at the time of introduction of the vessel is not to exceed 400°C.

a) The heating rate above 400°C is not to exceed:
   - 220°C per hour if the maximum thickness is not more than 25 mm, or
   - (5500 / t_A)°C per hour, with a minimum of 55°C per hour, if the maximum thickness t_A, in mm, is more than 25 mm

b) The cooling rate in the furnace is not to exceed:
   - –280°C per hour if the maximum thickness is not more than 25 mm, or
   - –(7000 / t_A)°C per hour, with a minimum of –55°C per hour, if the maximum thickness t_A, in mm, is more than 25 mm.

Unless specially justified, heat treatment temperatures and duration for maintaining these temperatures are to comply with the values in Tab 12.

Table 12 : Heat treatment procedure

Grade	Temperatures	Time per 25 mm of maximum thickness	Minimum time
Carbon steels	580-620°C	1 hour	1 hour
0,3Mo 1Mn 0,5Mo 1Mn 0,5MoV 0,5Cr 0,5Mo	620-660°C	1 hour	1 hour
1Cr 0,5Mo	620-660°C	1hour	2 hours
2,25Cr 1Mo	600-750°C **(1)**	2 hours	2 hours
(1) The temperature is to be chosen, with a tolerance of ± 20°C, in this temperature range in order to obtain the required mechanical characteristics			

3.7.4 Alternatives

When, for special reasons, heat treatment is carried out in conditions other than those given in [3.7.2], all details regarding the proposed treatment are to be submitted to the Society, which reserves the right to require tests or further investigations in order to verify the efficiency of such treatment.

3.7.5 Execution of heat treatment

Furnaces for heat treatments are to be fitted with adequate means for controlling and recording temperature; temperatures are to be measured on the vessel itself. The atmosphere in the furnaces is to be controlled in order to avoid abnormal oxidation of the vessel.

3.7.6 Treatment of test plates

Test plates are normally to be heated at the same time and in the same furnace as the vessel.

When separate heat treatment of test plates cannot be avoided, all precautions are to be taken such that this treatment is carried out in the same way as for the vessel, specifically with regard to the heating rate, the maximum temperature, the duration for maintaining this temperature and the cooling conditions.

3.7.7 Welding after heat treatment

a) Normally, welding after heat treatment is only allowed if:
   - the throat of welding fillets does not exceed 10 mm
   - the largest dimension of openings in the vessel for the accessories concerned does not exceed 50 mm.

b) Any welding of branches, doubling plates and other accessories on boilers and pressure vessels after heat treatment is to be submitted for special examination by the Society.

3.8 Welding samples

3.8.1 Test plates for welded joints

a) Test plates of sufficient size, made of the same grade of steel as the shell plates, are to be fitted at each end of the longitudinal joints of each vessel so that the weld in the test plates is the continuation of these welded joints. There is to be no gap when passing from the deposited metal of the joint to the deposited metal of the test plate.

b) No test plate is required for circumferential joints if these joints are made with the same process as longitudinal joints. Where this is not the case, or if there are only circumferential joints, at least one test plate is to be welded separately using the same welding process as for the circumferential joints, at the same time and with the same welding materials.

c) Test plates are to be stiffened in order to reduce as far as possible warping during welding. The plates are to be straightened prior to their heat treatment which is to be carried out in the same conditions as for the corresponding vessel (see also [3.7.6]).

d) After radiographic examination, the following test pieces are to be taken from the test plates:
   - one test piece for tensile test on welded joint
   - two test pieces for bend test, one direct and one reverse
   - three test pieces for impact test
   - one test piece for macrographic examination.

3.8.2 Mechanical tests of test plates

a) The tensile strength on welded joint is not to be less than the minimum specified tensile strength of the plate.

b) The bend test pieces are to be bent through an angle of 180° over a former of 4 times the thickness of the test piece. There is to be no crack or defect on the outer surface of the test piece exceeding in length 1,5 mm transversely or 3 mm longitudinally. Premature failure at the edges of the test piece is not to lead to rejection. As an alternative, the test pieces may be bent through an angle of 120° over a former of 3 times the thickness of the test piece.

c) The impact energy measured at 0°C is not to be less than the values given in NR216 Materials and Welding for the steel grade concerned.

d) The test piece for macrographic examination is to permit the examination of a complete transverse section of the weld. This examination is to demonstrate good penetration without lack of fusion, large inclusions and similar defects. In case of doubt, a micrographic examination of the doubtful zone may be required.

3.8.3 Re-tests

a) If one of the test pieces yields unsatisfactory results, two similar test pieces are to be taken from another test plate.

b) If the results for these new test pieces are satisfactory and if it is proved that the previous results were due to local or accidental defects, the results of the re-tests may be accepted.

3.9 Specific requirements for class 1 vessels

3.9.1 General

The following requirements apply to class 1 pressure vessels, as well as to pressure vessels of other classes, whose scantlings have been determined using an efficiency of welded joint e greater than 0,90.

3.9.2 Non-destructive tests

a) All longitudinal and circumferential joints of class 1 vessels are to be subject of 100% radiographic or equivalent examination with the following exceptions:
   - for pressure vessels or parts designed to withstand external pressures only, at the Society's discretion, the extent may be reduced up to approximately 30% of the length of the joints. In general, the positions included in the examinations are to include all welding crossings.
   - for vessels not intended to contain toxic or dangerous matters, made of carbon steels having thickness below 20 mm when the joints are welded by approved automatic processes at the Society's discretion, the extent may be reduced up to approximately 10% of the length of the joints. In general, the positions included in the examinations are to include all welding crossings.
   - for circumferential joints having an external diameter not exceeding 175 mm, at the Society's discretion, the extent may be reduced up to approximately 10% of the total length of the joints.

b) Fillet welds for parts such as doubling plates, branches or stiffeners are to undergo a spot magnetic particle test for at least 10% of their length. If magnetic particle tests cannot be used, it is to be replaced by liquid penetrant test.

c) Welds for which non destructive tests reveal unacceptable defects, such as cracks or areas of incomplete fusion, are to be rewelded and are then to undergo a new non destructive examination.

3.9.3 Number of test samples

a) During production, at least one test plate for each 20 m of length (or fraction) of longitudinal weldings is to be tested as per [3.8.2].

b) During production, at least one test plate for each 30 m of length (or fraction) of circumferential welding is to be tested as per [3.8.2].

c) When several vessels made of plates of the same grade of steel, with thicknesses varying by not more than 5 mm, are welded successively, only one test plate may be accepted per each 20 m of length of longitudinal joints (or fraction) and per each 30 m of circumferential welding (or fraction) provided that the welders and the welding process are the same. The thickness of the test plates is to be the greatest thickness used for these vessels.

3.10 Specific requirements for class 2 vessels

3.10.1 General

For vessels whose scantlings have been determined using an efficiency of welded joint e greater than 0,90, see [3.9.1].

3.10.2 Non-destructive tests

All longitudinal and circumferential joints of class 2 vessels are to be subjected to radiographic or equivalent examination to an extent of 10% of each weld length. This examination is to cover all the junctions between welds.

This extension may be increased at the Society's discretion depending on the actual thickness of the welded plates.

For actual thickness ≤ 15 mm, this examination can be omitted. In this case, the value of the efficiency should be as indicated in Tab 5.

3.10.3 Number of test samples

In general, the same requirements of [3.9.3] apply also to class 2 pressure vessels. However, test plates are required for each 50 m of longitudinal and circumferential weldings (or fraction).

3.11 Specific requirements for class 3 vessels

3.11.1 For vessels whose scantlings have been determined using an efficiency of welded joint e greater than 0,90, see [3.9.1].

Heat treatment, mechanical tests and non-destructive tests are not required for welded joints of other class 3 vessels.

4 Design and construction - Control and monitoring

4.1 Boiler control and monitoring system

4.1.1 Local control and monitoring

Means to effectively operate, control and monitor the operation of oil fired boilers and their associated auxiliaries are to be provided locally. The functional condition of the fuel, feed water and steam systems and the boiler operational status are to be indicated by pressure gauges, temperature indicators, flow-meter, lights or other similar devices.

4.1.2 Emergency shut-off

Means are to be provided to shut down boiler forced draught or induced draught fans and fuel oil service pumps from outside the space where they are located, in the event that a fire in that space makes their local shut-off impossible.

4.1.3 Water level indicators

a) Each boiler is to be fitted with at least two separate means for indicating the water level. One of these means is to be a level indicator with transparent element. The other may be either an additional level indicator with transparent element or an equivalent device. Level indicators are to be of an approved type.

b) The transparent element of level indicators is to be made of glass, mica or other appropriate material.

c) Level indicators are to be located so that the water level is readily visible at all times. The lower part of the transparent element is not to be below the safety water level defined by the builder.

d) Level indicators are to be fitted either with normally closed isolating cocks, operable from a position free from any danger in case of rupture of the transparent element or with self-closing valves restricting the steam release in case of rupture of this element.

4.1.4 Water level indicators - Special requirements for water tube boilers

a) For water tube boilers having an athwartships steam drum more than 4 m in length, a level indicator is to be fitted at each end of the drum.

b) Water tube boilers serving turbine propulsion machinery are to be fitted with a high-water-level audible and visual alarm (see also Tab 14).

Table 13 : Minimum internal diameters d_N and d_C

Internal diameter of the boiler	d_N (mm)	d_C (mm)
D > 3 m	60	38
2,30 m ≤ D ≤ 3 m	50	32
D < 2,30 m	45	26

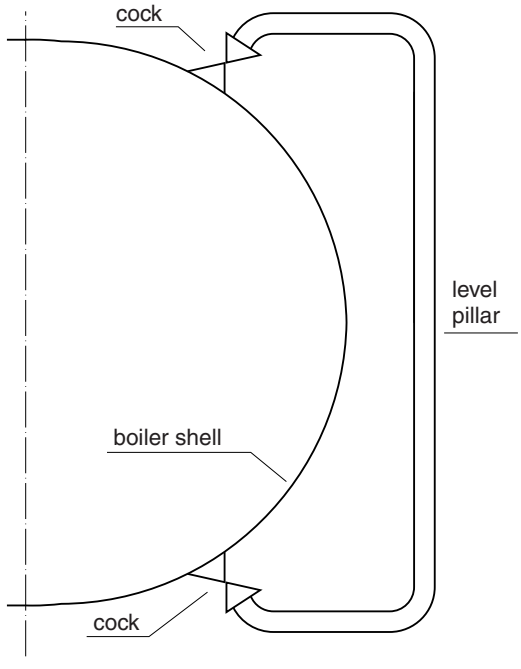
4.1.5 Water level indicators - Special requirements for fire tube boilers (vertical and cylindrical boilers)

a) For cylindrical boilers, the two water level indicators mentioned in [4.1.3] are to be distributed at each end of the boiler; i.e. double front cylindrical boilers are to have two level indicators on each front.

b) A system of at least two suitably located and remote controlled gauge-cocks may be considered as the equivalent device mentioned in [4.1.3] for cylindrical boilers having a design pressure lower than 1 MPa, for cylindrical boilers having a diameter lower than 2 m and for vertical boilers having height lower than 2,3 m. Gauge-cocks are to be fixed directly on the boiler shell.

c) Where level indicators are not fixed directly on the boiler shell, but on level pillars, the internal diameter of such pillars is not to be less than the value d_N given in Tab 13. Level pillars are to be either fixed directly on the boiler shell or connected to the boiler by pipes fitted with cocks secured directly to the boiler shell. The internal diameter of these pipes d_C is not to be less than the values given in Tab 13. The upper part of these pipes is to be arranged so that there is no bend where condense water can accumulate. These pipes are not to pass through smoke boxes or uptakes unless they are located inside metallic ducts having internal diameter exceeding by not less than 100 mm the external diameter of the pipes. Fig 38 shows the sketch of a level pillar arrangement.

Figure 38 : Level pillar arrangement



4.1.6 Pressure control devices

a) Each boiler is to be fitted with a steam pressure gauge so arranged that its indications are easily visible from the stokehold floor. A steam pressure gauge is also to be provided for superheaters which can be shut off from the boiler they serve.

b) Pressure gauges are to be graduated in units of effective pressure and are to include a prominent legible mark for the pressure that is not to be exceeded in normal service.

c) Each pressure gauge is to be fitted with an isolating cock.

d) Double front boilers are to have a steam pressure gauge arranged in each front.

4.1.7 Temperature control devices

Each boiler fitted with a superheater is to have an indicator or recorder for the steam temperature at the superheater outlet.

4.1.8 Automatic shut-off of oil fired propulsion and auxiliary boilers

a) Each burner is to be fitted with a flame scanner designed to automatically shut off the fuel supply to the burner in the event of flame failure. In the case of failure of the flame scanner, the fuel to the burner is to be shut off automatically.

b) A low water condition is to automatically shut off the fuel supply to the burners. The shut-off is to operate before the water level reaches a level so low as to affect the safety of the boiler and no longer be visible in the gauge glass. Means are to be provided to minimise the risk of shut-off provoked by the effect of roll and pitch and/or transients. This shut-off system need not be installed in auxiliary boilers which are under local supervision and are not intended for automatic operation.

c) Forced draft failure is to automatically shut off the fuel supply to the burners.

d) Loss of boiler control power is to automatically shut off the fuel supply to the burners.

4.1.9 Alarms

Any actuation of the fuel-oil shut-off listed in [4.1.8] is to operate a visual and audible alarm.

4.1.10 Additional requirements for boilers fitted with automatic control systems

a) The flame scanner required in [4.1.8], item a) is to operate within 6 seconds from the flame failure.

b) A timed boiler purge with all air registers open is to be initiated manually or automatically when boilers are fitted with an automatic ignition system. The purge time is based on a minimum of 4 air changes of the combustion chamber and furnace passes. Forced draft fans are to be operating and air registers and dampers are to be open before the purge time commences.

c) Means are to be provided to bypass the flame scanner control system temporarily during a trial-for-ignition for a period of 15 seconds from the time the fuel reaches the burners. Except for this trial-for-ignition period, no means are to be provided to bypass one or more of the burner flame scanner systems unless the boiler is locally controlled.

d) Where boilers are fitted with an automatic ignition system, and where residual fuel oil is used, means are to be provided for lighting of burners with igniters lighting properly heated residual fuel oil. In the case of flame failure, the burner is to be brought back into automatic service only in the low-firing position.

e) An alarm is to be activated whenever a burner operates outside the limit conditions stated by the manufacturer.

f) Immediately after normal shutdown, an automatic purge of the boiler equal to the volume and duration of the pre-purge is to occur. Following automatic fuel valve shut-off, the air flow to the boiler is not to automatically increase; post-purge in such cases is to be carried out under manual control.

g) Propulsion and auxiliary boilers associated with propulsion machinery intended for centralised, unattended operations are to comply with the requirements of Part C, Chapter 3.

4.2 Pressure vessel instrumentation

4.2.1

a) Pressure vessels are to be fitted with the necessary devices for checking pressure, temperature and level, where it is deemed necessary.

b) In particular, each air pressure vessel or air group is to be fitted with a local manometer.

4.3 Control and monitoring requirements

4.3.1 Tab 14 and Tab 15 summarise the control and monitoring requirements for main propulsion boilers and auxiliary boilers, respectively.

5 Arrangement and installation

5.1 Foundations

5.1.1 For boilers and pressure vessels bolting down to their foundations, see Ch 3, Sec 1, [2.3]. Where necessary, they are also to be secured to the adjacent hull structures by suitable ties.

Where chocks are required to be fitted between the boilers and their foundations, they are to be of cast iron or steel.

5.2 Boilers

5.2.1 Thermal expansion

Means are to be provided to compensate thermal expansion of boilers.

5.2.2 Minimum distance of boilers from vertical bulkheads and fuel tanks

a) The distance between boilers and vertical bulkheads is to be not less than the minimum distance necessary to provide access for inspection and maintenance of the structure adjacent to the boiler.

b) In addition to the requirement in a), the distance of boilers from fuel oil tanks is to be such as to prevent the possibility that the temperature of the tank bulkhead may approach the flash point of the oil.

c) In any event, the distance between a boiler and a vertical bulkhead is not to be less than 450 mm.

5.2.3 Minimum distance of boilers from double bottom

a) Where double bottoms in way of boilers may be used to carry fuel oil, the distance between the top of the double bottom and the lower metal parts of the boilers is not to be less than:

- 600 mm, for cylindrical boilers
- 750 mm, for water tube boilers.

b) The minimum distance of vertical tube boilers from double bottoms not intended to carry oil may be 200 mm.

5.2.4 Minimum distance of boilers from ceilings

a) A space sufficient for adequate heat dissipation is to be provided on the top of boilers.

b) Oil tanks are not permitted to be installed in spaces above boilers.

5.2.5 Installation of boilers on engine room flats

Where boilers are installed on an engine room flat and are not separated from the remaining space by means of a watertight bulkhead, a coaming of at least 200 mm in height is to be provided on the flat. The area surrounded by the coaming may be drained into the bilge.

5.2.6 Drip trays and gutterways

Boilers are to be fitted with drip trays and gutterways in way of burners so arranged as to prevent spilling of oil into the bilge.

5.2.7 Hot surfaces

Hot surfaces with which the crew are likely to come into contact during operation are to be suitably guarded or insulated. See Ch 3, Sec 1, [2.7].

5.2.8 Registers fitted in the smoke stacks of oil fired boilers

Where registers are fitted in smoke stacks, they are not to obstruct more than two thirds of the cross-sectional area of gas passage when closed. In addition, they are to be provided with means for locking them in open position when the boiler is in operation and for indicating their position and degree of opening.

5.3 Pressure vessels

5.3.1 Safety devices on multiple pressure vessels

Where two or more pressure vessels are interconnected by a piping system of adequate size so that no branch of piping may be shut off, it is sufficient to provide them with one safety valve and one pressure gauge only.

Table 14: Main propulsion boilers

Symbol convention H = High, HH = High high, G = Group alarm L = Low, LL = Low low, I = Individual alarm X = Function is required, R = Remote	Monitoring		Automatic control				
			Boiler			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil							
• Fuel oil delivery pressure or flow	L						
• Fuel oil temperature after heater or viscosity fault	L + H	local					
• Master fuel oil valve position (open / close)		local					
• Fuel oil input burner valve position (open / close)		local					
Combustion							
• Flame failure of each burner	X						
• Failure of atomizing fluid	X					5	
• Boiler casing and economizer outlet smoke temperature (in order to detect possible fire out-break)	H						
	HH			X			
Air							
• Air register position		local					
General steam							
• Superheated steam pressure	L + H	local					
					X		
• Superheated steam temperature	H	local					
• Lifting of safety valve (or equivalent: high pressure alarm for instance)	X						
• Water level inside the drum of each boiler	L + H	local **(1)**					
	LL			X			
					X		
(1) Duplication of level indicator is required.							

Table 15 : Auxiliary boilers

Symbol convention H = High, HH = High high, G = Group alarm L = Low, LL = Low low, I = Individual alarm X = Function is required, R = Remote	Monitoring		Automatic control				
			Boiler			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Water level	L + H	local					
	LL			X			
Circulation stopped (when forced circulation boiler)	X			X			
Fuel oil temperature	L + H	local					
Flame failure	X			X			
Temperature in boiler casing (Fire)	H						
Steam pressure	H **(1)**	local		X			
(1) When the automatic control does not cover the entire load range from zero load.							

Part D
Systems

Chapter 4
POWER SUPPLY

SECTION 1 GENERAL

SECTION 2 GENERAL DESIGN REQUIREMENTS

SECTION 3 SYSTEM DESIGN

SECTION 4 ROTATING MACHINES

SECTION 5 TRANSFORMERS

SECTION 6 SEMICONDUCTOR CONVERTORS

SECTION 7 STORAGE BATTERIES AND CHARGERS

SECTION 8 SWITCH GEAR AND CONTROL GEAR ASSEMBLIES

SECTION 9 CABLES

SECTION 10 MISCELLANEOUS EQUIPMENT

SECTION 11 LOCATION

SECTION 12 INSTALLATION

SECTION 13 ELECTRIC PROPULSION PLANT

SECTION 14 TESTING

APPENDIX 1 INDIRECT TEST METHOD FOR SYNCHRONOUS MACHINES

SECTION 1 GENERAL

1 Application

1.1 General

1.1.1 The requirements of this Chapter apply to electrical installations on submarines. In particular, they apply to the components of electrical installations for essential services:

The other parts of the installation are to be so designed as not to introduce any risks or malfunctions to the above services.

1.2 References to other regulations and standards

1.2.1 The Society may refer to other regulations and standards when deemed necessary. These include the IEC publications, notably the IEC 60092 series.

1.2.2 When referred to by the Society, publications by the International Electrotechnical Commission (IEC) or other internationally recognised standards (OTAN to be checked), are those currently in force at the date of agreement for ship classification.

2 Documentation to be submitted

2.1

2.1.1 The documents listed in Tab 1 are to be submitted.

The list of documents requested is to be intended as guidance for the complete set of information to be submitted, rather than an actual list of titles.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Documents to be submitted
1	A	General arrangement of electrical installation, lay out of main battery
2	A	Single line diagram of main power and lighting systems
3	I	Electrical power balance (Ch 4, Sec 3, [2])
4	A	Calculation of short-circuit currents for each installation in which the sum of rated power of the energy sources which may be connected contemporaneously to the network is greater than 500 kVA (kW)
5	A	List of circuits including, for each supply and distribution circuit, data concerning the nominal current, the cable type, length and cross-section, nominal and setting values of the protective and control devices
6	A	Single line diagram and detailed diagram of the main switchboard
7	A	Diagram of the most important section boards and motor control boards (above 100 kW)
8	A	Diagram of the supply for monitoring and control systems of propulsion motors
9	A	Diagram of the general emergency alarm system, of the public address system and other intercommunication systems
10	A	Detailed diagram of the navigation-light switchboard
11	A	List of batteries including type and manufacturer, voltage and capacity, location and equipment and/or system(s) served (when used for essential services)
12	A	Single line diagram of electric propulsion
13	A	Principles of control system of electric propulsion and its power supply
14	A	Alarm and monitoring system of electric propulsion including: • list of alarms and monitoring points • power supply diagram
15	A	Safety system of electric propulsion including: • list of monitored parameters for safety system • power supply diagram
16	I	Arrangements and details of the electric propulsion control consoles and panels
17	I	Arrangements and details of the frequency convertors together with the justification of their characteristics
18	I	Arrangements of the cooling system provided for the frequency convertor and motor enclosure
19	A	Test program for convertors and rotating machines having rated power > 1 MW, dock and sea trials
(1) A : to be submitted for approval I : to be submitted for information.		

The Society reserves the right to request the submission of additional documents in the case of non-conventional design or if it is deemed necessary for the evaluation of the system, equipment or components.

Unless otherwise agreed with the Society, documents for approval are to be sent in triplicate if submitted by the Shipyard and in four copies if submitted by the equipment supplier.

Documents requested for information are to be sent in duplicate.

In any case, the Society reserves the right to require additional copies when deemed necessary.

3 Definitions

3.1 General

3.1.1 Unless otherwise stated, the terms used in this Chapter have the definitions laid down by the IEC standards.

The definitions given in the following requirements also apply.

3.2 Essential services

3.2.1 Essential services are defined in Pt A, Ch 1, Sec 1, [1.2.1].

3.3 Safety voltage

3.3.1 A voltage which does not exceed 50 V a.c. r.m.s. between conductors, or between any conductor and earth, in a circuit isolated from the supply by means such as a safety isolating transformer.

3.3.2 A voltage which does not exceed 50 V d.c. between conductors or between any conductor and earth in a circuit isolated from higher voltage circuits.

3.4 Low-voltage systems

3.4.1 Alternating current systems with rated voltages greater than 50 V r.m.s. up to 1000 V r.m.s. inclusive and direct current systems with a maximum instantaneous value of the voltage under rated operating conditions greater than 50 V up to 1500 V inclusive.

3.5 High-voltage systems

3.5.1 Alternating current systems with rated voltages greater than 1000 V r.m.s. and direct current systems with a maximum instantaneous value of the voltage under rated operating conditions greater than 1500 V.

3.6 Basic insulation

3.6.1 Insulation applied to live parts to provide basic protection against electric shock.

Note 1: Basic insulation does not necessarily include insulation used exclusively for functional purposes.

3.7 Supplementary insulation

3.7.1 Independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation.

3.8 Double insulation

3.8.1 Insulation comprising both basic insulation and supplementary insulation.

3.9 Reinforced insulation

3.9.1 A single insulation system applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation.

Note 1: The term "insulation system" does not imply that the insulation must be one homogeneous piece. It may comprise several layers which cannot be tested singly as supplementary or basic insulation.

3.10 Earthing

3.10.1 The earth connection to the general mass of the hull of the ship in such a manner as will ensure at all times an immediate discharge of electrical energy without danger.

3.11 Normal operational and habitable condition

3.11.1 A condition under which the ship as a whole, the machinery, services, means and aids ensuring propulsion, ability to steer, safe navigation, payload, fire and flooding safety, internal and external communications and signals, means of escape, as well as the designed comfortable conditions of habitability are in working order and functioning normally.

3.12 Emergency condition

3.12.1 A condition under which any services needed for normal operational and habitable conditions are not in working order due to failure of the main source of electrical power.

3.13 DG

3.13.1 DG means a diesel genset delivering direct current.

3.14 AIP

3.14.1 AIP means an air independent propulsion system.

3.15 Main source of electrical power

3.15.1 A source intended to supply electrical power to the main switchboard for distribution to all services necessary for maintaining the ship in normal operational and habitable condition.

3.16 Main switchboard

3.16.1 A switchboard which is directly supplied by at least one main source of electrical power and is intended to distribute electrical energy to the submarine.

3.17 Section boards

3.17.1 A switchgear and controlgear assembly which is supplied by another assembly and arranged for the distribution of electrical energy to other section boards or distribution boards.

3.18 Distribution board

3.18.1 A switchgear and controlgear assembly arranged for the distribution of electrical energy to final sub-circuits.

3.19 Circuit

3.19.1 Final subcircuit

That portion of a wiring system extending beyond the final required overcurrent protective device of a board.

3.19.2 Circuit

An assembly of electrical equipment of the installation supplied from the same origin and protected against overcurrents by the same protective device.

3.20 Hazardous areas

3.20.1 Areas in which an explosive atmosphere is present, or may be expected to be present due to the presence of vapours, gases, flammable dusts or explosives in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

3.20.2 Hazardous areas are classified in zones based upon the frequency and the duration of the occurrence of explosive atmosphere.

3.20.3 Hazardous areas for explosive gas atmosphere are classified in the following zones:

- Zone 0: an area in which an explosive gas atmosphere is present continuously or is present for long periods
- Zone 1: an area in which an explosive gas atmosphere is likely to occur in normal operation
- Zone 2: an area in which an explosive gas atmosphere is not likely to occur in normal operation and if it does occur, is likely to do only infrequently and will exist for a short period only.

3.21 Certified safe-type equipment

3.21.1 Certified safe-type equipment is electrical equipment of a type for which a national or other appropriate authority has carried out the type verifications and tests necessary to certify the safety of the equipment with regard to explosion hazard when used in an explosive gas atmosphere.

3.22 Environmental categories

3.22.1 Electrical equipment is classified into environmental categories according to the temperature range, vibration levels, and resistance to chemically active substances and to humidity.

The designation of the environmental categories is indicated by the EC Code in Tab 2.

The first characteristic numeral indicates the temperature range in which the electrical equipment operates satisfactorily, as specified in Tab 3.

The second characteristic numeral indicates the vibration level in which the electrical equipment operates satisfactorily, as specified in Tab 4.

3.22.2 The tests for verifying the additional and supplementary letters and the characteristic numeral of the environmental categories are defined in Ch 5, Sec 6.

Table 2 : EC Code

Code letter	First characteristic numeral	Second characteristic numeral	Additional letter	Supplementary letter
EC	(numerals 1 to 4)	(numerals 1 to 3)	(letter S) **(1)**	(letter C) **(2)**

(1) The additional letter S indicates the resistance to salt mist (exposed decks, masts) of the electrical equipment.

(2) The supplementary letter C indicates the relative humidity up to 80% (air conditioned areas) in which the electrical equipment operates satisfactorily.

Table 3 : First characteristic numeral

First characteristic numeral	Brief description of location	Temperature range °C	
1	Air conditioned areas	+ 5	+ 40
2	Enclosed spaces	+ 5	+ 45
3	Inside consoles or close to combustion engines and similar	+ 5	+ 55
4	Exposed decks, masts	– 25	+ 45

Table 4 : Second characteristic numeral

Second characteristic numeral	Brief description of location	Frequency range Hz	Displacement amplitude mm	Acceleration amplitude g
1	Machinery spaces, command and control stations, accommodation spaces, exposed decks	from 2,0 to 13,2	1,0	–
		from 13,2 to 100	–	0,7
2	Masts	from 2,0 to 13,2	3,0	–
		from 13,2 to 50	–	2,1
3	On air compressors, on diesel engines and similar	from 2,0 to 25,0	1,6	–
		from 25,0 to 100	–	4,0

SECTION 2 GENERAL DESIGN REQUIREMENTS

1 Environmental conditions

1.1 General

1.1.1 The electrical components of installations located inside the submarine are to be designed and constructed to operate satisfactorily under the environmental conditions on board, as given in Pt B, Ch 1, Sec 3.

In particular, the conditions shown in the tables of this Section are to be taken into account.

Note 1: The environmental conditions are characterised by:

- one set of variables including climatic conditions (e.g. ambient air temperature and humidity), conditions dependent upon chemically active substances (e.g. salt mist) or mechanically active substances (e.g. dust or oil), mechanical conditions (e.g. vibrations or inclinations) and conditions dependent upon electromagnetic noise and interference, and
- another set of variables dependent mainly upon location on vessels, operational patterns and transient conditions.

1.1.2 For electrical equipment located outside the pressure hull, they are to withstand the maximum depth pressure.

1.2 Salt mist

1.2.1 The applicable salt mist content in the air is to be 1 mg/m^3.

2 Quality of power supply

2.1 General

2.1.1 All electrical components are to be so designed and manufactured that they are capable of operating satisfactorily under the variations of voltage, frequency and harmonic distortion of the power supply specified from [2.2] to [2.4].

2.2 a.c. distribution systems

2.2.1 For alternating current components the voltage and frequency variations of power supply shown in Tab 1 are to be assumed.

Table 1 : Voltage and frequency variations of power supply in a.c.

Parameter	Variations	
	Continuous	Transient
Voltage	+ 6% – 10%	± 20% (recovery time: 1,5 s)
Frequency	± 5%	± 10% (recovery time: 5 s)

2.3 d.c. distribution systems

2.3.1 For direct current components supplied by electrical vented battery the following voltage variations are to be assumed:

- +40% to –25% for components connected to the battery during full charging (see Note 1)
- +20% to –25% for components connected to the battery during partial charging. The reference voltage is the gas release limit voltage, with an electrolyte at a temperature of 30°C
- Voltage transient variation (recovery time 2 s): +60% ; –32%. The reference voltage is the open circuit voltage with a state of charge of 100%.

Note 1: Different voltage variations as determined by the charging/discharging characteristics, including ripple voltage from the charging device, may be considered.

Note 2: The upper limits of the voltage variations may be adjusted, depending on the electrolyte temperature.

Note 3: The voltage variations may be adjusted, depending on the battery technology.

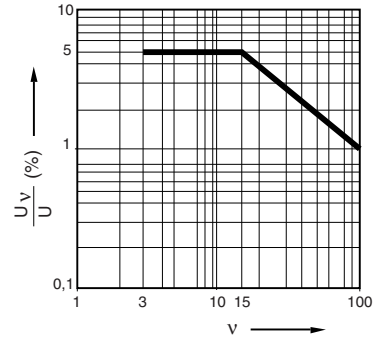
2.4 Harmonic distortions

2.4.1 For components intended for systems without substantially static converter loads and supplied by synchronous generators, it is assumed that the total voltage harmonic distortion does not exceed 5%, and the single harmonic does not exceed 3% of the nominal voltage.

2.4.2 For components intended for systems fed by static converters, and/or systems in which the static converter load predominates, it is assumed that:

- the single harmonics do not exceed 5% of the nominal voltage up to the 15th harmonic of the nominal frequency, decreasing to 1% at the 100th harmonic (see Fig 1), and
- the total harmonic distortion does not exceed 10%.

Figure 1 :



2.4.3 Higher values for the harmonic content (e.g. in electric propulsion plant systems) may be accepted on the basis of correct operation of all electrical devices.

3 Electromagnetic susceptibility

3.1

3.1.1 For electronic type components such as sensors, alarm panels, automatic and remote control equipment, protective devices and speed regulators, the conducted and radiated disturbance levels to be assumed are those given in Part D, Chapter 5.

Note 1: See also IEC Publication 60533 - "Electromagnetic Compatibility of Electrical and Electronic Installations in Ships and of Mobile and Fixed Offshore Units", other national naval standard may be accepted.

4 Materials

4.1 General

4.1.1 In general, and unless it is adequately protected, all electrical equipment is to be constructed of durable, flame-retardant, moisture-resistant materials which are not subject to deterioration in the atmosphere and at the temperatures to which they are likely to be exposed. Particular consideration is to be given to sea air and oil vapour contamination.

Note 1: The flame-retardant and moisture-resistant characteristics may be verified by means of the tests cited in IEC Publication 60092-101 or in other recognised standards.

4.1.2 Where the use of incombustible materials or lining with such materials is required, the incombustibility characteristics may be verified by means of the test cited in IEC Publication 60092-101 or in other recognised standards.

4.2 Insulating materials for windings

4.2.1 Insulated windings are to be resistant to moisture, sea air and oil vapour unless special precautions are taken to protect insulants against such agents.

4.2.2 The insulation classes given in Tab 2 may be used in accordance with IEC Publication 60085.

Table 2 : Insulation classes

Class	Maximum continuous operating temperature (°C)
A	105
E	120
B	130
F	155
H	180

4.3 Insulating materials for cables

4.3.1 See Ch 4, Sec 9.

5 Construction

5.1 General

5.1.1 All electrical apparatus is to be so constructed as not to cause injury when handled or touched in the normal manner.

5.1.2 The design of electrical equipment is to allow accessibility to each part that needs inspection or adjustment, also taking into account its arrangement on board.

5.1.3 Enclosures are to be of adequate mechanical strength and rigidity.

5.1.4 Enclosures for electrical equipment are generally to be of metal; other materials may be accepted for accessories such as connection boxes, socket-outlets, switches and luminaires. Other exemptions for enclosures or parts of enclosures not made of metal will be specially considered by the Society.

5.1.5 Cable entrance are not to impair the degree of protection of the relevant enclosure (see Ch 4, Sec 3, Tab 2).

5.1.6 All nuts and screws used in connection with current-carrying parts and working parts are to be effectively locked.

5.1.7 All equipment is generally to be provided with suitable, fixed terminal connectors in an accessible position for convenient connection of the external cables.

5.2 Degree of protection of enclosures

5.2.1 Electrical equipment is to be protected against the ingress of foreign bodies and water.

The minimum required degree of protection, in relation to the place of installation, is generally that specified in Ch 4, Sec 3, Tab 2.

5.2.2 The degrees of protection are to be in accordance with:

- IEC Publication No. 60529 for equipment in general
- IEC Publication No. 60034-5 for rotating machines.

6 Protection against explosion hazard

6.1 Protection against explosive gas or vapour atmosphere hazard

6.1.1 Electrical equipment intended for use in areas where explosive gas or vapour atmospheres may occur, is to be of a "safe type" suitable for the relevant flammable atmosphere and for shipboard use.

6.1.2 The following "certified safe type" equipment is considered:

- intrinsically-safe: Ex(ia) - Ex(ib)
- flameproof: Ex(d)
- increased safety: Ex(e)
- pressurised enclosure: Ex(p)
- encapsulated: Ex(m)
- sand filled: Ex(q)
- special protection: Ex(s) (apparatus not conforming with IEC 60079 may be considered safe by a national or other authorised body for use in potentially explosive atmospheres. In such cases, the apparatus is identified with the symbol "s")
- oil-immersed apparatus (only when required by the application): Ex(o).

6.1.3 Other equipment complying with types of protection other than those in [6.1.2] may be considered by the Society, such as:

- simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules
- electrical apparatus specifically designed and certified by the appropriate authority for use in Zone 0 or specially tested for Zone 2 (e.g. type "n" protection)
- equipment the type of which ensures the absence of sparks and arcs and of "hot spots" during its normal operation
- pressurised equipment
- equipment having an enclosure filled with a liquid dielectric, or encapsulated.

SECTION 3 SYSTEM DESIGN

1 Supply systems and characteristics of the supply

1.1 Supply systems

1.1.1 The following distribution systems may be used:

a) on d.c. installations:
- two-wire insulated

b) on a.c. installations:
- three-phase three-wire with neutral insulated
- three-phase three-wire with neutral earthed through an impedance
- single-phase two-wire insulated
- single-phase two-wire with one phase earthed through an impedance.

1.1.2 Distribution systems other than those listed in [1.1.1] (e.g. with hull return, three-phase four-wire insulated) will be considered by the Society on a case -by-case basis.

1.1.3 The requirement of [1.1.2] does not preclude, under conditions approved by the Society, the use of:

a) impressed current cathodic protective systems

b) limited and locally earthed systems, or

c) insulation level monitoring devices provided the circulation current does not exceed 30 mA under the most unfavourable conditions.

Note 1: Limited and locally earthed systems such as starting and ignition systems of internal combustion engines are accepted provided that any possible resulting current does not flow directly through any dangerous spaces.

1.2 Maximum voltages

1.2.1 The maximum voltages for both alternating current and direct current low-voltage systems of supply for the services are given in Tab 1.

1.2.2 Voltages exceeding those shown will be specially considered in the case of specific systems.

2 Sources of electrical power

2.1 General

2.1.1 The capacity of the main battery and the nominal power of the recharging device (DG, AIP) are not covered by class.

2.1.2 The different components of the electrical network are to be sized for the maximum current that can be delivered by the main battery, recharging device (DG, AIP), or shore supply in different operating conditions.

Table 1 : Maximum voltages for various services

Use		Maximum voltage V
For permanently installed and connected to fixed wiring	Power equipment	1000
	Heating equipment (except in accommodation spaces)	500
	Cooking equipment	500
	Lighting	250
	Space heaters in accommodation spaces	250
	Control **(1)**, communication (including signal lamps) and instrumentation equipment	250
For permanently installed and connected by flexible cable	Power and heating equipment, where such connection is necessary because of the application (e.g. for moveable cranes or other hoisting gear)	1000
For socket-outlets supplying	Portable and fixed appliances such as fortune connection which are not hand-held during operation by flexible cables	1000
	Portable appliances and other consumers by flexible cables	250
	Equipment requiring extra precaution against electric shock where an isolating transformer is used to supply one appliance **(2)**	250
	Equipment requiring extra precaution against electric shock with or without a safety transformer **(2)**	50

(1) For control equipment which is part of a power and heating installation (e.g. pressure or temperature switches for start/stop motors), the same maximum voltage as allowed for the power and heating equipment may be used provided that all components are constructed for such voltage. However, the control voltage to external equipment is not to exceed 500 V.

(2) Both conductors in such systems are to be insulated from earth.

2.2 Main sources

2.2.1 The source of electrical power is to be based on a permanent source and an occasional source of electrical power.

The permanent source is to consist of at least two main batteries, installed in separate compartment (see Ch 4, Sec 11, [2.1.1]).

The occasional source is to consist of at least one recharging device (DG, AIP).

3 Distribution

3.1 Insulated distribution systems

3.1.1 Every insulated distribution system shall be provided with a device capable of continuously monitoring the insulation level to earth (i.e. the values of electrical insulation to earth) and of giving an audible and visual indication of abnormally low insulation values, see Ch 4, Sec 14.

3.2 Main distribution of electrical power

3.2.1 At least two main switchboards are to be provided, each one supplied from his associated battery switchboard and main battery.

3.2.2 Provision is to be made to connect the two main switchboards by means of a circuit breakers or other approved means.

3.2.3 The electrical propulsion switchboard is to be supplied directly and separately from each main battery switchboard.

3.2.4 The electrical distribution to the electrical network is to be divided in two separate parts, each one coming from a main switchboard.

3.2.5 The supply of the duplicated essential services and their auxiliaries are to be equally divided between the two main switchboards and their associated networks.

3.2.6 Non duplicated essential services are to be supplied either by two separate feeders, each one coming from a separate network (see Note 1) or, through a UPS with an autonomy sufficient to recover the normal supply.

Note 1: The design is to be such as to prevent the loss of an essential service in case of single failure

Note 2: When the loss of power leads to a loss of the function during more than 10 minutes, the supply through a UPS is required

3.3 Shore supply

3.3.1 Arrangements are to be made for charging the main battery and for supplying hotel loads from sources on shore or elsewhere. Suitable connecting devices are to be installed on the submarine in a convenient locations to receive the flexible cable from the external sources, fitted with appropriate connectors.

The connecting devices are to be designed to be kept watertight for the depth of the submarine, in navigating situation.

3.3.2 Permanently fixed cables of adequate rating are to be provided for connecting the box to the main switchboard.

3.3.3 Where necessary for systems with earthed neutrals, the box is to be provided with an earthed terminal for connection between the shore's and submarine's neutrals or for connection of a protective conductor.

3.3.4 The shore connection is to be protected against short-circuit and overload. This protection is to be provided ashore.

3.3.5 Means are to be provided for checking the phase sequence, or polarity of the incoming supply in relation to the submarine's system.

3.3.6 The cable connection to the box is to be provided with at least one switch-disconnector on the main switchboard.

3.3.7 The shore connection is to be provided with an indicator at the main switchboard in order to show when the cable is energised.

3.3.8 Adequate means are to be provided to equalise the potential between the hull and the shore when the electrical installation of the submarine is supplied from shore.

3.3.9 Where the shore connection is used to supply external load, the necessary protection against short circuit are to be provided to protect also the external link.

3.4 Supply of motors

3.4.1 A separate final sub-circuit is to be provided for every motor required for an essential service (and for every motor rated at 0,5 kW or more).

3.4.2 Each motor is to be provided with controlgear ensuring its satisfactory starting.

Direct on line starters are accepted if the voltage drop does not exceed 15% of the network voltage supplying directly the motor.

3.4.3 Efficient means are to be provided for the isolation of the motor and its associated control gear from all live poles of the supply.

Where the control gear is mounted on or adjacent to a switchboard, a disconnecting switch in the switchboard may be used for this purpose.

Otherwise, a disconnecting switch within the control gear enclosure or a separate enclosed disconnecting switch is to be provided.

3.4.4 Where the starter or any other apparatus for disconnecting the motor is remote from the motor itself, one of the following is to be arranged:

a) provision for locking the circuit disconnecting switch in the OFF position

b) an additional disconnecting switch fitted near the motor

c) provision such that the fuses in each live pole or phase can be readily removed and retained by persons authorised to have access to the motor.

3.5 Specific requirements for special power services

3.5.1 For the supply and characteristics of the distribution of the following services, see the requirements in:

- for fire-extinguishing and detecting systems: Pt E, Ch 1, Sec 3 and Pt E, Ch 1, Sec 6
- for ventilation fans: Part C, Chapter 4
- for fuel pumps: Ch 3, Sec 5.

3.6 Power supply to heaters

3.6.1 Each heater rated more than 16 A is to be connected to a separate final circuit.

3.7 Power supply to lighting installations

3.7.1 Final sub-circuits for lighting supplying more than one lighting point and for socket-outlets are to be fitted with protective devices having a current rating not exceeding 16 A.

3.8 Special lighting services

3.8.1 In spaces such as:

- main machinery spaces
- galleys
- passageways
- stairways
- public spaces
- control room,

there is to be more than one final circuit for lighting such that failure of any one circuit does not reduce the lighting to an insufficient level (see [3.2.5]).

3.8.2 Colour lighting is to be provided in living quarters and normal operational room (i.e. control room, weapon room). This colour lighting is supplementary to the normal lighting and is used for night operation.

3.8.3 A low voltage lighting is to be provided in wet zone (Kiosk, batteries compartment). A multipole switch is to be fitted outside the lighted zone.

3.9 Navigation lights

3.9.1 Navigation lights are to be connected separately to a distribution board specially reserved for this purpose.

3.9.2 The distribution board in [3.9.1] is to be supplied from two sources of power; see also [3.2].

Note 1: This arrangement is not in line with International Standards IEC 60092-201.

3.9.3 Each navigation light is to be controlled and protected in each insulated pole by a double-pole switch and a fuse or, alternatively, by a double-pole circuit-breaker, fitted on the distribution board referred to in [3.9.1].

3.9.4 Where there are double navigation lights, i.e. lights with two lamps or where for every navigation light a spare is also fitted, the connections to such lights may run in a single cable provided that means are foreseen in the distribution board to ensure that only one lamp or light may be supplied at any one time.

3.9.5 Each navigation light is to be provided with an automatic indicator giving audible and/or visual warning in the event of failure of the light. If an audible device alone is fitted, it is to be connected to a separate source of supply from that of the navigation lights, for example an accumulator (storage) battery.

If a visual signal is used connected in series with the navigation light, means are to be provided to prevent the extinction of the navigation light due to the failure of the visual signal.

A minimum level of visibility is to be assured in the case of use of dimmer devices.

3.10 Public address system

3.10.1 The public address system is to be a loudspeaker installation enabling the broadcast of messages into all spaces where people on board are normally present.

If not feasible, adequate additional visual indications to be provided to indicate that a message is being broadcasted.

3.10.2 The public address is to be continuously powered from 2 sources of electrical power (see [3.2]).

3.10.3 The system is to allow for the broadcast of messages from the control room and from other places on board the submarine as deemed necessary.

3.10.4 The system is not to require any action from the addressee.

3.10.5 Where an individual loudspeaker has a device for local silencing, an override arrangement from the control station(s), including the control room, is to be in place.

3.10.6 The public address system, excluding loudspeakers, is to be constructed to withstand the tests required in Ch 5, Sec 6.

3.11 Combined general emergency alarm-public address system

3.11.1 Where the public address system is the only means for sounding the general emergency alarm including fire alarm, the following requirements are to be satisfied, in addition to [3.10]:

- the system automatically overrides any other non emergency input system when an emergency alarm is required
- the system automatically overrides any volume control provided to give the required output for the emergency mode when an emergency alarm is required
- the system is arranged to prevent feedback or other interference
- the system is arranged to minimise the effect of a single failure so that the alarm signal is still audible (above ambient noise levels) also in the case of failure of any one circuit or component, by means of the use of:
  - multiple amplifiers
  - segregated cable routes to public rooms, alleyways, stairways and control stations
  - more than one device for generating electronic sound signal
  - electrical protection for individual loudspeakers against short-circuits.

3.12 Control and indication circuits

3.12.1 For the supply of automation systems, comprising control, alarm and safety system, see the requirements of Part D, Chapter 5.

3.12.2 Control and indicating circuits relative to essential services are to be supplied from the main circuit in which the relevant equipment is installed. Equivalent arrangements may be accepted by the Society.

Auxiliary supply may be accepted, provided that the redundancy of the system is not downgraded by this auxiliary supply.

4 Degrees of protection of the enclosures

4.1 General

4.1.1 The minimum required degree of protection for electrical equipment, in relation to the place of installation, is generally that specified in Tab 2.

The minimum required degree of protection may be modified under specific justification to the Society.

Table 2 : Minimum required degrees of protection

Condition in location	Example of location	Switchboard, control gear, motor starters	Generators	Motors	Transformers	Luminaires	Heating appliances	Cooking appliances	Socket outlets	Accessories **(1)**
Danger of touching live parts only	Dry accommodation spaces, dry control rooms	IP 20	X	IP 20	IP 20	IP 20	IP 20	IP 20	IP 20	IP 20
Danger of dripping liquid and/or moderate mechanical damage	Control rooms, radio room	IP 22	X	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22
	Engine and boiler rooms above floor	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	IP 44	IP 44
	Propulsion room	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	X	IP 44	IP 44
	General storerooms	IP 22	X	IP 22	IP 22	IP 22	IP 22	X	IP 22	IP 44
	Pantries	IP 22	X	IP 22	IP 22	IP 22	IP 22	IP 22	IP 44	IP 44
	Provision rooms	IP 22	X	IP 22	IP 22	IP 22	IP 22	X	IP 44	IP 44
	Ventilation ducts	X	X	IP 22	X	X	X	X	X	X
Increased danger of liquid and/or mechanical damage	Bathrooms and/or showers	X	X	X	X	IP 34	IP 44	X	IP 55	IP 55
	Engine and boiler rooms below floor	X	X	IP 44	X	IP 34	IP 44	X	X	IP 55
Increased danger of liquid and/or mechanical damage	Refrigerated rooms	X	X	IP 44	X	IP 34	IP 44	X	IP 55	IP 55
	Galleys and laundries	IP 44	X	IP 44	IP 44	IP 34	IP 44	IP 44	IP 44	IP 44
Danger of liquid spraying, serious mechanical damage, aggressive fumes	Ventilation trunks	X	X	IP 55	X	X	X	X	X	X

(1) such as switches, connection boxes.

Note 1: The symbol "X" denotes equipment which it is not advised to install.

4.1.2 In addition to the requirements of this Article, equipment installed in spaces with an explosion hazard is also subject to the provisions of Ch 4, Sec 2, [6].

5 Diversity (demand) factors

5.1 General

5.1.1 The cables and protective devices of final sub-circuits are to be rated in accordance with their connected load.

5.1.2 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justifiable, to the application of a diversity (demand) factor.

5.1.3 A diversity (demand) factor may be applied provided that the known or anticipated operating conditions in a particular part of an installation are suitable for the application of diversity.

6 Electrical protection

6.1 General requirements for overcurrent protection

6.1.1 Electrical installations are to be protected against short-circuit.

The choice, arrangement and performance of the various protective devices are to provide complete and coordinated automatic protection in order to ensure, as far as possible:

- continuity of supply in the event of a fault, through coordinated and discriminative action of the protective devices for the main switchboard
- elimination of the effects of faults to reduce damage to the system and the hazard of fire as far as possible.

Note 1: A short-circuit is the accidental connection by a relatively low resistance or impedance of two or more points in a circuit which are normally at different voltages.

6.1.2 Systems are to be such as to withstand the thermal and electrodynamic stresses caused by the possible overcurrent, including short-circuit, for the admissible duration.

6.2 Short-circuit currents

6.2.1 In calculating the maximum prospective short-circuit current, the source of current is to include the maximum number of electrical sources which can be simultaneously connected (as far as permitted by any interlocking arrangements).

The maximum number of electrical sources is to be evaluated without taking into consideration short-term parallel operation (e.g. for load transfer) provided that suitable interlock is foreseen.

Note 1: The contribution of electric motors supplied through convertors to the short circuit current is to be evaluated, taking into account the convertors technologies and the types of protection.

6.2.2 Short-circuit current calculations are to be performed and submitted to the Society, according to Ch 4, Sec 1, Tab 1.

6.2.3 In the absence of precise data concerning the characteristics of generators, accumulator batteries and motors, the maximum short-circuit currents on the main busbars may be calculated as follows:

- for alternating current systems:

  $I_{ac} = 3\ I_n + 3{,}5\ I_{TM}$

  $I_{pk} = 2{,}4\ I_{ac}$
- for direct current systems supplied by batteries:

  $I_p = K\ C_{10}$
- for direct current systems supplied by rotating machines:

  $I_p = 12\ I_{AR}$

where:

I_p : Maximum short-circuit current

I_n : Rated current of converter

I_{AR} : Rated current of alternator rectifier

I_{ac} : r.m.s. value of the symmetrical component (at the instant T/2)

I_{pk} : Maximum peak value

I_{TG} : Rated current of all generators which can be connected simultaneously

C_{10} : Battery capacity in Ah for a discharge duration of 10 hours

K : Ratio of the short-circuit current of the batteries to C_{10} (see Note 1)

I_{TM} : Rated current of all motors which are normally simultaneously connected in the system.

Note 1: For stationary batteries, the following values may be assumed for guidance:

- vented lead-acid batteries: K = 5
- vented alkaline type batteries intended for discharge at low rates corresponding to a battery duration exceeding three hours: K = 15
- sealed lead-acid batteries having a capacity of 100 Ah or more or alkaline type batteries intended for discharge at high rates corresponding to a battery duration not exceeding three hours: K = 30.

6.3 Selection of equipment

6.3.1 Circuit-breakers of withdrawable type are required.

6.3.2 Equipment is to be chosen on the basis of its rated current and its making/breaking capacity, as far as practicable.

6.3.3 In the selection of circuit-breakers with intentional short-time delay for short-circuit release, those of utilisation category B are to be used and they are to be selected also taking into account their rated short-time withstand current capacity (Icw).

For circuit-breakers without intentional short-time delay for short-circuit release, circuit breakers of utilisation category A may be used and they are to be selected according to their rated service short-circuit breaking capacity (Ics).

Note 1: For the purpose of these Rules, utilisation categories A and B are defined as follows:

- utilisation category A: circuit-breakers not specifically intended for selectivity under short-circuit conditions with respect to other short-circuit protective devices in series on the load side, i.e. without an intentional short-time delay provided for selectivity under short-circuit conditions
- utilisation category B: circuit-breakers specifically intended for selectivity under short-circuit conditions with respect to other short-circuit protective devices in series on the load side, i.e. with an intentional short-time delay (which may be adjustable) provided for selectivity under short-circuit conditions.

6.3.4 Selection of DC circuit breaker according to IEC 157-1 may be accepted.

6.3.5 For switches, the making/breaking capacity is to be in accordance with utilisation category AC-22 B or DC-22 B (in compliance with IEC Publication 60947-3).

6.3.6 For fuse-switch disconnectors or switch-disconnector fuse units, the making/breaking capacity is to be in accordance with utilisation categories AC-23 B or DC-23 B (in compliance with IEC Publication 60947-3).

6.4 Protection against short-circuit

6.4.1 Protection against short-circuit currents is to be provided by circuit- breakers or fuses.

6.4.2 The rated short-circuit breaking capacity of every DC circuit breaker is to be not less than the maximum prospective value of short-circuit current at the point of installation reached with a determined time constant of the circuit.

The use of circuit breaker not having a short-circuit breaking capacity at least equal to the maximum prospective value of short-circuit current at the point where it is installed is permitted, provided that this circuit breaker is backed up, on the up stream side, by a limiting circuit breaker which separate very quickly the sources connected on each board.

If it's not the case, the breaking capacity is to be shared with the up stream side circuit breaker. This is to be ensured by calculation, in cooperation with the manufacturer, and the default arc voltage shall be considered (typical: 100 Vdc).

6.4.3 The rated short-circuit making capacity of every DC circuit breaker to be considered as identical to the value given for breaking capacity. This value is to be not less than the maximum prospective value of short-circuit current at the point installation.

6.4.4 Every protective device or contactor not intended for short-circuit interruption is to be adequate for the maximum short-circuit current liable to occur at the point of installation having regard to the time required for the short-circuit to be removed.

6.4.5 The use of a protective device not having a short-circuit breaking or making capacity at least equal to the maximum prospective short-circuit current at the point where it is installed is permitted, provided that it is backed up on the supply side by a fuse or by a circuit-breaker having at least the necessary short-circuit rating and not being the generator circuit-breaker.

6.4.6 The same fuse or circuit-breaker may back up more than one circuit-breaker where the circuits concerned do not involve essential services.

6.4.7 The short-circuit performance of the back-up arrangement is to be equal to the requirements of IEC Publication 60947-2 for a single circuit-breaker having the same short-circuit performance category as the backed-up circuit-breaker and rated for the maximum prospective short-circuit level at the supply terminals of the arrangement.

6.4.8 Circuit-breakers with fuses connected to the load side may be used, provided the back-up fuses and the circuit-breakers are of coordinated design, in order to ensure that the operation of the fuses takes place in due time so as to prevent arcing between poles or against metal parts of the circuit-breakers when they are submitted to overcurrents involving the operation of the fuse.

6.5 Protection against overload

6.5.1 Devices provided for overload protection are to have a tripping characteristic (overcurrent-trip time) adequate for the overload ability of the elements of the system to be protected and for any discrimination requirements.

6.5.2 The use of fuses up to 320 A for overload protection is permitted.

6.6 Localisation of overcurrent protection

6.6.1 Short-circuit protection is to be provided for every non-earthed conductor.

6.6.2 For a.c. distribution, overload protection is to be provided for every non-earthed conductor; nevertheless, in insulated single-phase circuits or insulated three-phase circuits having substantially balanced loads, the overload protection may be omitted on one conductor.

6.6.3 For a. c. distribution, short-circuit and overload protective devices are not to interrupt earthed conductors, except in the case of multiple disconnection devices which simultaneously interrupt all the conductors, whether earthed or not.

6.6.4 Electrical protection is to be located as close as possible to the origin of the protected circuit.

6.7 Protection of alternators rectifiers

6.7.1 Alternators rectifiers are to be protected against short-circuits and overloads by multipole circuit-breakers.

6.7.2 Where a circuit-breaker is used the overload protection is to trip the alternators rectifiers circuit-breaker at an overload of 100% of the maximum current of the alternators rectifiers. The maximum current is the current corresponding to the thermal capacity of the alternators rectifiers.

6.8 Protection of circuits

6.8.1 Each separate circuit is to be protected against short circuit.

6.8.2 Each separate final subcircuit shall be protected against short-circuit and against overload, unless otherwise specified in these Rules or where the Society may exceptionally otherwise permit.

6.8.3 Each final subcircuit is to be protected by a multipole circuit-breaker or switch and fuses against overloads and short-circuits.

6.8.4 Circuits for lighting are to be disconnected on both non-earthed conductors; single-pole disconnection of final sub-circuits with both poles insulated is permitted only in accommodation spaces.

6.8.5 The protective devices of the circuits supplying motors are to allow excess current to pass during transient starting of motors.

6.8.6 Final sub-circuits which supply one consumer with its own overload protection (for example motors), or consumers which cannot be overloaded (for example permanently wired heating circuits and lighting circuits), may be provided with short-circuit protection only.

6.9 Protection of motors

6.9.1 Electrical motors supplied from DC source through converter are protected against overload. Consequently short circuit protection only is to be made available.

6.9.2 Motors of rating exceeding 1 kW and all motors for essential services are to be protected individually against overload and short-circuit. The short-circuit protection may be provided by the same protective device for the motor and its supply cable (see [6.8.6]).

6.9.3 For motors intended for essential services, the overload protection may be replaced by an overload alarm.

6.9.4 The protective devices are to be designed so as to allow excess current to pass during the normal accelerating period of motors according to the conditions corresponding to normal use.

If the current/time characteristic of the overload protection device does not correspond to the starting conditions of a motor (e.g. for motors with extra-long starting period), provision may be made to suppress operation of the device during the acceleration period on condition that the short-circuit protection remains operative and the suppression of overload protection is only temporary.

6.9.5 For continuous duty motors the protective gear is to have a time delay characteristic which ensures reliable thermal protection against overload.

6.9.6 The protective devices are to be adjusted so as to limit the maximum continuous current to a value within the range 105% - 120% of the motor's rated full load current.

6.9.7 For intermittent duty motors the current setting and the delay (as a function of time) of the protective devices are to be chosen in relation to the actual service conditions of the motor.

6.9.8 Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor against unacceptable overload in the case of single phasing.

6.9.9 Motors rated above 1 kW are to be provided with:

- undervoltage protection, operative on the reduction or failure of voltage, to cause and maintain the interruption of power in the circuit until the motor is deliberately restarted, or
- undervoltage release, operative on the reduction or failure of voltage, so arranged that the motor restarts automatically when power is restored after a power failure.

6.9.10 The automatic restart of a motor is not to produce a starting current such as to cause excessive voltage drop.

In the case of several motors required to restart automatically, the total starting current is not to cause an excessive voltage drop or sudden surge current; to this end, it may be necessary to achieve a sequence start.

6.9.11 The undervoltage protective devices are to allow the motor to be started when the voltage exceeds 85% of the rated voltage and are to intervene without fail when the voltage drops to less than approximately 20% of the rated voltage, at the rated frequency and with a time delay as necessary.

6.10 Protection of storage batteries

6.10.1 Batteries are to be protected against short-circuit by means of fuses or multipole circuit-breakers at a position adjacent to the battery compartment.

Overcurrent protection may be omitted for the circuit to the starter motors when the current drawn is so large that is impracticable to obtain short-circuit protection.

6.11 Protection of shore power connection

6.11.1 Permanently fixed cables connecting the shore connection box to the main switchboard are to be protected by fuses or circuit-breakers.

6.11.2 The shore connection for battery charging is to be separate from hotel connection. This one may be arranged without electrical protection. A disconnecting link is to be provided.

6.12 Protection of measuring instruments, pilot lamps and control circuits

6.12.1 Measuring circuits and devices (voltage transformers, voltmeters, voltage coils of measuring instruments, insulation monitoring devices etc.) and pilot lamps are to be protected against short-circuit by means of multipole circuit-breakers or fuses.

Measuring circuits and devices for DC installation (voltmeters, insulation monitoring devices etc.) and pilot lamps are to be protected against short-circuit.

Secondary shunt circuit is not to be protected.

The protective devices are to be placed as near as possible to the tapping from the supply.

The secondary side of current transformers is not to be protected.

6.12.2 Control circuits and control transformers are to be protected against overload and short-circuit by means of multipole circuit-breakers or fuses on each pole not connected to earth.

Overload protection may be omitted for transformers with a rated current of less than 2 A on the secondary side.

The short-circuit protection on the secondary side may be omitted if the transformer is designed to sustain permanent short-circuit current.

6.12.3 Where a fault in a pilot lamp would impair the operation of essential services, such lamps are to be protected separately from other circuits such as control circuits.

Note 1: Pilot lamps connected via short-circuit-proof transformers may be protected in common with control circuits.

6.12.4 Circuits whose failure could endanger operation, such as steering gear control feeder circuits, are to be protected only against short-circuit.

6.12.5 The protection is to be adequate for the minimum cross-section of the protected circuits.

6.13 Protection of transformers

6.13.1 The primary winding side of power transformers is to be protected against short-circuit and overload by means of multipole circuit-breakers or switches and fuses.

Overload protection on the primary side may be dispensed with where it is provided on the secondary side or when the total possible load cannot reach the rated power of the transformer.

6.13.2 The protection against short-circuit is to be such as to ensure the selectivity between the circuits supplied by the secondary side of the transformer and the feeder circuit of the transformer.

6.13.3 When transformers are arranged to operate in parallel, means are to be provided so as to trip the switch on the secondary winding side when the corresponding switch on the primary side is open.

7 System components

7.1 General

7.1.1 The components of the electrical system are to be dimensioned such as to withstand the currents that can pass through them during normal service without their rating being exceeded.

7.1.2 The components of the electrical system are to be designed and constructed so as to withstand for the admissible duration the thermal and electrodynamic stresses caused by possible overcurrents, including short-circuit.

8 Electrical cables

8.1 General

8.1.1 All electrical cables and wiring external to equipment shall be at least of a flame-retardant type, in accordance with IEC Publication 60332-1.

8.1.2 In addition to the provisions of [8.1.1], when cables are laid in bunches, cable types are to be chosen in compliance with IEC Publication 60332-3 Category A, or other means (see Ch 4, Sec 12) are to be provided such as not to impair their original flame-retarding properties.

8.1.3 Where necessary for specific applications such as radio frequency or digital communication systems, which require the use of particular types of cables, the Society may permit the use of cables which do not comply with the provisions of [8.1.1] and [8.1.2].

8.1.4 Cables which are required to have fire-resisting characteristics are to comply with the requirements stipulated in IEC Publication 60331.

8.1.5 Cables used on board are to be of the halogen free type and tested according to IEC 60754-1, IEC 60754-2,61034-1 and 61034-2.

Halogen cables may be accepted if they do not exceed 10% of the total mass of cables passing in the room.

8.2 Choice of insulation

8.2.1 The maximum rated operating temperature of the insulating material is to be at least 10°C higher than the maximum ambient temperature liable to occur or to be produced in the space where the cable is installed.

8.2.2 The maximum rated conductor temperature for normal and short-circuit operation, for the type of insulating compounds normally used for shipboard cables, is not to exceed the values stated in Tab 3. Special consideration will be given to other insulating materials.

8.2.3 PVC insulated cables are not to be used either in refrigerated spaces, or on decks exposed to the weather of submarines.

8.2.4 Mineral insulated cables will be considered on a case by case basis.

Table 3 : Maximum rated conductor temperature

Type of insulating compound	Abbreviated designation	Maximum rated conductor temperature (°C)	
		Normal operation	Short-circuit
Elastomeric or thermosetting:			
- based upon ethylene-propylene rubber or similar (EPM or EPDM)	EPR	90	250
- based upon high modulus or hardgrade ethylene propylene rubber	HEPR	90	250
- based upon cross-linked polyethylene	XLPE	90	250
- based upon rubber silicon	S 95	95	350
- based upon ethylene-propylene rubber or similar (EPM or EPDM) halogen free	HF EPR	90	250
- based upon high modulus or hardgrade halogen free ethylene propylene rubber	HF HEPR	90	250
- based upon cross-linked polyethylene halogen free	HF XLPE	90	250
- based upon rubber silicon halogen free	HF S 95	95	350
- based upon cross-linked polyolefin material for halogen free cable **(1)**	HF 85	90	250
(1) Used on sheathed cable only.			

8.3 Choice of protective covering

8.3.1 The conductor insulating materials are to be enclosed in an impervious sheath of material appropriate to the expected ambient conditions where cables are installed in the following locations:

- on decks exposed to the weather
- in damp or wet spaces (e.g. in bathrooms)
- in refrigerated spaces
- in machinery spaces and, in general
- where condensation water or harmful vapour may be present.

8.3.2 Where cables are provided with armour or metallic braid (e.g. for cables installed in hazardous areas), an overall impervious sheath or other means to protect the metallic elements against corrosion is to be provided; see Ch 4, Sec 9, [1.5].

8.3.3 An impervious sheath is not required for single-core cables installed in tubes or ducts inside accommodation spaces, in circuits with maximum system voltage 250 V.

8.3.4 In choosing different types of protective coverings, due consideration is to be given to the mechanical action to which each cable may be subjected during installation and in service.

If the mechanical strength of the protective covering is considered insufficient, the cables are to be mechanically protected (e.g. by an armour or by installation inside pipes or conduits).

8.3.5 Single-core cables for a.c. circuits with rated current exceeding 20 A are to be either non-armoured or armoured with non-magnetic material.

8.4 Cables in refrigerated spaces

8.4.1 Cables installed in refrigerated spaces are to have a watertight or impervious sheath and are to be protected against mechanical damage. If an armour is applied on the sheath, the armour is to be protected against corrosion by a further moisture-resisting covering.

8.5 Cables in areas with a risk of explosion

8.5.1 For cables in areas with a risk of explosion, see [9.2].

8.6 Cables in circuits required to be operable under fire condition

8.6.1 Cables for services required to be operable under fire conditions, including those for their power supplies, are to be of a fire-resistant type where they pass through high fire risk areas.

Systems that are self-monitoring, fail safe or duplicated with cable runs as widely separated as is practicable may be exempted.

Note 1: In the case of cables for services required to be operable under fire conditions, the fire-resistant cables are to extend from the control/monitoring panel to the nearest local distribution panel serving the relevant area or zone.

Note 2: In the case of power supply cables used for services required to be operable under fire conditions, the fire-resistant cables are to extend from their distribution point within the space containing the second source of electrical power to the nearest local distribution panel serving the relevant area or zone.

8.6.2 Electrical services required to be operable under fire conditions include:

- fire and general alarm system
- fire-extinguishing systems and fire-extinguishing medium alarms
- fire detection system
- emergency lighting
- public address system.

8.6.3 Cables for services required to be operable under fire conditions, including their power supplies, are to be run as directly as is practicable.

8.7 Cables for external application

8.7.1 Electrical cables used outside the pressure hull are to be constructed as specified in Ch 4, Sec 9.

8.8 Internal wiring of switchboards and other enclosures for equipment

8.8.1 For installation in switchboards and other enclosures for equipment, single-core cables may be used without further protection (sheath).

Other types of flame-retardant switchboard wiring may be accepted at the discretion of the Society.

8.9 Current carrying capacity of cables

8.9.1 The current carrying capacity for continuous service of cables given in Tab 4 to Tab 10 is based on the maximum permissible service temperature of the conductor also indicated therein and on an ambient temperature of 45°C.

8.9.2 The current carrying capacity cited in [8.9.1] is applicable, with rough approximation, to all types of protective covering (e.g. both armoured and non-armoured cables).

8.9.3 Values other than those shown in Tab 4 to Tab 8 may be accepted provided they are determined on the basis of calculation methods or experimental values approved by the Society.

8.9.4 When the actual ambient temperature obviously differs from 45°C, the correction factors shown in Tab 11 may be applied to the current carrying capacity in Tab 4 to Tab 8.

8.9.5 Where more than six cables are bunched together in such a way that there is an absence of free air circulating around them, and the cables can be expected to be under full load simultaneously, a correction factor of 0,85 is to be applied.

8.9.6 Where a cable is intended to supply a short-time load for 1/2-hour or 1-hour service (e.g. mooring winches or bow thruster propellers), the current carrying capacity obtained from Tab 4 to Tab 8 may be increased by applying the corresponding correction factors given in Tab 12.

In no case is a period shorter than 1/2-hour to be used, whatever the effective period of operation.

8.9.7 For supply cables to single services for intermittent loads, the current carrying capacity obtained from Tab 4 to Tab 8 may be increased by applying the correction factors given in Tab 13.

The correction factors are calculated with rough approximation for periods of 10 minutes, of which 4 minutes with a constant load and 6 minutes without load.

Table 4 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 60°C (ambient temperature 45°C)

Nominal section (mm^2)	Number of conductors		
	1	2	3 or 4
1,0	8	7	6
1,5	12	10	8
2,5	17	14	12
4,0	22	19	15
6,0	29	25	20
10	40	34	28
16	54	46	38
25	71	60	50
35	87	74	61
50	105	89	74
70	135	115	95
95	165	140	116
120	190	162	133
150	220	187	154
185	250	213	175
240	290	247	203
300	335	285	235

Table 5 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 85°C (ambient temperature 45°C)

Nominal section, in mm^2	Number of conductors		
	1	2	3 or 4
1,5	21	18	15
2,5	28	24	20
4,0	38	32	27
6,0	49	42	34
10	67	57	47
16	91	77	64
25	120	102	84
35	148	126	104
50	184	156	129
70	228	194	160
95	276	235	193
120	319	271	223
150	367	312	257
185	418	355	293
240	492	418	344
300	565	480	396
400	dc: 650 ac: 630	dc: 553 ac: 536	dc: 455 ac: 441
500	dc: 740 ac: 680	dc: 629 ac: 578	dc: 518 ac: 476
630	dc: 840 ac: 740	dc: 714 ac: 629	dc: 588 ac: 518

Table 6 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 70°C (ambient temperature 45°C)

Nominal section, in mm²	Number of conductors		
	1	2	3 or 4
1,5	15	13	11
2,5	21	18	15
4,0	29	25	20
6,0	37	31	26
10	51	43	36
16	68	58	48
25	90	77	63
35	111	94	78
50	138	117	97
70	171	145	120
95	207	176	145
120	239	203	167
150	275	234	193
185	313	266	219
240	369	314	258
300	424	360	297
400	dc: 500 ac: 490	dc: 425 ac: 417	dc: 350 ac: 343
500	dc: 580 ac: 550	dc: 493 ac: 468	dc: 406 ac: 385
630	dc: 670 ac: 610	dc: 570 ac: 519	dc: 469 ac: 427

Table 7 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 90°C (ambient temperature 45°C)

Nominal section (mm²)	Number of conductors		
	1	2	3 or 4
1,5	23	20	16
2,5	30	26	21
4,0	40	34	28
6,0	52	44	36
10	72	61	50
16	96	82	67
25	127	108	89
35	157	133	110
50	196	167	137
70	242	206	169
95	293	249	205
120	339	288	237
150	389	331	272
185	444	377	311
240	522	444	365
300	601	511	421
400	dc: 690 ac: 670	dc: 587 ac: 570	dc: 483 ac: 469
500	dc: 780 ac: 720	dc: 663 ac: 612	dc: 546 ac: 504
630	dc: 890 ac: 780	dc: 757 ac: 663	dc: 623 ac: 546

Table 8 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 95°C (ambient temperature 45°C)

Nominal section (mm²)	Number of conductors		
	1	2	3 or 4
1,5	26	22	18
2,5	32	27	22
4,0	43	37	30
6,0	55	47	39
10	76	65	53
16	102	87	71
25	135	115	95
35	166	141	116
50	208	177	146
70	256	218	179
95	310	264	217
120	359	305	251
150	412	350	288
185	470	400	329
240	553	470	387
300	636	541	445
400	dc: 760 ac: 725	dc: 646 ac: 616	dc: 532 ac: 508
500	dc: 875 ac: 810	dc: 744 ac: 689	dc: 612 ac: 567
630	dc: 1010 ac: 900	dc: 859 ac: 765	dc: 707 ac: 630

Table 9 : Current carrying capacity, in A, in continuous service for flexible cables FZH based on maximum conductor operating temperature of 85 °C (ambient temperature 45°C)

Nominal section (mm²)	Number of conductors		
	1	2	3
1,5		15	
2,5			18
4,0		40	
10		47	39
25		91	
50	181		
70			
95	278		
185	459		
300	582		

8.10 Minimum nominal cross-sectional area of conductors

8.10.1 In general the minimum allowable conductor cross-sectional areas are those given in Tab 14.

8.10.2 The nominal cross-sectional area of the neutral conductor in three-phase distribution systems is to be equal to at least 50% of the cross-sectional area of the phases, unless the latter is less than or equal to 16 mm². In such case the cross-sectional area of the neutral conductor is to be equal to that of the phase.

Table 10 : Current carrying capacity, in A, in continuous service for flexible cables FTF based on maximum conductor operating temperature of 85 °C (ambient temperature 45°C)

Nominal section (mm^2)	Number of conductors		
	1	2	3
2,5			20
4,0		34	
10			48,5
50	220		
80	305		
100	338		
125	400		
150	446		
200	557		

8.10.3 For the nominal cross-sectional area of:

- earthing conductors, see Ch 4, Sec 12, [2.3]
- earthing connections for distribution systems, see Ch 4, Sec 12, [2.5].

8.11 Choice of cables

8.11.1 The rated voltage of any cable is to be not lower than the nominal voltage of the circuit for which it is used.

8.11.2 The nominal cross-sectional area of each cable is to be sufficient to satisfy the following conditions with reference to the maximum anticipated ambient temperature:

- the current carrying capacity is to be not less than the highest continuous load carried by the cable
- the voltage drop in the circuit, by full load on this circuit, is not to exceed the specified limits
- the cross-sectional area calculated on the basis of the above is to be such that the temperature increases which may be caused by overcurrents or starting transients do not damage the insulation.

8.11.3 The highest continuous load carried by a cable is to be calculated on the basis of the power requirements and of the diversity factor of the loads and machines supplied through that cable.

8.11.4 When the conductors are carrying the maximum nominal service current, the voltage drop in AC from the main switchboard busbars to any point in the installation is not to exceed 6% of the nominal voltage.

For battery circuits with supply voltage less than 55 V, this value may be 5%.

For battery circuits with supply voltage over 55 V, this value may be limited to 3%.

For the circuits of navigation lights, the voltage drop is not to exceed 5% of the rated voltage under normal conditions.

Table 11 : Correction factors for various ambient air temperatures

Maximum conductor temperature (°C)	Correction factors for an ambient air temperature of:										
	35°C	40°C	45°C	50°C	55°C	60°C	65°C	70°C	75°C	80°C	85°C
60	1,29	1,15	1,00	0,82	–	–	–	–	–	–	–
75	1,15	1,08	1,00	0,91	0,82	0,71	0,58	–	–	–	–
80	1,13	1,07	1,00	0,93	0,85	0,76	0,65	0,53	–	–	–
85	1,12	1,06	1,00	0,94	0,87	0,79	0,71	0,61	0,50	–	–
95	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

Table 12 : Correction factors for short-time loads

1/2-hour service		1-hour service		Correction factor
Sum of nominal cross-sectional areas of all conductors, in mm^2				
Cables with metallic sheath and armoured cables	Cables with non-metallic sheath and non-armoured cables	Cables with metallic sheath and armoured cables	Cables with non-metallic sheath and non-armoured cables	
up to 20	up to 75	up to 80	up to 230	1,06
21 - 41	76 - 125	81 - 170	231 - 400	1,10
41 - 65	126 - 180	171 - 250	401 - 600	1,15
66 - 95	181 - 250	251 - 430	601 - 800	1,20
96 - 135	251 - 320	431 - 600	–	1,25
136 - 180	321 - 400	601 - 800	–	1,30
181 - 235	401 - 500	–	–	1,35
236 - 285	501 - 600	–	–	1,40
286 - 350	–	–	–	1,45

Table 13 : Correction factors for intermittent service

Sum of nominal cross-sectional area of all conductors, in mm²		Correction factor
Cables with metallic sheath and armoured cables	Cables with non-metallic sheath and non-armoured cables	
	S ≤ 5	1,10
	5 < S ≤ 8	1,15
	8 < S ≤ 16	1,20
S ≤ 4	16 < S ≤ 25	1,25
4 < S ≤ 7	25 < S ≤ 42	1,30
7 < S ≤ 17	42 < S ≤ 72	1,35
17 < S ≤ 42	72 < S ≤ 140	1,40
42 < S ≤ 110	140 < S	1,45
110 < S	–	1,50

9 Electrical installations in hazardous areas

9.1 Electrical equipment

9.1.1 No electrical equipment is to be installed in hazardous areas unless the Society is satisfied that such equipment is:

- essential for operational purposes
- of a type which will not ignite the mixture concerned
- appropriate to the space concerned, and
- appropriately certified for safe usage in the dusts, vapours or gases likely to be encountered.

9.1.2 Where electrical equipment of a safe type is permitted in hazardous areas it is to be selected with due consideration to the risk of explosive gas atmosphere (see Ch 4, Sec 2, [6.1]).

9.1.3 Where electrical equipment is permitted in hazardous areas, all switches and protective devices are to interrupt all poles or phases and, where practicable, to be located in a non-hazardous area unless specifically permitted otherwise.

Such switches and equipment located in hazardous areas are to be suitably labelled for identification purposes.

9.1.4 For electrical equipment installed in Zone 0 hazardous areas, only the following types are permitted:

- certified intrinsically-safe apparatus Ex(ia)
- simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category "ia" not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules, and accepted by the appropriate authority
- equipment specifically designed and certified by the appropriate authority for use in Zone 0.

9.1.5 For electrical equipment installed in Zone 1 hazardous areas, only the following types are permitted:

- any type that may be considered for Zone 0
- certified intrinsically-safe apparatus Ex(ib)
- simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category "ib" not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules, and accepted by the appropriate authority
- certified flameproof Ex(d)
- certified pressurised Ex(p)
- certified increased safety Ex(e)
- certified encapsulated Ex(m)
- certified sand filled Ex(q)
- certified specially Ex(s)
- through runs of cable.

9.1.6 For electrical equipment installed in Zone 2 hazardous areas, only the following types are permitted:

- any type that may be considered for Zone 1
- tested specially for Zone 2 (e.g. type "n" protection)
- pressurised, and accepted by the appropriate authority
- encapsulated, and accepted by the appropriate authority
- the type which ensures the absence of sparks and arcs and of "hot spots" during its normal operation (minimum class of protection IP 55).

9.1.7 When apparatus incorporates a number of types of protection, it is to be ensured that all are suitable for use in the zone in which it is located.

Table 14 : Minimum nominal cross-sectional areas

Service	Nominal cross-sectional area (mm²)	
	External wiring	Internal wiring
Power, heating and lighting systems	1,0	1,0
Control circuits for power plant	1,0	1,0
Control circuits other than those for power plant	0,75	0,5
Control circuits for telecommunications, measurement, alarms	0,5	0,2
Telephone and bell equipment, not required for the safety of the submarine or crew calls	0,2	0,1
Bus and data cables	0,2	0,1

9.2 Electrical cables

9.2.1 Electrical cables are not to be installed in hazardous areas except as specifically permitted or when associated with intrinsically safe circuits.

9.2.2 All cables installed in Zone 0, Zone 1 or weather exposed areas are to be sheathed with at least one of the following:

a) a non-metallic impervious sheath in combination with braiding or other metallic covering

b) a copper or stainless steel sheath (for mineral insulated cables only).

9.2.3 All cables installed in non-weather exposed Zone 2 areas are to be provided with at least a non-metallic external impervious sheath.

9.2.4 Cables of intrinsically safe circuits are to have a metallic shielding with at least a non-metallic external impervious sheath.

9.2.5 The circuits of a category "ib" intrinsically safe system are not to be contained in a cable associated with a category "ia" intrinsically safe system required for a hazardous area in which only category "ia" systems are permitted.

9.3 Electrical installations in battery compartments

9.3.1 Lighting fittings may be installed in compartments assigned solely to large vented storage batteries (see Ch 4, Sec 11, [5.3]).

The associated switches are to be installed outside such spaces.

Overcurrent protective devices are to be installed as close as possible to, but outside of, battery rooms.

Electrical cables other than those pertaining to the equipment arranged in battery rooms are not permitted.

9.3.2 Electrical equipment for use in battery rooms is to have minimum explosion group IIC and temperature class T1.

9.3.3 Standard marine electrical equipment may be installed in compartments assigned solely to valve-regulated sealed storage batteries.

9.3.4 Following equipment may be found in main battery room, in addition to lighting fixtures:

- hydrogen detection system
- monitoring of battery systems.

9.3.5 For ventilation requirements in battery room, see Pt D, Ch 4, Sec 11, [5.3.1].

SECTION 4 ROTATING MACHINES

1 Constructional and operational requirements for generators and motors

1.1 Mechanical construction

1.1.1 Materials and construction of electrical machines are to conform to the relevant requirements of Ch 4, Sec 2, [4] and Ch 4, Sec 2, [5].

1.1.2 Shafts are to be made of material complying with the provisions of NR216 Materials and Welding, Ch 2, Sec 3 or, where rolled products are allowed in place of forgings, with those of NR216 Materials and Welding, Ch 2, Sec 1.

1.1.3 Where welded parts are foreseen on shafts and rotors, the provisions of NR216 Materials and Welding, Chapter 5 are to apply.

1.1.4 Sleeve bearings are to be efficiently and automatically lubricated at all running speeds.

Provision is to be made for preventing the lubricant from gaining access to windings or other insulated or bare current carrying parts.

1.1.5 Means are to be provided to prevent bearings from being damaged by the flow of currents circulating between them and the shaft. According to the manufacturer's requirements, electrical insulation of at least one bearing is to be considered.

1.1.6 When liquid cooling is used, the coolers are to be so arranged as to avoid entry of water into the machine, whether by leakage or condensation in the heat exchanger, and provision is to be made for the detection of leakage.

1.1.7 Rotating machines whose ventilation or lubrication system efficiency depends on the direction of rotation are to be provided with a warning plate.

1.2 Sliprings, commutators and brushes

1.2.1 Sliprings and commutators with their brushgear are to be so constructed that undue arcing is avoided under all normal load conditions.

1.2.2 The working position of brushgear is to be clearly and permanently marked.

1.2.3 Sliprings, commutators and brushgear are to be readily accessible for inspection, repairs and maintenance.

1.3 Terminal connectors

1.3.1 Suitable, fixed terminal connectors are to be provided in an accessible position for connection of the external cables.

1.3.2 All terminal connectors are to be clearly identified with reference to a diagram.

1.3.3 The degree of protection of terminal boxes is to be adequate to that of the machine.

1.4 Electrical insulation

1.4.1 Insulating materials for windings and other current carrying parts are to comply with the requirements of Ch 4, Sec 2, [4.2] and Ch 4, Sec 2, [4.3].

2 Special requirements for generators

2.1 Prime movers, speed governors and overspeed protection

2.1.1 Prime movers for generators are to comply with the relevant requirements of Ch 3, Sec 2, [2.6].

2.1.2 When a.c. generators are to operate in parallel, the characteristics of speed governors are to comply with the provisions of [2.2].

2.2 A.c. generators

2.2.1 Alternators are to be so constructed that, when started up, they take up the voltage without the aid of an external electrical power source.

Where these provisions are not complied with, the external electrical power source is to be issued from a reliable source.

2.2.2 The voltage wave form is to be approximately sinusoidal, with a maximum deviation from the sinusoidal fundamental curve of 5% of the peak value.

2.2.3 Each alternator is to be provided with automatic means of voltage regulation.

2.2.4 For a.c. generating sets operating in parallel, the governing characteristics regarding the load are to comply with requirement of Ch 3, Sec 2, [2.6.4].

2.2.5 When a.c. generators are operated in parallel, the reactive loads of the individual generating sets are not to differ from their proportionate share of the total reactive load by more than 10% of the rated reactive power of the largest machine, or 25% of that of the smallest machine, whichever is the lesser.

2.2.6 Each alternator fitted with rectifier is to produce a DC current with a voltage cyclic variation limited to 5%

2.2.7 Where alternator with rectifier are operated in parallel, the automatic voltage regulator is to be arranged so as the load sharing between each machine do not differ from their proportionate share of the total load by more than 15%.

3 Testing of rotating machines

3.1 General

3.1.1 All machines are to be tested by the manufacturers.

3.1.2 The manufacturer is to issue a test report giving, inter alia, information concerning the construction, type, serial number, insulation class and all other technical data relevant to the machine, as well as the results of the tests required.

Such test reports are to be provided to the Society, for machines for essential services. For other machines, these test reports are to be made available upon request of the Society.

3.1.3 All tests are to be carried out according to IEC Publication 60092-301.

3.1.4 All machines of 100 kW and over, intended for essential services are to be surveyed by the Society during testing and, if appropriate, during manufacturing.

Note 1: An alternative inspection scheme may be agreed by the Society with the manufacturer whereby the attendance of the Surveyor will not be required as indicated above.

3.2 Shaft material

3.2.1 Shaft material for electric propulsion motors and for main engine driven generators where the shaft is part of the propulsion shafting is to be certified by the Society.

3.2.2 Shaft material for other machines is to be in accordance with recognised international or national standard.

3.3 Tests

3.3.1 Type test are to be carried out on a proptoype a.c. machine or on the first batch of machines, and routine tests carried out on subsequent a.c. machines in accordance with Tab 1.

3.3.2 Type test are to be carried out on a proptoype d.c. machine or on the first batch of machines, and routine tests carried out on subsequent d.c. machines in accordance with Tab 2.

3.3.3 Where the test procedure is not specified, the requirements of IEC 60034-1 apply.

3.3.4 Alternative type test, according to naval standard, may be applied, subject to submission to the Society of a type test procedure.

Table 1 : Tests to be carried out on electrical rotating machines

No.	Tests	a.c. Generators		Motors	
		Type test **(1)**	Routine test **(2)**	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection	X	X	X	X
2	Insulation resistance measurement	X	X	X	X
3	Winding resistance measurement	X	X	X	X
4	Verification of the voltage regulation system	X	X **(3)**		
5	Rated load test and temperature rise measurement	X		X	
6	Overload/overcurrent test	X	X **(4)**	X	X **(4)**
7	Verification of steady short-circuit conditions **(5)**	X			
8	Overspeed test	X	X	X **(6)**	X **(6)**
9	Dielectric strength test	X	X	X	X
10	No load test	X	X	X	X
11	Verification of degree of protection	X		X	
12	Verification of bearings	X	X	X	X

(1) Type test on prototype machine or test on at least the first batch of machines.
(2) The reports of machines routine tested are to contain the manufacturer's serial number of the machine which has been type tested and the test result.
(3) Only functional test of the voltage regulator system.
(4) Only applicable for machine of essential services rated above 100 kW/kVA.
(5) Verification of steady short-circuit condition applies to synchronous machines only.
(6) Not applicable for squirrel cage motors.

Table 2 : Tests to be carried out on electrical d.c. rotating machines

No.	Tests	d.c. Generators		Motors	
		Type test **(1)**	Routine test **(2)**	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection	X	X	X	X
2	Insulation resistance measurement	X	X	X	X
5	Rated load test and temperature rise measurement	X		X	
6	Overload/overcurrent test	X	X **(4)**	X	X **(4)**
8	Overspeed test	X	X	X **(6)**	X **(6)**
9	Dielectric strength test	X	X	X	X
10	No load test	X	X	X	X
11	Verification of degree of protection	X		X	
12	Verification of bearings	X	X	X	X

(1) Type test on prototype machine or test on at least the first batch of machines.
(2) The reports of machines routine tested are to contain the manufacturer's serial number of the machine which has been type tested and the test result.
(3) Only functional test of the voltage regulator system.
(4) Only applicable for machine of essential services rated above 100 kW/kVA.
(5) Verification of steady short-circuit condition applies to synchronous machines only.
(6) Not applicable for squirrel cage motors.

4 Description of test

4.1 Technical documentation and visual inspection

4.1.1 Technical documentation of machines rated at 100 kW (kVA) and over are to be available for examination by the Surveyor.

4.1.2 A visual inspection of the machine is to be made to ensure, as far as practicable, that it complies with the technical documentation.

4.2 Insulation resistance measurement

4.2.1 Immediately after the high voltage tests the insulation resistances are to be measured using a direct current insulation tester between:

a) all current carrying parts connected together and earth

b) all current carrying parts of different polarity or phase, where both ends of each polarity or phase are individually accessible.

The minimum values of test voltages and corresponding insulation resistances are given in Tab 3. The insulation resistance is to be measured close to the operating temperature, or an appropriate method of calculation is to be used.

Table 3 : Minimum insulation resistance

Rated voltage Un (V)	Minimum test voltage (V)	Minimum insulation resistance (MΩ)
Un = 250	2 Un	1
250 < Un ≤ 1000	500	1
1000 < Un ≤ 7200	1000	Un/1000 + 1
7200 < Un ≤ 15000	5000	Un/1000 + 1

4.3 Winding resistance measurement

4.3.1 The resistances of the machine windings are to be measured and recorded using an appropriate bridge method or voltage and current method.

4.4 Verification of the a.c. voltage regulation

4.4.1 The alternating current generator, together with its voltage regulation system, is to be verified in such a way that, at all loads from no load running to full load, the rated voltage at the rated power factor is maintained under steady conditions within ± 2,5%.

4.4.2 When the generator is driven at rated speed, giving its rated voltage, and is subjected to a sudden change of symmetrical load within the limits of specified current and power factor, the voltage is not to fall below 85% nor exceed 120% of the rated voltage.

4.4.3 The voltage of the generator is then to be restored to within plus or minus 3% of the rated voltage for the main generator sets in not more than 1,5 s.

4.4.4 In the absence of precise information concerning the maximum values of the sudden loads, the following conditions may be assumed: 60% of the rated current with a power factor of between 0,4 lagging and zero to be suddenly switched on with the generator running at no load, and then switched off after steady - state conditions have been reached.

4.5 Verification of the d.c. voltage regulation

4.5.1 The d.c.current generator, together with its voltage regulation system, is to be verified in such a way that, at all loads from no load running to full load, the rated voltage is maintained under steady conditions within ±2,5%.

4.5.2 When the generator is driven at rated speed, giving its rated voltage, and is subjected to a sudden change from full load to no load, the voltage is not to exceed 115% of the initial voltage.

When the generator is driven at rated speed, giving its rated voltage, and is subjected to a change from half load to full load, the voltage is not to fall below 80% of the initial voltage.

4.5.3 The voltage of the generator is then to be restored to within plus or minus 3% of the initial voltage for the main generator sets in not more than 2 s.

4.6 Rated load test and temperature rise measurements

4.6.1 The temperature rises are to be measured at the rated out-put, voltage and frequency and for the duty for which the machine is rated and marked in accordance with the testing methods specified in IEC Publication 60034-1, or by means of a combination of other tests.

4.6.2 The limits of temperature rise above ambient air temperature of 45°C for air-cooled machines are those given in Tab 4.

4.7 Overload/ overcurrent test

4.7.1 Overload test is to be carried out as a type test for generators as proof of overload capability of generators and the excitation system, for motors as proof of momentary excess torque as required in IEC Publication 60034-1. The over-load test can be replaced at a routine test by an over-current test. The overcurrent test is to be proof of the current capability of the windings, wires, connections etc. of each machine. The overcurrent test can be performed at reduced speed (motors) or at short-circuit (generators).

4.7.2 In the case of machines for special uses (e.g. for windlasses), overload values other than the above may be considered.

4.8 Verification of the steady short circuit current

4.8.1 It is to be verified that under steady state short-circuit conditions, the generator with its voltage regulating system is capable of maintaining, without sustaining any damage, a current of at least three times the rated current for a duration of at least 2 s or, where precise data is available, for a duration of any time delay which may be fitted in a tripping device for discrimination purposes.

Table 4 : Temperature rise limits for air-cooled machines based on an ambient temperature of 45°C

No.	Part of machines	Method of measurement of temperature **(1)**	Temperature rise °C by class of insulation				
			A	E	B	F	H
1	a) a.c. windings of machines having outputs of 5000 kW (or kVA) or more	R ETD	55 60	– –	75 80	95 100	120 125
	b) a.c. windings of machines having outputs of less than 5000 kW (or kVA)	R ETD	55 60	70 –	75 85	100 105	120 125
2	Windings of armatures with commutators	T R	45 55	60 70	65 75	80 100	100 120
3	Field windings of a.c. and d.c machines having d.c. excitation other than those in item 4	T R	45 55	60 70	65 75	80 100	100 120
4	a) Field windings of synchronous machines with cylindrical rotors having d.c. excitation	R	–	–	85	105	130
	b) Stationary field windings of d.c. machines having more than one layer	T R ETD	45 55 –	60 70 –	65 75 85	80 100 105	100 120 130
	c) Low resistance field windings of more than one layer, and compensating windings	T, R **(2)**	55	70	75	95	120
	d) Single-layer windings with exposed bare surfaces	T, R **(2)**	60	75	85	105	130
5	Permanently short-circuited, insulated windings	T	55	70	75	95	120
6	Permanently short-circuited uninsulated windings	The temperature rise of these parts is in no case to reach such a value that there is a risk of damage to any insulating or other material on adjacent parts					
7	Magnetic core and other parts not in contact with windings						
8	Magnetic core and other parts in contact with windings	T	55	70	75	95	120
9	Commutators and sliprings, open or enclosed **(3)**	T	55	65	75	85	95

(1) T : Measurement by the thermometer method.
R : Measurement by the resistance method.
ETD : Measurement by embedded temperature detectors.

(2) Temperature rise measurement is to use the resistance method R whenever practicable.

(3) If commutators and sliprings are adjacent to windings with a lower insulation class, the temperature rises for this class apply.

4.9 Overspeed test

4.9.1 Machines are to withstand the overspeed test as specified in IEC Publication 60034-1. This test is not applicable for squirrel cage motors.

4.10 Dielectric strength test

4.10.1 New and completed rotating machines are to withstand a dielectric test as specified in IEC Publication 60034-1.

4.10.2 When it is necessary to perform an additional high voltage test, this is to be carried out after any further drying, with a test voltage of 80% of that specified in IEC Publication 60034-1.

4.10.3 Completely rewound windings of used machines are to be tested with the full test voltage applied in the case of new machines.

4.10.4 Partially rewound windings are to be tested at 75% of the test voltage required for new machines. Prior to the test, the old part of the winding is to be carefully cleaned and dried.

4.10.5 Following cleaning and drying, overhauled machines are to be subjected to a test at a voltage equal to 1,5 times the rated voltage, with a minimum of 500 V if the rated voltage is less than 100 V, and with a minimum of 1000 V if the rated voltage is equal to or greater than 100 V.

4.10.6 A repetition of the high voltage test for groups of machines and apparatus is to be avoided if possible, but if a test on an assembled group of several pieces of new apparatus, each of which has previously passed its high voltage test, is per-formed, the test voltage to be applied to such assembled group is 80% of the lowest test voltage appropriate for any part of the group.

Note 1: For windings of one or more machines connected together electrically, the voltage to be considered is the maximum voltage that occurs in relation to earth.

4.11 No load test

4.11.1 Machines are to be operated at no load and rated speed whilst being supplied at rated voltage and frequency as a motor while generators are to be driven by a suitable means and excited to give rated terminal voltage.

During the running test, the vibration of the machine and operation of the bearing lubrication system, if appropriate, are to be checked.

4.12 Verification of degree of protection

4.12.1 As specified in IEC Publication 60034-5.

4.13 Verification of bearings

4.13.1 Upon completion of the above tests, machines which have sleeve bearings are to be opened upon request for examination by the Surveyor, to establish that the shaft is correctly seated in the bearing shells.

SECTION 5 TRANSFORMERS

1 Constructional and operational requirements

1.1 Construction

1.1.1 Transformers, except those for motor starting, are to be double wound (two or more separate windings).

1.1.2 Transformers are normally to be of the dry, air-cooled type.

1.1.3 When a forced air cooling system is used, an alarm is to be activated in the event of its failure.

1.1.4 Liquid-cooled transformers may be used provided that:

- the liquid is non-toxic and of a type which does not readily support combustion
- the construction is such that the liquid is not spilled in inclined position
- temperature and pressure relief devices with an alarm are installed
- drip trays or other suitable arrangements for collecting the liquid from leakages are provided
- a liquid gauge indicating the normal liquid level range is fitted.

1.1.5 Transformers are to have enclosures with a degree of protection in accordance with Ch 4, Sec 3, Tab 2.

1.2 Terminals

1.2.1 Suitable fixed terminal connections are to be provided in an accessible position with sufficient space for convenient connection of the external cables.

1.2.2 Terminals are to be clearly identified.

1.3 Voltage variation, short-circuit conditions and parallel operation

1.3.1 Under resistive load (cos Φ = 1), the voltage drop from no load to full load is not to exceed 2,5%.

For transformers with a power lower than 5 kVA per phase, this voltage drop is not to exceed 5%.

An exception is made for special transformers, such as starting and instrument transformers, for which a different voltage variation may be considered.

1.3.2 In determining the voltage ratio and the impedance voltage of transformers, account is to be taken of the total permitted voltage drop from the main switchboard's busbars to the consumers (see Ch 4, Sec 3, [8.11.4]).

1.3.3 Transformers are to be constructed to withstand, without damage, the thermal and mechanical effects of a secondary terminal short-circuit for 2 s, with rated primary voltage and frequency.

For transformers of 1 MVA and over, this is to be justified with appropriate tests or documentation.

1.3.4 When transformers are so arranged that their secondary windings may be connected in parallel, their winding connections are to be compatible, their rated voltage ratios are to be equal (with tolerances allowed) and their short-circuit impedance values, expressed as a percentage, are to have a ratio within 0,9 to 1,1.

When transformers are intended for operation in parallel, the rated power of the smallest transformer in the group is to be not less than half of the rated power of the largest transformer in the group.

1.4 Electrical insulation and temperature rise

1.4.1 Insulating materials for windings and other current carrying parts are to comply with the requirements of Ch 4, Sec 2.

1.4.2 All windings of air-cooled transformers are to be suitably treated to resist moisture, air salt mist and oil vapours.

1.4.3 The permissible limits of temperature rise with an ambient air temperature of 45°C for (natural or forced) air-cooled transformers are given in Tab 1. The temperature rises shown for windings refer to measurement by the resistance method while those for the core refer to the thermometer method.

Table 1 : Temperature rise limits for transformers

No.	Part of machine	Temperature rise by class of insulation °C				
		A	E	B	F	H
1	Windings	55	70	75	95	120
2	Cores and other parts: a) in contact with the windings b) not in contact with the windings	a) the same values as for the windings b) in no case is the temperature to reach values such as to damage either the core itself or other adjacent parts or materials				

1.4.4 For dry-type transformers cooled with an external liquid cooling system, the permissible limits of temperature rise with a sea water temperature of 32°C are 13°C higher than those specified in Tab 1.

1.4.5 For liquid-cooled transformers, the following temperature rises measured by the resistance method apply:

- 55°C where the fluid is cooled by air
- 68°C where the fluid is cooled by water.

1.5 Insulation tests

1.5.1 Transformers are to be subjected to a high voltage test in accordance with the procedure defined in Ch 4, Sec 4, [4.10].

1.5.2 The test voltage is to be applied between each winding under test and the other windings not under test, core and enclosure all connected together.

Single-phase transformers for use in a polyphase group are to be tested in accordance with the requirements applicable to that group.

1.5.3 The r.m.s. value of the test voltage is to be equal to 2 U + 1000 V, with a minimum of 2500 V, where U is the rated voltage of the winding. The full voltage is to be maintained for 1 minute.

1.5.4 Partially rewound windings are to be tested at 75% of the test voltage required for new machines.

1.5.5 The insulation resistance of a new, clean and dry transformer, measured after the temperature rise test has been carried out (at or near operating temperature) at a voltage equal to 500 V d.c., is to be not less than 5 MΩ.

1.5.6 Transformers are to be subjected to an induced voltage insulation test by applying to the terminals of the winding under test a voltage equal to twice the rated voltage. The duration of the test is to be 60 s for any test frequency fp up to and including twice the rated frequency fn.

If the test frequency exceeds twice the rated frequency, the test time in seconds will be 120 fn / fp with a minimum of 15 s.

2 Testing

2.1 General

2.1.1 On new transformers intended for essential services the tests specified in [2.2] are to be carried out.

2.1.2 The manufacturer is to issue a test report giving, inter alia, information concerning the construction, type, serial number, insulation class and all other technical data relevant to the transformer, as well as the results of the tests required.

Such test reports are to be made available to the Society.

2.1.3 In the case of transformers which are completely identical in rating and in all other constructional details, it will be acceptable for the temperature rise test to be performed on only one transformer.

The results of this test and the serial number of the tested transformer are to be inserted in the test reports for the other transformers.

2.1.4 Where the test procedure is not specified, the requirements of IEC 60076 and 60726 apply.

2.1.5 The tests and, if appropriate, manufacture of transformers of 100 kVA and over (60 kVA when single phase) intended for essential services are to be attended by a Surveyor of the Society.

Transformers of 5 kVA up to the limit specified above are approved on a case by case basis, at the discretion of the Society, subject to the submission of adequate documentation and routine tests.

2.2 Tests on transformers

2.2.1 Tests to be carried out on transformers are specified in Tab 2.

Table 2 : Tests to be carried out on transformers

No.	Tests	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection **(3)**	X	X
2	Insulation resistance measurement	X	X
3	Voltage drop	X	X
4	High voltage test	X	X
5	Temperature rise measurement	X	
6	Induced voltage test	X	X
7	Voltage ratio	X	X

(1) Type test on prototype transformer or test on at least the first batch of transformers.

(2) The certificates of transformers routine tested are to contain the manufacturer's serial number of the transformer which has been type tested and the test result.

(3) A visual examination is to be made of the transformer to ensure, as far as practicable, that it complies with technical documentation.

SECTION 6 SEMICONDUCTOR CONVERTORS

1 Constructional and operational requirements

1.1 Construction

1.1.1 Semiconductor convertors are generally to comply with the requirements for switchgear assemblies (see Ch 4, Sec 8).

1.1.2 The monitoring and control circuits are generally to comply with the requirements of Part C, Chapter 3.

1.1.3 For liquid-cooled convertors the following provisions are to be satisfied:

- liquid is to be non-toxic and of low flammability
- drip trays or other suitable means are to be provided to contain any liquid leakages
- the resistivity of the cooling fluid in direct contact with semiconductor or other current carrying parts is to be monitored and an alarm initiated if the resistivity is outside the specified limits.

1.1.4 Where forced cooling is used, the temperature of the heated cooling medium is to be monitored.

If the temperature exceeds a preset value an alarm is to be given and the shutdown of the convertor is to be activated.

1.1.5 Where forced (air or liquid) cooling is provided, it is to be so arranged that the convertor cannot be or remain loaded unless effective cooling is maintained.

Alternatively, other effective means of protection against overtemperature may be provided.

1.1.6 Stacks of semiconductor elements, and other equipment such as fuses, or control and firing circuit boards etc., are to be so arranged that they can be removed from equipment without dismantling the complete unit.

1.1.7 Semiconductor convertors are to be rated for the required duty having regard to the peak loads, system transient and overvoltage and to be dimensioned so as to withstand the maximum short-circuit currents foreseen at the point of installation for the time necessary to trip the protection of the circuits they supply.

1.2 Protection

1.2.1 Semiconductor elements are to be protected against short-circuit by means of devices suitable for the point of installation in the network.

1.2.2 Overcurrent or overvoltage protection is to be installed to protect the convertor. When the semiconductor convertor is designed to work as an inverter supplying the network in transient periods, precautions necessary to limit the current are to be taken.

1.2.3 Semiconductor convertors are not to cause distortion in the voltage wave form of the power supply at levels exceeding the voltage wave form tolerances at the other user input terminals (see Ch 4, Sec 2, [2.4]).

1.2.4 An alarm is to be provided for tripping of protective devices against overvoltages and overcurrents in electric propulsion convertors.

1.3 Parallel operation with other power sources

1.3.1 For convertors arranged to operate in parallel with other power sources, load sharing is to be such that under normal operating conditions overloading of any unit does not occur and the combination of paralleled equipment is stable.

1.4 Temperature rise

1.4.1 The permissible limit of temperature rise of the enclosure of the semiconductors is to be assessed on the basis of an ambient air temperature of 45°C or sea water temperature of 32°C for water-cooled elements, taking into account its specified maximum permissible temperature value.

1.4.2 The value of the maximum permissible temperature of the elements at the point where this can be measured (point of reference) is to be stated by the manufacturer.

1.4.3 The value of the mean rated current of the semiconductor element is to be stated by the manufacturer.

1.5 Insulation test

1.5.1 The test procedure is that specified in IEC Publication 60146.

1.5.2 The effective value of the test voltage for the insulation test is to be as shown in Tab 1.

Table 1 : Test voltages for high voltage test on static convertors

$\frac{U_m}{\sqrt{2}} = U$ in V **(1)**	Test voltage V
U ≤ 60	600
60 < U ≤ 90	900
90 < U	2 U + 1000 (at least 2000)

(1) U_m : Highest crest value to be expected between any pair of terminals.

2 Testing

2.1 General

2.1.1 Convertors intended for essential services are to be subjected to the tests stated in [2.2].

2.1.2 The manufacturer is to issue a test report giving information on the construction, type, serial number and all technical data relevant to the convertor, as well as the results of the tests required.

2.1.3 In the case of convertors which are completely identical in rating and in all other constructional details, it will be acceptable for the rated current test and temperature rise measurement stipulated in [2.2] not to be repeated.

2.1.4 The tests and, if appropriate, manufacture of convertors of 50 kVA and over intended for essential services are to be attended by a Surveyor of the Society.

2.2 Tests on convertors

2.2.1 Convertors are to be subjected to tests in accordance with Tab 2.

Type tests are the tests to be carried out on a prototype convertor or the first of a batch of convertors, and routine tests are the tests to be carried out on subsequent convertors of a particular type.

2.2.2 The electronic components of the convertors are to be constructed to withstand the tests required in Ch 5, Sec 6.

2.2.3 Final approval of convertors is to include complete function tests after installation on board, performed with all ship's systems in operation and in all characteristic load conditions.

Table 2 : Tests to be carried out on static convertors

No.	Tests	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection **(3)** including check of earth continuity	X	X
2	Light load function test to verify all basic and auxiliary functions	X	X
3	Rated current test	X	
4	Temperature rise measurement	X	
5	Insulation test (dielectric strength test and insulation resistance measurement)	X	X
6	Protection of the convertors in case of failure of forced cooling system	X	X

(1) Type test on prototype convertor or test on at least the first batch of convertors.

(2) The certificates of convertors routine tested are to contain the manufacturer's serial number of the convertor which has been type tested and the test result.

(3) A visual examination is to be made of the convertor to ensure, as far as practicable, that it complies with technical documentation.

SECTION 7 STORAGE BATTERIES AND CHARGERS

1 Constructional requirements for batteries

1.1 General

1.1.1 The requirements of this Section apply to permanently installed storage batteries (not to portable batteries).

The requirements of this Section don't apply to the main battery of the submarine, used for distribution and propulsion.

1.1.2 Storage batteries may be of the lead-acid or nickel-alkaline type, due consideration being given to the suitability for any specific application.

Other types of storage batteries of satisfactorily proven design (e.g. silver/zinc) may be accepted provided they are suitable for shipboard use to the satisfaction of the Society.

1.1.3 Cells are to be assembled in suitable crates or trays equipped with handles for convenient lifting.

1.2 Vented batteries

1.2.1 Vented batteries are those in which the electrolyte can be replaced and freely releases gas during periods of charge and overcharge.

1.2.2 Vented batteries are to be constructed to withstand the movement of the ship and the atmosphere (salt mist, oil etc.) to which they may be exposed.

1.2.3 Battery cells are to be so constructed as to prevent spilling of electrolyte at any inclination of the battery up to the limit of exceptional environment attitude Pt B, Ch 1, Sec 3).

1.2.4 It is to be possible to check the electrolyte level and the ph.

1.3 Valve-regulated sealed batteries

1.3.1 Valve-regulated sealed batteries are batteries whose cells are closed under normal conditions but which have an arrangement which allows the escape of gas if the internal pressure exceeds a predetermined value. The cells cannot normally receive addition to the electrolyte.

Note 1: The cells of batteries which are marketed as "sealed" or "maintenance free" are fitted with a pressure relief valve as a safety precaution to enable uncombined gas to be vented to the atmosphere; they should more properly be referred to as valve-regulated sealed batteries. In some circumstances the quantity of gas vented can be up to 25% of the equivalent vented design. The design is to take into consideration provision for proper ventilation.

1.3.2 Cell design is to minimize risks of release of gas under normal and abnormal conditions.

1.4 Tests on batteries

1.4.1 The battery autonomy is to be verified on board or during the factory acceptance tests, in accordance with the operating conditions.

2 Constructional requirements for chargers

2.1 Characteristics

2.1.1 Chargers are to be adequate for the batteries for which they are intended and provided with a voltage regulator.

2.1.2 In the absence of indications regarding its operation, the battery charger is to be such that the completely discharged battery can be recharged to 80% capacity within a period of 10 hours without exceeding the maximum permissible charging current. A charging rate other than the above (e.g. fully charged within 6 hours for batteries for starting of motors) may be required in relation to the use of the battery.

2.1.3 For floating service or for any other condition where the load is connected to the battery while it is on charge, the maximum battery voltage is not to exceed the safe value of any connected apparatus.

Note 1: Consideration is to be given to the temperature variation of the batteries.

2.1.4 The battery charger is to be designed so that the charging current is set within the maximum current allowed by the manufacturer when the battery is discharged and the floating current to keep the battery fully charged.

2.1.5 Trickle charging to neutralise internal losses is to be provided. An indication is to be provided to indicate a charging voltage being present at the charging unit.

2.1.6 Protection against reversal of the charging current is to be provided.

2.1.7 Battery chargers are to be constructed to simplify maintenance operation. Indications are to be provided to visualise the proper operation of the charger and for troubleshooting.

2.2 Tests on chargers

2.2.1 Battery chargers are to be subjected to tests in accordance with Tab 1.

Type tests are the tests to be carried out on a prototype charger or the first of a batch of chargers, and routine tests are the tests to be carried out on subsequent chargers of a particular type.

2.2.2 The electronic components of the battery chargers are to be constructed to withstand the tests required in Ch 5, Sec 6.

2.2.3 The tests of battery chargers of 5 kW and over intended for essential services are to be attended by a Surveyor of the Society.

Table 1 : Tests to be carried out on battery chargers

No.	Tests	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection **(3)** including check of earth continuity	X	X
2	Functional tests (current and voltage regulation, quick, slow, floating charge, alarms)	X	X
3	Temperature rise measurement	X	
4	Insulation test (dielectric strength test and insulation resistance measurement)	X	X

(1) Type test on prototype battery charger or test on at least the first batch of battery chargers.

(2) The certificates of battery chargers routine tested are to contain the manufacturer's serial number of the battery charger which has been type tested and the test result.

(3) A visual examination is to be made of the battery charger to ensure, as far as practicable, that it complies with technical documentation.

SECTION 8 SWITCH GEAR AND CONTROL GEAR ASSEMBLIES

1 Constructional requirements for main switchboards

1.1 Construction

1.1.1 Construction is to be in accordance with IEC Publication 60092-302.

1.1.2 Where the framework, panels and doors of the enclosure are of steel, suitable measures are to be taken to prevent overheating due to the possible circulation of eddy currents.

1.1.3 Insulating material for panels and other elements of the switchboard is at least to be moisture-resistant and flame-retardant.

1.1.4 Switchboards are to be of dead front type, with enclosure protection according to Ch 4, Sec 3, Tab 2.

1.1.5 Switchboards are to be provided with insulated handrails or handles fitted in an appropriate position at the front of the switchboard. Where access to the rear is necessary for operational or maintenance purposes, an insulated handrail or insulated handles are to be fitted.

1.1.6 Where there is a single main switchboard, a separate cubicle for each main batteries circuit breaker is to be arranged with flame-retardant partitions between the different cubicles. Similar partitions are to be provided between the batteries circuit breaker cubicles and outgoing circuits.

1.1.7 Instruments, handles or push-buttons for switch gear operation are to be placed on the front of the switchboard. All other parts which require operation are to be accessible and so placed that the risk of accidental touching of live parts, or accidental making of short-circuits and ear things, is reduced as far as practicable.

1.1.8 Where it is necessary to make provision for the opening of the doors of the switchboard, this is to be in accordance with one of the following requirements:

a) opening is to necessitate the use of a key or tool (e.g. when it is necessary to replace a lamp or a fuse-link)

b) all live parts which can be accidentally touched after the door has been opened are to be disconnected before the door can be opened

c) the switchboard is to include an internal barrier or shutter with a degree of protection not less than IP2X shielding all live parts such that they cannot accidentally be touched when the door is open. It is not to be possible to remove this barrier or shutter except by the use of a key or tool.

1.1.9 All parts of the switchboard are to be accessible for maintenance, repair or replacement. In particular, fuses are to be able to be safely inserted and withdrawn from their fuse-bases.

1.1.10 Hinged doors which are to be opened for operation of equipment on the door or inside are to be provided with fixing devices for keeping them in open position.

1.1.11 Where components with voltage exceeding the safety voltage are mounted on hinged doors, the latter are to be electrically connected to the switchboard by means of a separate, flexible protective conductor.

1.1.12 All measuring instruments and all monitoring and control devices are to be clearly identified with indelible labels of durable, flame-retardant material.

1.2 Bus bars and bare conductors

1.2.1 Bus bars are to be of copper.

1.2.2 All connections are to be so made as to inhibit oxidation.

1.2.3 Bus bars are to be dimensioned in accordance with IEC Publication 60092-302.

The mean temperature of bus bars is not to exceed 105°C and is not to have any harmful effect on adjacent components.

1.2.4 Bare main bus bars, excluding the conductors between the main bus bars and the supply side of outgoing units, are to have the minimum clearances and creepage distances given in Tab 1. The values shown apply to clearances and creepage distances between live parts as well as between live parts and exposed conductive parts.

Note 1: Clearance is the distance between two conductive parts along a string stretched the shortest way between such parts. Creepage distance is the shortest distance along the surface of an insulating material between two conductive parts.

Table 1 : Clearance and creepage distances

Rated insulation voltage a.c. (r.m.s.) or d.c. (V)	Minimum clearance (mm)	Minimum creepage distance (mm)
≤ 250	15	20
> 250 to ≤ 690	20	25
> 690	25	35

1.2.5 Reduced values as specified in IEC Publication 60092-302 may be accepted for type tested and partially type tested assemblies.

The reference values for the evaluation of the minimum clearances and creepage distances for these assemblies are based on the following:

- pollution degree 3 (conductive pollution occurs, or dry non-conductive pollution occurs which becomes conductive due to condensation which is expected)
- over voltage category III (distribution circuit level)
- non-homogeneous field conditions (case A)
- rated operational voltage 1000 V a.c., 1500 V d.c.
- group of insulating material IIIa.

Special consideration is to be given to equipment located in spaces where a pollution degree higher than 3 is applicable, e.g. in diesel engine rooms.

1.2.6 Bus bars and other bare conductors with their supports are to be mechanically dimensioned and fixed such that they can withstand the stresses caused by short-circuits.

Calculation for the main switchboard is to be submitted to the Society.

1.2.7 Bus bars and bare conductors are to be protected, where necessary, against falling objects (e.g. tools, fuses or other objects).

1.3 Internal wiring

1.3.1 Insulated conductors for internal wiring of auxiliary circuits of switchboards are to be constructed in accordance with Ch 4, Sec 9, [1.1.5].

1.3.2 All insulated conductors provided for in [1.3.1] are to be of flexible construction and of the stranded type.

1.3.3 Connections from bus bars to protective devices are to be as short as possible. They are to be laid and secured in such a way to minimize the risk of a short-circuit.

1.3.4 All conductors are to be secured to prevent vibration and are to be kept away from sharp edges.

1.3.5 Connections leading to indicating and control instruments or apparatus mounted in doors are to be installed such that they cannot be mechanically damaged due to movement of the doors.

1.3.6 No-metallic trays for internal wiring of switchboards are to be of flame-retardant material.

1.3.7 Control circuits are to be installed and protected such that they cannot be damaged by arcs from the protective devices.

1.3.8 Where foreseen, fixed terminal connectors for connection of the external cables are to be arranged in readily accessible positions, as far as practicable.

1.4 Switch gear and control gear

1.4.1 Switch gear and control gear are to comply with IEC Publication 60947 series and to be chosen from among that type approved by the Society.

For DC switch gear, they may comply to IEC 157-1.

1.4.2 The characteristics of switch gear, control gear and protective devices for the various consumers are to be in compliance with Ch 4, Sec 3, [6].

1.5 Auxiliary circuits

1.5.1 Auxiliary circuits are to be designed in such a manner that, as far as practicable, faults in such circuits do not impair the safety of the system. In particular, control circuits are to be designed so as to limit the dangers resulting from a fault between the control circuit and earth (e.g. inadvertent operation or malfunction of a component in the installation), also taking account of the earthing system of their supply.

1.5.2 Auxiliary circuits of essential systems are to be independent of other auxiliary circuits.

1.5.3 Common auxiliary circuits for groups of consumers are permitted only when the failure of one consumer jeopardises the operation of the entire system to which it belongs.

1.5.4 Means are to be provided for isolating the auxiliary circuits as well when the main circuit is isolated (e.g. for maintenance purposes).

1.5.5 For the protection of auxiliary circuits see Ch 4, Sec 3, [6.12].

1.6 Instruments

1.6.1 The upper limit of the range of every voltmeter is to be not less than 120% of the rated voltage of the circuit in which it is installed.

1.6.2 The upper limit of the range of every ammeter is to be not less than 130% of the normal rating of the circuit in which it is installed.

1.6.3 The upper limit of the range of every wattmeter is to be not less than 120% of the rated voltage of the circuit in which it is installed.

1.6.4 Ammeters or wattmeters for use with a.c. generators which may be operated in parallel are to be capable of indicating 15% reverse-current or reverse power, respectively.

1.6.5 For wattmeters using one current circuit only, the measurement of the current of all generators is to be made in the same phase.

1.6.6 Frequency meters are to have a scale at least ± 5% of the nominal frequency.

1.6.7 The secondary windings of instrument transformers are to be earthed.

1.6.8 Each secondary distribution system is to be provided with one voltmeter, or "Power on" indication.

1.6.9 Main switchboards are to be fitted with means for monitoring the insulation level of insulated distribution systems as stipulated in Ch 4, Sec 3, [3.1.1].

1.6.10 Main switchboards are to be fitted with a voltmeter or signal lamp indicating that the cable between the shore-connection box and the main switchboard is energized (see Ch 4, Sec 3, [3.3.7]).

1.6.11 For each d.c. power sources, one voltmeter and one ammeter, are to be provided, except for d.c. power sources for starting devices.

In addition to above, main batteries switchboards are to be fitted with one ampere hour counter charged and one ampere hour counter discharged.

2 Constructional requirements for section boards and distribution boards

2.1 Construction

2.1.1 Section boards and distribution boards are to be constructed according to IEC 61439 series.

2.1.2 Distribution switchboards which are provided with two or more supply circuits arranged for automatic standby connection are to be provided with positive indication of which of the circuits is feeding the switchboard.

2.1.3 Where switchboard supplying essential services is provided with a forced air cooling system, the air temperature is to be monitored. An alarm is to be activated when temperature exceeds a preset value.

3 Testing

3.1 General

3.1.1 Switchboards are to be subjected to the tests specified from [3.2] to [3.4].

3.1.2 The manufacturer is to issue the relative test reports providing information concerning the construction, serial number and technical data relevant to the switchboard, as well as the results of the tests required.

3.1.3 The tests are to be carried out prior to installation on board.

3.1.4 The test procedures are as specified in IEC Publication 60092-302.

3.2 Inspection of equipment, check of wiring and electrical operation test

3.2.1 It is to be verified that the switchboard:

- complies with the approved drawings
- maintains the prescribed degree of protection
- is constructed in accordance with the relevant constructional requirements, in particular as regards creepage and clearance distances.

3.2.2 The connections, especially screwed or bolted connections, are to be checked for adequate contact, possibly by random tests.

3.2.3 Depending on the complexity of the switchboard it may be necessary to carry out an electrical functioning test. The test procedure and the number of tests depend on whether or not the switchboard includes complicated interlocks, sequence control facilities, hectic. In some cases it may be necessary to conduct or repeat this test following installation on board.

3.3 High voltage test

3.3.1 The test is to be performed with alternating voltage at a frequency between 25 and 100 Hz of approximately sinusoidal form.

3.3.2 The test voltage is to be applied:

- between all live parts connected together and earth
- between each polarity and all the other polarities connected to earth for the test.

During the high voltage test, measuring instruments, ancillary apparatus and electronic devices may be disconnected and tested separately in accordance with the appropriate requirements.

3.3.3 The test voltage at the moment of application is not to exceed half of the prescribed value. It is then to be increased steadily within a few seconds to its full value. The prescribed test voltage is to be maintained for 1 minute.

3.3.4 The value of the test voltage for main and auxiliary circuits is given in Tab 2 and Tab 3.

Table 2 : Test voltages for main circuits

Rated insulation voltage Ui (V)	Test voltage a.c. (r.m.s.) or d.c. (V)
Ui ≤ 60	1000
60 < Ui ≤ 300	2000
300 < Ui ≤ 660	2500
660 < Ui ≤ 800	3000
800 < Ui ≤ 1000	3500

Table 3 : Test voltage for auxiliary circuits

Rated insulation voltage Ui (V)	Test voltage a.c. (r.m.s.) or d.c. (V)
Ui ≤ 12	250
12 < Ui ≤ 60	500
Ui > 60	2 Ui + 1000 (at least 1500)

3.4 Measurement of insulation resistance

3.4.1 Immediately after the high voltage test, the insulation resistance is to be measured using a device with a direct current voltage of at least 500 V.

3.4.2 The insulation resistance between all current carrying parts and earth (and between each polarity and the other polarities) is to be at least equal to 1 M.

SECTION 9 CABLES

1 Constructional requirements

1.1 Construction

1.1.1 Cables and insulated wiring are generally to be constructed in accordance with IEC Publications of the series 60092-3.., as well as with the provisions of this Chapter.

1.1.2 Regarding smoke emission and halogen acid gas content, subject to Sec 3, [9.1.5], cables are to be in compliance with IEC 60754-1, 60754-2, 61034-1, 61034-2.

1.1.3 Optical fibre cables are to be constructed in accordance with IEC Publication 60794.

1.1.4 Flexible cables qualified according to national standards may be accepted.

1.1.5 Cables and insulated wires other than those specified in IEC Publications are subject to special consideration by the Society in each case. Those for general purposes are to be constructed of materials having characteristics which produce a cable at least equivalent to those constructed from materials referred to in IEC Publications.

1.1.6 Insulated wiring for auxiliary circuits of switchboards may be constituted by cables with a single conductor of the stranded type for all sections, PVC- or rubber-insulated in accordance with the Publications cited in [1.1.1] and without further protection.

The insulated wiring is to be at least of the flame-retardant type according to IEC Publication 60332-1. Equivalent types of flame-retardant switchboard wires will be specially considered by the Society.

1.1.7 Underwater cables are to be radially watertight, up to the pressure corresponding to the destructive pressure of the pressure hull.

1.2 Conductors

1.2.1 Conductors are to be of annealed electrolytic copper with a resistivity not exceeding 17,241 $\Omega \cdot mm^2/km$ at 20°C according to IEC 60228.

1.2.2 Individual conductor wires of rubber-insulated cables are to be tinned or coated with a suitable alloy.

1.2.3 All conductors are to be stranded, except for cables of nominal cross-sectional area 2,5 mm^2 and less (provided that adequate flexibility of the finished cable is assured).

1.2.4 For the minimum nominal cross-sectional areas permitted, see Ch 4, Sec 3, [8.10].

1.3 Insulating materials

1.3.1 The materials used for insulation are to comply with IEC Publication 60092-351 and to have the thicknesses specified for each type of cable in the relevant standard. The maximum permissible rated temperature is specified for the various materials.

1.3.2 Materials and thicknesses other than those in [1.3.1] will be specially considered by the Society.

1.4 Inner covering, fillers and binders

1.4.1 The cores of a multicore cable are to be laid up. The spaces between the cores are to be filled so as to obtain an assembly having an essentially circular cross-section. The filling may be omitted in multicore cables having a conductor cross-sectional area not exceeding 4 mm^2.

When a non-metallic sheath is applied directly over the inner covering or the fillers, it may substitute partially for the inner covering or fillers.

1.4.2 The materials used, the binders and the thicknesses of the inner coverings are generally to be in accordance with IEC Publications of the series 60092-3.., or 60794 in relation to the type of cable.

1.5 Protective coverings (armour and sheath)

1.5.1 Metallic armour, if not otherwise protected against corrosion, is to be protected by means of a coating of protective paint (see Ch 4, Sec 3, [8.3]).

1.5.2 The paint is to be non-flammable and of adequate viscosity. When dry, it is not to flake off.

1.5.3 The materials and construction used for (metal) armour are to be in accordance with IEC Publication 60092-350 and their dimensions are to be those specified for each type of cable in the relevant standard.

1.5.4 The materials used for sheaths are to be in accordance with IEC Publication 60092-359 and are to have the thicknesses specified for each type of cable in the relevant standard.

The quality of the materials is to be adequate to the service temperature of the cable.

1.5.5 Materials other than those in [1.5.3] and [1.5.4] will be specially considered by the Society.

1.6 Identification

1.6.1 Each cable is to have clear means of identification so that the manufacturer can be determined.

1.6.2 Fire non propagating cables are to be clearly labelled with indication of the standard according to which this characteristic has been verified and, if applicable, of the category to which they correspond.

2 Testing

2.1 Type tests

2.1.1 Type tests are to be in accordance with the relevant IEC 60092-3.. Series Publications and IEC 60332-1, IEC 60332-3 Category A, and IEC 60331 where applicable.

Type test according to national standard may be accepted.

2.1.2

For underwater cables, a specific qualification test is to be done. The test procedure is to include a watertightness with pressure cycles reflecting the operational profile of the submarine.

2.2 Routine tests

2.2.1 Every length of finished cable is to be subjected to the tests specified in [2.2.2].

2.2.2 The following routine tests are to be carried out:

a) visual inspection

b) check of conductor cross-sectional area by measuring electrical resistance

c) high voltage test

d) insulation resistance measurement

e) dimensional checks (as necessary).

2.2.3 The manufacturer is to issue a statement providing information on the type and characteristics of the cable, as well as the results of the tests required and the Type Approval Certificates.

2.2.4 The test procedure is as specified in IEC Publication 60092-350.

2.2.5 Where an alternative scheme, e.g. a certified quality assurance system, is recognised by the Society, attendance of the Surveyor may not be required.

SECTION 10 MISCELLANEOUS EQUIPMENT

1 Switch gear and control gear, protective devices

1.1 General

1.1.1 Switch gear and control gear are to comply with IEC Publication 60947 and 157-1 where applicable.

1.1.2 For materials and construction see Ch 4, Sec 2, [4] and Ch 4, Sec 2, [5].

1.2 Circuit-breakers

1.2.1 Power-driven circuit-breakers are to be equipped with an additional separate drive operated by hand.

1.2.2 Power circuit-breakers with a making capacity exceeding 10 kA are to be equipped with a drive which performs the make operation independently of the actuating force and speed.

1.2.3 Where the conditions for closing the circuit-breaker are not satisfied (e.g. if the undervoltage trip is not energised), the closing mechanism is not to cause the closing of the contacts.

1.2.4 All circuit-breakers rated more than 16 A are to be of the trip-free type, i.e. the breaking action initiated by overcurrent or undervoltage releases is to be fulfilled independently of the position of the manual handle or other closing devices.

1.3 Protection devices

1.3.1 Short-circuit releases are generally to be independent of energy supplied from circuits other than that to be protected. Tripping due to short-circuit is to be reliable even in the event of a total loss of voltage in the protected circuit.

1.3.2 Overload releases or relays are to operate reliably at any voltage variation of the supply voltage in the protected circuit.

1.3.3 Undervoltage relays or releases are to cause the circuit-breaker to open if the voltage drops to 70% - 35% of the rated voltage.

1.3.4 Shunt releases are to ensure the disconnection of the circuit-breaker even when the supply voltage of the release drops to 85% of the rated supply voltage.

1.3.5 The reverse power protection device is to respond to the active power regardless of the power factor, and is to operate only in the event of reverse power.

1.3.6 Insulation monitoring devices are to continuously monitor the insulation resistance to earth and trigger an alarm should the insulation resistance fall below a predetermined value.

The measuring current of such devices is not to exceed 30 mA in the event of a total short to earth.

2 Lighting fittings

2.1 Applicable requirements

2.1.1 Lighting fittings are to comply with IEC Publications 60598 and 60092-306.

Lighting fittings complying with other standards will be specially considered by the Society.

2.2 Construction

2.2.1 The temperature of terminals for connection of supplying cables is not to exceed the maximum conductor temperature permitted for the cable (see Ch 4, Sec 3, [8.9]).

Where necessary, luminaires are to be fitted with terminal boxes which are thermally insulated from the light source.

2.2.2 Wires used for internal connections are to be of a temperature class which corresponds to the maximum temperature within the luminaire.

2.2.3 The temperature rise of parts of luminaires which are in contact with the support is not to exceed 50°C. The rise is not to exceed 40°C for parts in contact with flammable materials.

2.2.4 The temperature rise of surface parts which can easily be touched in service is not to exceed 15°C.

2.2.5 High-power lights with higher surface temperatures than those in [2.2.2] and [2.2.3] are to be adequately protected against accidental contact.

3 Accessories

3.1 Applicable requirements

3.1.1 Accessories are to be constructed in accordance with the relevant IEC Publications, and in particular with Publication 60092-306.

3.2 Construction

3.2.1 Enclosures of accessories are to be of metal having characteristics suitable for the intended use on board, or of flame-retardant insulating material.

3.2.2 Terminals are to be suitable for the connection of stranded conductors, except in the case of rigid conductors for mineral-insulated cables.

3.2.3 Electrical pressure hull penetration are to be qualified according to a certification scheme. This scheme is to be submitted to the Society, and is to contain at least the water-tightness verification of the penetration.

4 Plug-and-socket connections

4.1 Applicable requirements

4.1.1 Plug-and-socket connections are to comply with IEC Publication 60092-306 and with the following additional standards in relation to their use:

- in accommodation spaces, day rooms and service rooms (up to 16 A, 250 V a.c.):

  IEC Publication 60083 or 60320, as applicable

- for power circuits (up to 250 A, 690 V a.c.):

  IEC Publication 60309

- for electronic switch gear:

  IEC Publications, e.g. 60130 and 60603.

5 Heating and cooking appliances

5.1 Applicable requirements

5.1.1 Heating and cooking appliances are to comply with the relevant IEC Publications (e.g. those of series 60335), with particular attention to IEC 60092-307.

5.2 General

5.2.1 Heating elements are to be enclosed and protected with metal or refractory material.

5.2.2 The terminals of the power supply cable are not to be subjected to a higher temperature than that permitted for the conductor of the connection cable.

5.2.3 The temperature of parts which are to be handled in service (switch knobs, operating handles and the like) is not to exceed the following values:

- 55°C for metal parts
- 65°C for vitreous or moulded material.

5.3 Space heaters

5.3.1 The casing or enclosure of heaters is to be so designed that clothing or other flammable material cannot be placed on them.

5.3.2 The temperature of the external surface of space heaters is not to exceed 60°C.

5.3.3 Space heaters are to be provided with a temperature limiting device without automatic reconnection which automatically trips all poles or phases not connected to earth when the temperature exceeds the maximum permissible value.

5.4 Cooking appliances

5.4.1 Live parts of cooking appliances are to be protected such that any foods or liquids which boil over or spill do not cause short-circuits or loss of insulation.

5.5 Fuel oil and lube oil heaters

5.5.1 In continuous-flow fuel oil and lube oil heaters, the maximum temperature of the heating elements is to be below the boiling point of the oil.

5.5.2 Each oil heater is to be provided with a thermostat maintaining the oil temperature at the correct level.

5.5.3 In addition to the thermostat in [5.5.2], each oil heater is to be provided with a temperature limiting device without automatic reconnection, and with the sensing device installed as close as possible to the heating elements and permanently submerged in the liquid.

5.6 Water heaters

5.6.1 Water heaters are to be provided with a thermostat and safety temperature limiter.

SECTION 11 LOCATION

1 General

1.1 Location

1.1.1 The degree of protection of the enclosures and the environmental categories of the equipment are to be appropriate to the spaces or areas in which they are located; see Ch 4, Sec 3, Tab 2 as well as Ch 4, Sec 3, Tab 3 and Ch 4, Sec 2, [5.2.2].

1.2 Areas with a risk of explosion

1.2.1 Except where the installation of equipment for explosive gas atmosphere is provided for by the Rules, electrical equipment is not to be installed where flammable gases or vapours are liable to accumulate; see Ch 4, Sec 3, [9].

2 Main electrical system

2.1 Main battery switchboard

2.1.1 The main battery switchboard shall be so placed relative to the associated main battery that, as far as is practicable, the integrity of the normal electrical supply may be affected only by a fire or other casualty in one space.

2.1.2 The main battery switchboard is not to be located at the vertical of the fin access hatch.

2.2 Main battery

2.2.1 The main battery is to be located in two or more compartments. When contiguous compartments, the bulkhead is to be designed to withstand a battery explosion.

2.2.2 The access hatch to the main battery compartment is not to be located at the vertical of the fin access hatch.

3 Distribution boards

3.1 Distribution board for navigation lights

3.1.1 The distribution board for navigation lights is to be placed in an accessible position on the control room.

4 Cable runs

4.1 General

4.1.1 Cable runs are to be selected so as to be as far as practicable accessible, with the exception of single cables, situated behind walls or ceilings constructed of incombustible materials, supplying lighting fittings and socket-outlets in accommodation spaces, or cables enclosed in pipes or conduits for installation purposes.

4.1.2 Cable runs are to be selected so as to avoid action from condensed moisture and from dripping of liquids.

4.1.3 Connection and draw boxes are to be accessible, as far as practicable.

4.2 Location of cables in relation to the risk of fire and overheating

4.2.1 Cables and wiring serving essential power, lighting, internal communications or signals are, so far as is practicable, to be routed clear of galleys, laundries, machinery spaces of Category A and their casings and other high fire risk areas, except for supplying equipment in those spaces.

Where it is not possible, the cable runs will be protected against fire exposure by an appropriate insulation material in the exposed zone (i.e. A15 insulation).

4.2.2 When it is essential that a circuit functions for some time during a fire and it is unavoidable to carry the cable for such a circuit through a high fire risk area, the cable is to be of a fire-resistant type or adequately protected against direct exposure to fire.

4.2.3 Main cable runs (see Note 1) and cables for the supply and control of essential services are, as far as is practicable, to be kept away from machinery parts having an increased fire risk (see Note 2) unless:

- the cables have to be connected to the subject equipment
- the cables are protected by a steel bulkhead or deck, or an appropriate insulation material in the exposed zone
- the cables in that area are of the fire-resisting type.

Note 1: Main cable runs are, for example:

- cable runs from main battery switchboards to main switchboards, main battery switchboards to propulsion motors, DG to main switchboards
- cable runs directly above or below main switchboards, centralised motor starter panels, section boards and centralised control panels for propulsion and essential auxiliaries.

Note 2: Machinery, machinery parts or equipment handling combustibles are considered to present an increased fire risk.

4.2.4 Cables and wiring serving essential power, lighting, internal communications or signals are to be arranged, as far as practicable, in such a manner as to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

4.2.5 Cables are to be arranged as remote as possible from sources of heat such as hot pipes, resistors, etc. Where installation of cables near heat sources cannot be avoided, and where there is consequently a risk of damage to the cables by heat, suitable shields are to be installed, or other precautions to avoid overheating are to be taken, for example use of ventilation, heat insulation materials or special heat-resisting cables.

4.3 Location of cables in relation to electromagnetic interference

4.3.1 For the installation of cables in the vicinity of radio equipment or of cables belonging to electronic control and monitoring systems, steps are to be taken in order to limit the effects of unwanted electromagnetic interference (see Ch 5, Sec 5).

4.4 Services with a duplicate feeder

4.4.1 Unless it is not possible, In the case of essential services requiring a duplicate supply (e.g. steering gear circuits), the supply and associated control cables are to follow different routes which are to be as far apart as practicable, separated both vertically and horizontally.

5 Storage batteries

5.1 General

5.1.1 Batteries are to be located where they are not exposed to excessive heat, extreme cold, spray, steam or other conditions which would impair performance or accelerate deterioration. They are to be installed in such a way that no damage may be caused to surrounding appliances by the vapours generated.

5.1.2 Storage batteries are to be suitably housed, and compartments (rooms, lockers or boxes) used primarily for their accommodation are to be properly constructed and efficiently ventilated so as to prevent accumulation of flammable gas.

5.1.3 Starter batteries are to be located as close as practicable to the engine or engines served.

5.1.4 Accumulator batteries shall not be located in sleeping quarters except where hermetically sealed to the satisfaction of the Society.

5.1.5 Lead-acid batteries and alkaline batteries are not to be installed in the same compartment (room, locker, box), unless of valve-regulated sealed type.

5.2 Main battery room

5.2.1 The main battery room is considered as zone 1 with regards to IEC 60079 series.

5.2.2 Provisions are to be made to periodically survey the following parameters:

- temperature of electrolyte
- battery voltage
- level of electrolyte
- density of the electrolyte.

Note 1: This periodical survey may be carried out at random.

5.2.3 The quantity of air extracted from compartments containing main vented type batteries is to be at least equal to:

$Q = 50 \cdot I \cdot n$

where:

Q : Quantity of air expelled, in litres per hour

I : Maximum current delivered by the charging equipment during gas formation

n : Number of cells in series.

5.2.4 The following parameters of the battery room are to be monitored:

- negative pressure of the room
- ventilation air flow
- H2 concentration
- position of ventilation circuit valves.

5.2.5 The battery room is to be painted with antistatic paintings in the circulating area.

5.3 Large vented batteries

5.3.1 Batteries connected to a charging device of power exceeding 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery (hereafter referred to as “large batteries”) are to be installed in a room assigned to batteries only.

5.3.2 Rooms assigned to large batteries are to be provided with mechanical exhaust ventilation.

5.3.3 The provisions of [5.3.1] and [5.3.2] also apply to several batteries connected to charging devices of total power exceeding 2 kW calculated for each one as stated in [5.3.1].

5.4 Moderate vented batteries

5.4.1 Batteries connected to a charging device of power between 0,2 kW and 2 kW calculated as stated in [5.3.1] (hereafter referred to as “moderate batteries”) are to be arranged in the same manner as large batteries or placed in a box or locker in suitable locations such as machinery spaces, storerooms or similar spaces. In machinery spaces and similar well-ventilated compartments, these batteries may be installed without a box or locker provided they are protected from falling objects, dripping water and condensation where necessary.

5.4.2 Rooms, lockers or boxes assigned to moderate batteries are to be provided with natural ventilation or mechanical exhaust ventilation, except for batteries installed without a box or locker (located open) in well-ventilated spaces.

5.4.3 The provisions of [5.4.1] and [5.4.2] also apply to several batteries connected to charging devices of total power between 0,2 kW and 2 kW calculated for each one as stated in [5.3.1].

5.5 Small vented batteries

5.5.1 Batteries connected to a charging device of power less than 0,2 kW calculated as stated in [5.3.1] (hereafter referred to as "small batteries") are to be arranged in the same manner as moderate or large batteries, or without a box or locker, provided they are protected from falling objects, or in a box in a ventilated area.

5.5.2 Boxes for small batteries may be ventilated only by means of openings near the top to permit escape of gas.

5.6 Ventilation

5.6.1 Ducts are to be made of a corrosion-resisting material or their interior surfaces are to be painted with corrosion-resistant paint.

5.6.2 Adequate air inlets (whether connected to ducts or not) are to be provided near the floor of battery rooms or the bottom of lockers or boxes (except for that of small batteries).

5.6.3 In mechanical exhaust ventilation systems, electric motors are to be outside the exhaust ducts and battery compartment.

Fans are to be so constructed and of a material such as to render sparking impossible in the event of the impeller touching the fan casing

5.6.4 For natural ventilation systems for boxes:

a) holes for air inlet are to be provided on at least two opposite sides of the box

b) the exhaust duct is to be of ample dimensions

c) the duct is to terminate at least 1,25 m above the box in a goose-neck or mushroom-head or the equivalent

d) the degree of protection is to be in accordance with Ch 4, Sec 3, Tab 2.

SECTION 12 INSTALLATION

1 General

1.1 Protection against injury or damage caused by electrical equipment

1.1.1 All electrical equipment is to be so installed as not to cause injury when handled or touched in the normal manner.

1.1.2 All electrical equipment is to be installed in such a way that live parts cannot be inadvertently touched, unless supplied at a safety voltage.

1.1.3 For protective earthing as a precaution against indirect contact, see [2].

1.1.4 Equipment is to be installed so as not to cause, or at least so as to reduce to a minimum, electromagnetic interference.

1.2 Protection against damage to electrical equipment

1.2.1 Electrical equipment is to be so placed that as far as practicable it is not exposed to risk of damage from water, steam, oil or oil vapours.

1.2.2 The air supply for internal ventilation of electrical equipment is to be as clean and dry as practicable; cooling air for internal ventilation is not to be drawn from below the floor plates in engine and/or boiler rooms.

1.2.3 Equipment is to be so mounted that its enclosing arrangements and the functioning of the built-in equipment will not be affected by distortions, vibrations and movements of the submarine's structure or by other damage liable to occur.

1.2.4 If electrical fittings, not of aluminium, are attached to aluminium, suitable provision is to be made to prevent galvanic corrosion.

1.3 Accessibility

1.3.1 Equipment is to be so installed that sufficient space is available for inspection and maintenance as required for all its parts (see [6.1.3]), as far as practicable.

2 Earthing of non-current carrying parts on a.c. installations

2.1 Parts which are to be earthed

2.1.1 Exposed metal parts of both fixed and portable electrical machines or equipment which are not intended to be live but which are liable under fault conditions to become live and similar metal parts inside non-metallic enclosures are to be earthed unless the machines or equipment are:

a) supplied at a voltage not exceeding 50 V d.c. or 50 V a.c., root mean square between conductors, achieved without the use of auto-transformers (safety voltage), or

b) supplied at a voltage not exceeding 250 V by safety isolating transformers supplying one consuming device only, or

c) constructed in accordance with the principle of double insulation.

2.1.2 To minimise shock from high frequency voltage induced by the radio transmitter, handles, handrails and other metal elements on the bridge or upper decks are to be in electrical connection with the hull or superstructures.

2.2 Methods of earthing

2.2.1 Metal frames or enclosures of apparatus and electrical machinery may be fixed to, and in metallic contact with, the submarine's structure, provided that the surfaces in contact are clean and free from rust, scale or paint when installed and are firmly bolted together.

2.2.2 For metal frames or enclosures which are not earthed as specified in [2.2.1], earthing connections complying with [2.3] and [2.4] are to be used.

2.2.3 For requirements regarding the earthing of coverings of cables and the mechanical protection of cables, see [7.11] and [7.12].

2.3 Earthing connections

2.3.1 Every earthing connection is to be of copper or other corrosion-resistant material and is to be securely installed and protected, where necessary, against damage and electrolytic corrosion.

2.3.2 The nominal cross-sectional area of each copper earthing connection is to be not less than that required in Tab 1.

Earthing connections of other metals are to have conductance at least equal to that specified for a copper earthing connection.

Table 1 : Cross-sectional area of earth-continuity conductors and earthing connections in d.c. systems

<table>
<tr><td colspan="2">Type of earthing connection</td><td>Cross-sectional area of associated current carrying conductor</td><td colspan="2">Minimum cross-sectional area of copper earthing connection</td></tr>
<tr><td>1</td><td>Earth-continuity conductor in flexible cable or flexible cord</td><td>any</td><td colspan="2">Same as current carrying conductor up to and including 16 mm^2 and one half above 16 mm^2 but at least 16 mm^2</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">Earth-continuity conductor incorporated in fixed cable</td><td rowspan="3">any</td><td colspan="2">a) for cables having an insulated earth-continuity conductor
• a cross-section equal to the main conductors up to and including 16 mm^2, but minimum 1,5 mm^2
• a cross-section not less than 50% of the cross-section of the main conductor when the latter is more than 16 mm^2, but at least 16 mm^2
b) for cables with a bare earth wire in direct contact with the lead sheath</td></tr>
<tr><td>Cross-section of main conductor (mm^2)</td><td>Earthing connection (mm^2)</td></tr>
<tr><td>1 ÷ 2,5
4 ÷ 6</td><td>1
1,5</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">Separate fixed earthing conductor</td><td>≤ 2,5 mm^2</td><td colspan="2">Same as current carrying conductor subject to minimum of 1,5 mm^2 for stranded earthing connection or 2,5 mm^2 for unstranded earthing connection</td></tr>
<tr><td>> 2,5 mm^2 but ≤ 120 mm^2</td><td colspan="2">One half the cross-sectional area of the current carrying conductor, subjected to a minimum of 4 mm^2</td></tr>
<tr><td>> 120 mm^2</td><td colspan="2">70 mm^2</td></tr>
</table>

2.3.3 Metal parts of portable appliances are to be earthed, where required (see [2.1.1]), by means of an earth-continuity conductor in the flexible supply cable or cord, which has the cross-sectional area specified in Tab 1 and which is earthed, for example, through the associated plug and socket.

2.3.4 In no circumstances is the lead sheathing or armour of cables to be relied upon as the sole means of earthing.

2.3.5 The resistance of earth connection is to be less than 0,1 Ω.

2.4 Connection to the submarine structure

2.4.1 Every connection of an earth-continuity conductor or earthing lead to the submarine structure is to be secured by means of a screw of brass or other corrosion-resistant material of diameter not less than 6 mm.

2.4.2 Such earthing connection is not to be used for other purposes.

2.4.3 The connection described in [2.4.1] is to be located in an accessible position where it may readily be checked, as far as practicable.

2.5 Earthed distribution systems

2.5.1 The system earthing of earthed distribution systems is to be effected by means independent of any earthing arrangements of non-current carrying parts and is to be connected to the hull at one point only.

2.5.2 In an earthed distribution system in which the earthing connection does not normally carry current, this connection is to conform with the requirements of [2.3], except that the lower limit of 70 mm^2 (see Tab 1) does not apply.

2.5.3 The earthing connection is to be in an accessible position where it may readily be inspected and disconnected for insulation testing.

3 Rotating machines

3.1

3.1.1 Every rotating machine is preferably to be installed with the shaft in the fore-and-aft direction. Where a rotating machine of 100 kW and over is installed athwartship, or vertically, it is to be ensured that the design of the bearings and the arrangements for lubrication are satisfactory to withstand the rolling specified in Pt B, Ch 1, Sec 3, Tab 5.

4 Semiconductor convertors

4.1 Semiconductor power convertors

4.1.1 Naturally air-cooled semiconductor convertors are to be installed such that the circulation of air to and from the stacks or enclosures is not impeded and that the temperature of the cooling inlet air to convertor stacks does not exceed the ambient temperature for which the stacks are specified.

5 Vented type storage batteries

5.1 General

5.1.1 Batteries are to be arranged so that each cell or crate of cells is accessible. Replacement and periodical maintenance are to be possible.

5.1.2 Cells or crates are to be carried on insulating supports of material non-absorbent to the electrolyte (e.g. treated wood).

5.1.3 Cells are to be securely chocked by means of insulating material non-absorbent to the electrolyte, e.g. strips of treated wood. Special mechanical precautions are to be taken to prevent the battery from being damaged by the shock due to a collision.

5.1.4 Provision is to be made for the free circulation of air.

5.2 Protection against corrosion

5.2.1 The interior of battery compartments (rooms, lockers, boxes) including all metal parts subject to the electrolyte is to be protected against the deteriorating effect of the latter by electrolyte-resistant coating or other equivalent means, unless corrosion-resistant materials are used.

5.3 Battery connection

5.3.1 The cable connection of the main battery are, as far as practicable, located on the same plate, fitted with cable gland, which maintain the tightness of the main battery room.

5.3.2 The direct current cables laid between the batteries and the protective device are to be as short as possible, and each cable is to be protected with a isolating conduit or rigidly supported on isolating supports so as to constitute a short circuit proof installation.

6 Switch gear and control gear assemblies

6.1 Main switchboard

6.1.1 The main switchboard is to be so arranged as to give easy access as may be needed to apparatus and equipment, without danger to personnel. If it is not possible, necessary label plates giving appropriate warning will be fitted on the switchboard.

6.1.2 An unobstructed space is to be left in front of the switchboard wide enough to allow access for operation.

When withdrawable equipment is contained in the switchboard, the width of the space is to be such as the equipment can be fully withdrawn.

6.1.3 If necessary, the clear height above the switchboard specified by the manufacturer is to be maintained for pressure relief in the event of a short-circuit.

6.1.4 When the voltage exceeds the safety voltage, non-conducting mats or gratings are to be provided at the front of the switchboard as necessary.

6.1.5 Piping and conduits are preferably not to be installed directly above or in the vicinity of switchboards.

Where it is unavoidable, pipes and conduits are to have welded joints only or to be provided with protection against spray from pressurised liquids or dripping.

6.2 Section boards and distribution boards

6.2.1 For the installation of section and distribution boards, the same requirements apply, as far as applicable, as given in [6.1] for the installation of the main switchboard.

7 Cables

7.1 General

7.1.1 Cables having insulating materials with different maximum permissible conductor temperatures are not to be bunched together.

Where this is not practicable, the cables are to be so installed that no cable reaches a temperature higher than its rating.

7.1.2 Cables having a protective covering which may damage the covering of more vulnerable cables are not to be bunched with the latter.

7.1.3 Cables having a bare metallic sheath (e.g. of copper) or braid or armour are to be installed in such a way that galvanic corrosion by contact with other metals is prevented.

7.1.4 All cables and wiring external to equipment are to be so installed as not to impair their original flame-retarding properties.

To this end, the following methods may be used:

a) the use of cables which have been tested in accordance with IEC Publication 332-3 Category A or an equivalent test procedure for cables installed in bunches, or

b) the use of fire stops having at least B0 penetrations fitted as follows (see Fig 1, Fig 2, Fig 3 and Fig 4):
   - cable entries at the main switchboard
   - where cables enter engine control rooms
   - cable entries at centralised control panels for propulsion machinery and essential auxiliaries
   - at each end of totally enclosed cable trunks
   - at every second deck or approximately 6 metres for verticals runs and every 14 metres for horizontal runs in enclosed and semi-enclosed spaces

c) the use of fire protection coating applied to at least 1 metre in every 14 metres on horizontal cable runs and over the entire length of vertical cable runs for cables installed in enclosed and semi-enclosed spaces.

The cable penetrations are to be installed in steel plates of at least 3 mm thickness extending all around to twice the largest dimension of the cable run for vertical runs and once for horizontal runs, but need not extend through ceilings, decks, bulkheads or solid sides of trunks. These precautions apply in particular to bunches of 5 or more cables in areas with a high fire risk (such as Category A machinery spaces, galleys etc.) and to bunches of more than 10 cables in other areas.

7.1.5 The cable of different voltage are to be segregated, according to their mutual influence. There shall be at least a segregation between following type of cable:

- control and measurement cable (sensitive cable)
- power cable
- high emissivity cable.

Figure 1 : Totally enclosed trunks

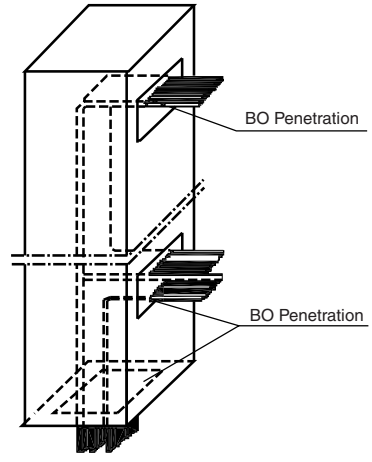


Figure 2 : Non-totally enclosed trunks, vertical

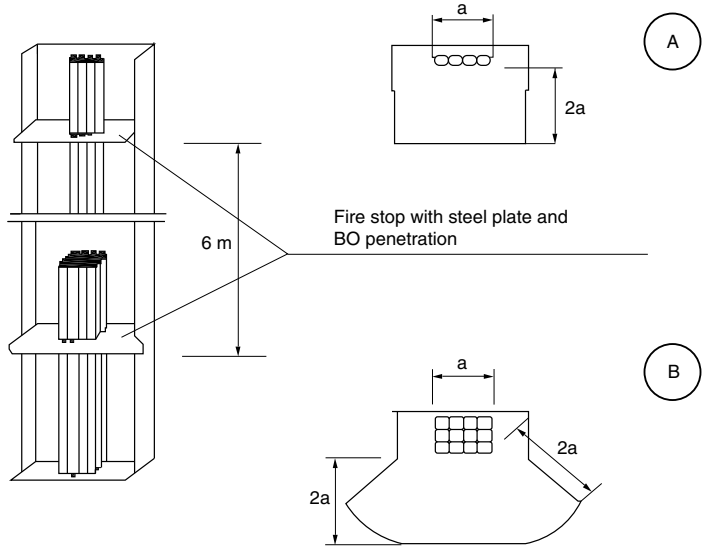


Figure 3 : Non-totally enclosed trunks, horizontal

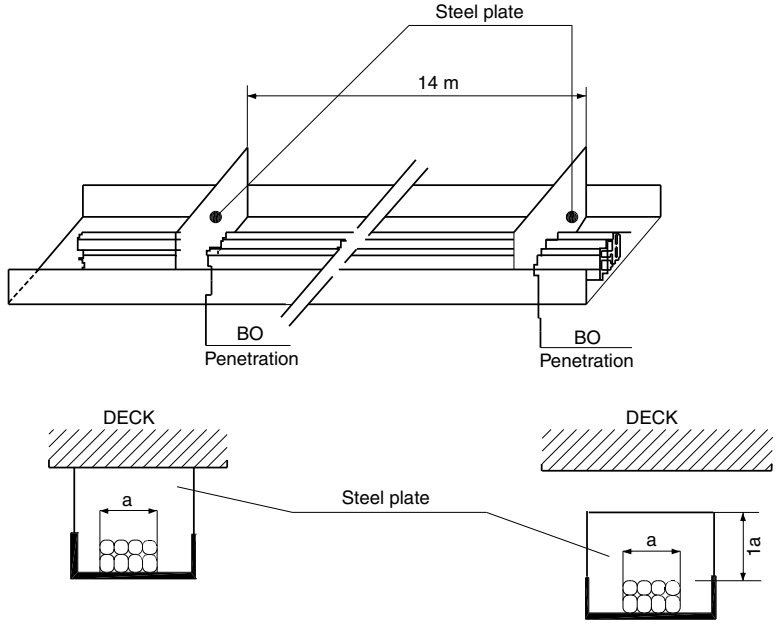


Figure 4 : Open cables runs

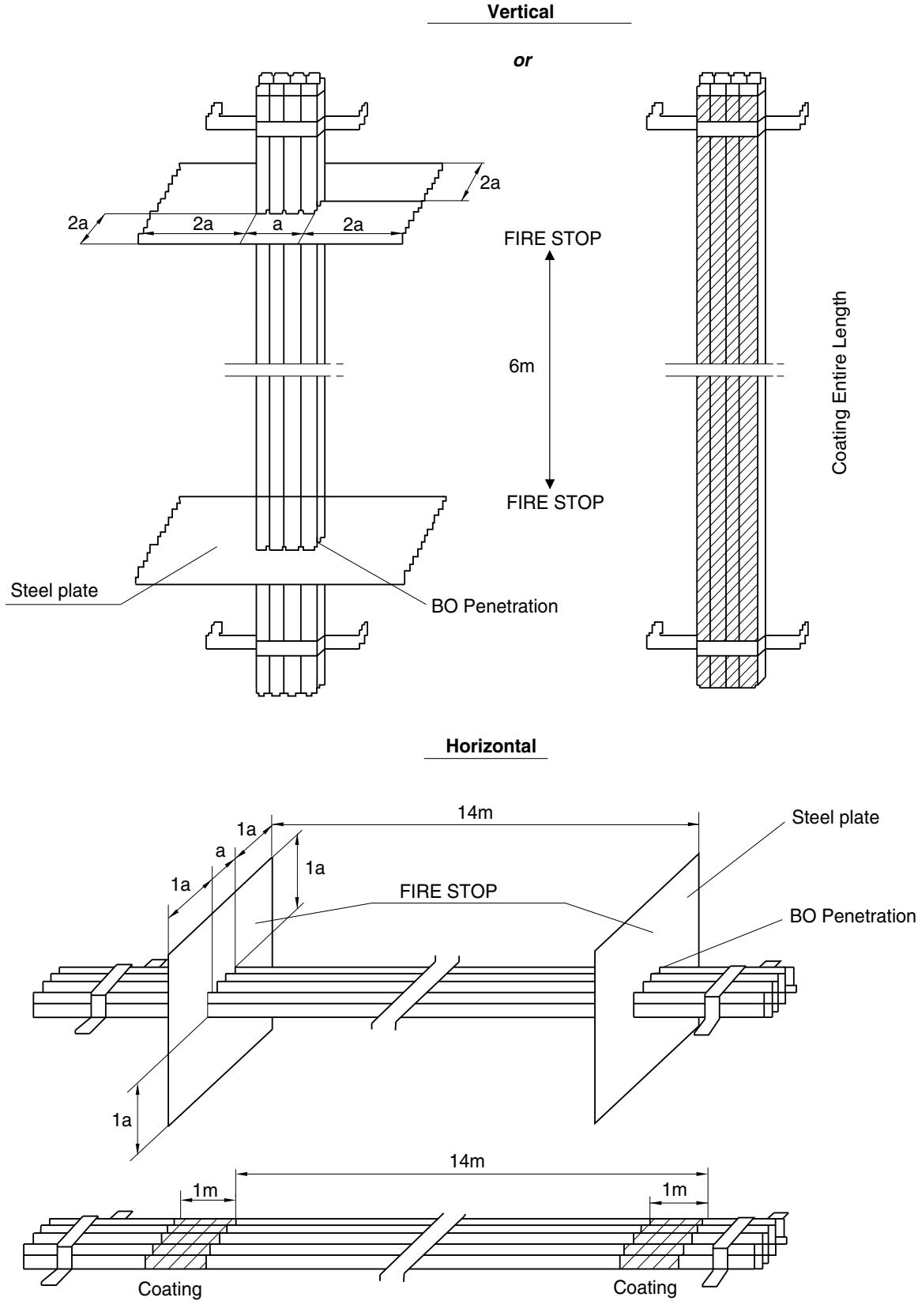


Table 2 : Bending radii

Cable construction		Overall diameter of cable (D)	Minimum internal radius of bend
Insulation	Outer covering		
Thermoplastic or thermosetting with circular copper conductors	unarmoured or unbraided	≤ 25 mm	4 D
		> 25 mm	6 D
	metal braid screened or armoured	any	6 D
	metal wire armoured metal tape armoured or metal-sheathed	any	6 D
	composite polyester/metal laminate tape screened units or collective tape screening	any	8 D
Thermoplastic or thermosetting with shaped copper conductors	any	any	8 D
Silicone flexible cable	silicone	any	3 D

7.2 Radius of bend

7.2.1 The internal radius of bend for the installation of cables is to be chosen according to the type of cable as recommended by the manufacturer.

Its value is generally to be not less than the figure given in Tab 2.

7.3 Fixing of cables

7.3.1 Cables shall be installed and supported in such a manner as to avoid chafing or other damage.

7.3.2 The supports (tray plates, separate support brackets or hanger ladders) and the corresponding accessories are to be of robust construction and of corrosion-resistant material or suitably treated before erection to resist corrosion.

When cables are installed directly on aluminium structures, fixing devices of aluminium or suitably treated steel are to be used.

7.3.3 With the exception of cables installed in pipes, conduits, trunkings or special casings, cables are to be fixed by means of clips, saddles or straps of suitable material, in order to tighten the cables without their coverings being damaged.

7.3.4 Cable clips or straps made from a material other than metal are to be manufactured of a flame-retardant material.

7.3.5 The distances between fastenings and between supports are to be suitably chosen according to the type and number of cables and the probability of vibration.

7.3.6 When cables are fixed by means of clips or straps made from a material other than metal and these cables are not laid on top of horizontal cable supports (e.g. in the case of vertical installation), suitable metal clips or saddles spaced not more than 1 metre apart are to be used in addition in order to prevent the release of cables during a fire.

7.3.7 Suspended cables of fire-resisting type are to be fixed by means of steel straps spaced not more than 500 mm apart.

7.4 Mechanical protection

7.4.1 Cables exposed to risk of mechanical damage are to be protected by metal casing, profiles or grids or enclosed in metal pipes or conduits, unless the cable covering (e.g. armour or sheath) provides adequate mechanical protection.

7.4.2 In situations where there would be an exceptional risk of mechanical damage, e.g. in holds, storage spaces, etc., cables are to be protected by metal casing, trunkings or conduits, even when armoured, if the submarine's structure or attached parts do not afford sufficient protection for the cables.

7.4.3 For the protection of cables passing through decks, see [7.5.4].

7.4.4 Metal casing used for mechanical protection of cables is to be effectively protected against corrosion.

7.5 Penetrations of bulkheads and decks

7.5.1 If cables have to pass without adequate support through non-watertight bulkheads and generally through holes drilled in sheets of structural steel, these holes are to be fitted with glands or bushings of suitable material.

7.5.2 If cables have to pass through a watertight bulkhead or deck, the penetration is to be effected in a watertight manner.

Either suitable individual watertight glands for single cables or boxes containing several cables and filled with a flame-retardant packing may be used for this purpose.

Whichever type of penetration is used, the watertight integrity of the bulkheads or deck is to be maintained.

7.5.3 For pressure hull penetration, where the cable is passing through the hull, this cable is to be longitudinally watertight.

Otherwise the electrical hull penetration, which receive the internal and external cable, is to be watertight. This piece of equipment is to be type approved or qualified.

7.5.4 Cables passing through decks and continuing vertically are to be protected against mechanical damage to a suitable height above the deck.

7.5.5 Where cables pass through bulkheads or decks separating areas with a risk of explosion, arrangements are to be such that hazardous gas or dust cannot penetrate through openings for the passage of cables into other areas.

7.5.6 Where cables pass through a bulkhead or deck which is required to have some degree of fire integrity, penetration is to be so effected as to ensure that the required degree of fire integrity is not impaired.

7.6 Expansion joints

7.6.1 If there is reason to fear that a tray plate, pipe or conduit may break because of the motion of the submarine, different load conditions, temperature variations and relative movement of platform, appropriate expansion joints are to be provided.

7.7 Cables in closed pipes or conduits

7.7.1 Closed pipes or conduits are to have such internal dimensions and radius of bend as will permit the easy drawing in and out of the cables which they are to contain; the internal radius of bend is to be not less than that permitted for cables and, for pipes exceeding 63 mm external diameter, not less than twice the external diameter of the pipe where this value is greater.

7.7.2 Closed pipes and conduits are to be suitably smooth on the interior and are to have their ends shaped or bushed in such a way as not to damage the cable covering.

7.7.3 The space factor (ratio of the sum of the cross-sectional areas corresponding to the external diameters of the cables to the internal cross-sectional areas of the pipe or conduit) is to be not greater than 0,4.

7.7.4 If necessary, openings are to be provided at the highest and lowest points so as to permit air circulation and ensure that the heat from the cables can be dissipated, and to obviate the possibility of water accumulating at any part of the pipe or conduit.

7.7.5 Vertical trunking for electrical cables is to be so constructed as not to jeopardise the required passive fire protection between the spaces.

7.7.6 Metal pipes or conduits are to be protected against corrosion.

7.7.7 Non-metallic pipes or conduits are to be flame-retardant.

7.8 Cables in casings or trunking and conduits with removable covers

7.8.1 Covers are to be removable and when they are open, cables are to be accessible.

7.8.2 Materials used are to comply with [7.7.6] and [7.7.7].

7.8.3 If the fixing of covers is by means of screws, the latter are to be of non-rusting material and arranged so as not to damage the cables.

7.8.4 Means are to be provided to ensure that the heat from the cables can be dissipated and water accumulation is avoided (see [7.7.4]).

7.9 Cable ends

7.9.1 Terminations in all conductors are to be so made as to retain the original electrical, mechanical, flame-retarding properties of the cable.

7.9.2 Where mechanical clamps are not used, the ends of all conductors having a cross-sectional area greater than 4 mm^2 are to be fitted with soldering sockets or compression-type sockets of sufficient size to contain all the strands of the conductor.

7.10 Joints and tappings (branch circuit)

7.10.1 Cable runs are normally not to include joints. Where absolutely necessary, cable joints are to be carried out by a junction method with rebuilding of the insulation and protective coverings.This method is accepted for hull junction

7.10.2 Joints in all conductors are to be so made as to retain the original electrical (continuity and isolation), mechanical (strength and protection), flame-retarding and, where necessary, fire-resisting properties of the cable.

7.10.3 Tappings (branch circuits) are to be made via suitable connections or in suitable boxes of such design that the conductors remain adequately insulated and protected from atmospheric action and are fitted with terminals or busbars of dimensions appropriate to the current rating.

7.10.4 Cables for safety voltages are not to terminate in the same connection boxes as cable for higher voltages unless separated by suitable means.

7.11 Earthing and continuity of metal coverings of cables

7.11.1 All metal coverings of cables are to be electrically connected to the metal hull of the submarine.

7.11.2 Metal coverings are generally to be earthed at both ends of the cable, except for [7.11.3], [7.11.4] and [7.11.4].

7.11.3 Single-point earthing is admitted for final sub-circuits (at the supply end), except for those circuits located in areas with a risk of explosion.

7.11.4 Earthing is to be at one end only in those installations (mineral-insulated cables, intrinsically safe circuits, control circuits (see Ch 5, Sec 5, etc.) where it is required for technical or safety reasons.

7.11.5 Metal coverings of single-core a.c. cables and special d.c. cables with high "ripple" content (e.g. for thyristor equipment) are to be earthed at one point only (e.g. at the mid-point).

7.11.6 The electrical continuity of all metal coverings of cables throughout the length of the latter, particularly at joints and tappings, is to be ensured.

7.11.7 The metal covering of cables may be earthed by means of glands intended for the purpose and so designed as to ensure an effective earth connection.

The glands are to be firmly attached to, and in effective electrical contact with, a metal structure earthed in accordance with these requirements.

7.11.8 The metal covering of cables may also be earthed by means of clamps or clips of corrosion-resistant material making effective contact with the covering and earthed metal.

7.12 Earthing and continuity of metal pipes, conduits and trunking or casings

7.12.1 Metal casings, pipes, conduits and trunking are to be effectively earthed.

7.12.2 Pipes or conduits may be earthed by being screwed into a metal enclosure, or by nuts on both sides of the wall of a metallic enclosure, provided the surfaces in contact are clean and free from rust, scale or paint and that the enclosure is in accordance with these requirements on earthing.

The connection is to be painted immediately after assembly in order to inhibit corrosion.

7.12.3 Pipes and conduits may be earthed by means of clamps or clips of corrosion-resistant metal making effective contact with the earthed metal.

7.12.4 Pipes, conduits or trunking together with connection boxes of metallic material are to be electrically continuous.

7.12.5 All joints in metal pipes and conduits used for earth continuity are to be soundly made and protected, where necessary, against corrosion.

7.12.6 Individual short lengths of pipes or conduits need not be earthed.

7.13 Precautions for single-core cables for a.c.

7.13.1 For the earthing of metal coverings see [7.11.5].

7.13.2 Where it is necessary to use single-core cables for alternating current circuits rated in excess of 20 A, the requirements of [7.13.3] to [7.13.7] are to be complied with.

7.13.3 Conductors belonging to the same circuit are to be contained within the same pipe, conduit or trunking, unless this is of non-magnetic material.

7.13.4 Cable clips are to include cables of all phases of a circuit unless the clips are of non-magnetic material.

7.13.5 In the installation of two, three or four single-core cables forming respectively single-phase circuits, three-phase circuits, or three-phase and neutral circuits, the cables are to be in contact with one another, as far as possible. In any event, the distance between the external covering of two adjacent cables is to be not greater than one diameter.

7.13.6 When single-core cables having a current rating greater than 250 A are installed near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm, unless the cables belonging to the same circuit are installed in trefoil twisted formation.

7.13.7 Magnetic material is not to be used between single-core cables of a group. Where cables pass through steel plates, all the conductors of the same circuit are to pass through a plate or gland, so made that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is to be no less than 75 mm, unless the cables belonging to the same circuit are installed in trefoil twisted formation.

7.14 Cables in refrigerated spaces

7.14.1 For the types of cables permitted in refrigerated spaces, see Ch 4, Sec 3, [8.4].

7.14.2 Power cables installed in refrigerated spaces are not to be covered by thermal insulation. Moreover, such cables are not to be placed directly on the face of the refrigerated space unless they have a thermoplastic or elastomeric extruded sheath.

7.14.3 Power cables entering a refrigerated space are to pass through the walls and thermal insulation at right angles, in tubes sealed at each end and protected against oxidation.

7.15 Cables in areas with a risk of explosion

7.15.1 For the types of cables permitted in areas with a risk of explosion, see Ch 4, Sec 3, [9.2].

7.15.2 For penetration of bulkheads or decks separating areas with a risk of explosion, see [7.5.5].

7.15.3 Cables of intrinsically safe circuits are to be separated from the cables of all other circuits (minimum 50 mm).

7.16 Cables and apparatus for services required to be operable under fire conditions

7.16.1 Cables and apparatus for services required to be operable under fire conditions including their power supplies are to be so arranged that the loss of these services is minimized due to a localized fire at any one area or zone listed in Pt E, Ch 1, Sec 5, [1.3].

7.17 Cables in the vicinity of radio equipment

7.17.1 All cables between antennas and transmitters are to be routed separately of any other cable.

7.17.2 Where it is necessary to use single-core cables, the arrangement of conductors is to be such as to avoid complete or partial loops.

7.18 Cable trays/protective casings made of plastics materials

7.18.1 Cable trays or protective casings made of plastics materials (thermoplastic or thermosetting plastic material) are to be type tested.

7.18.2 Cable trays/protective casings are to be supplemented by metallic fixing and straps such that in the event of a fire they, and the cables affixed, are prevented from falling and causing injury to personnel and/or an obstruction to any escape route.

When used on open deck, they are to be protected against U.V. light.

7.18.3 The load on the cable trays/ protective casings is to be within the Safe Working Load (SWL). The support spacing is not to be greater than the manufacturer recommendations nor in excess of spacing at SWL test. In general, the spacing is not to exceed 2 metres.

7.18.4 The selection and spacing of cable tray/protective casing supports are to take into account:

- cable trays/protective casings' dimensions
- mechanical and physical properties of their material
- mass of cable trays/protective casings
- loads due weight of cables, external forces, thrust forces and vibrations
- maximum accelerations to which the system may be subjected
- combination of loads.

7.18.5 The sum of the cables total cross-sectional area, based on the cables external diameter is not to exceed 40% of the protective casing internal cross-sectional area. This does not apply to a single cable in a protective casing.

8 Various appliances

8.1 Lighting fittings

8.1.1 Lighting fittings are to be so arranged as to prevent temperature rises which could damage the cables and wiring.

Note 1: Where the temperature of terminals of lighting fittings exceeds the maximum conductor temperature permitted for the supplied cable (see Ch 4, Sec 3, [8.9]), special installation arrangements, such as terminal boxes thermally insulated from the light source, are to be provided.

8.1.2 Lighting fittings are to be so arranged as to prevent surrounding material from becoming excessively hot.

8.1.3 Lighting fittings are to be secured in place such that they cannot be displaced by the motion of the vessel.

8.2 Heating appliances

8.2.1 Space heaters are to be so installed that clothing, bedding and other flammable material cannot come in contact with them in such a manner as to cause risk of fire.

Note 1: To this end, for example, hooks or other devices for hanging garments are not to be fitted above space heaters or, where appropriate, a perforated plate of incombustible material is to be mounted above each heater, slanted to prevent hanging anything on the heater itself.

8.2.2 Space heaters are to be so installed that there is no risk of excessive heating of the bulkheads or decks on which or next to which they are mounted.

8.2.3 Combustible materials in the vicinity of space heaters are to be protected by suitable incombustible and thermal-insulating materials.

8.3 Heating cables and tapes or other heating elements

8.3.1 Heating cables and tapes or other heating elements are not to be installed in contact with combustible materials.

Where they are installed close to such materials, they are to be separated by means of a non-flammable material.

SECTION 13 ELECTRIC PROPULSION PLANT

1 General

1.1 Applicable requirements

1.1.1 The following requirements apply to ships for which the main propulsion plants are provided by at least one electric propulsion motor and its electrical supply. All electrical components of the propulsion plants are to comply with these requirements.

1.1.2 Prime movers for Diesel alternator rectifier are to comply with the requirements of Ch 3, Sec 2.

1.1.3 For the torsional vibration characteristics of the electric propulsion plant, the provisions of Ch 2, Sec 2 apply.

1.1.4 Cooling and lubricating oil systems are to comply with the requirements of Ch 3, Sec 5.

1.1.5 Monitoring and control systems are to comply with the requirements of Part D, Chapter 5.

1.1.6 Rotating machines, transformers, and converters for electric propulsion plant are to comply with the respective sections of this Chapter, namely Ch 4, Sec 4, Ch 4, Sec 5 and Ch 4, Sec 6.

1.2 Operating conditions

1.2.1 The torque available on the electrical propulsion motors for manoeuvring is to be such as to enable the vessel to be stopped or reversed when sailing at is maximum service speed.

Note 1: The moment and duration where the energy of this torque is injected in braking resistances or applied on the shaftline depend on the sequence defined to achieve the maximal ship stopping distance specified in the ship specification.

1.2.2 Adequate torque margin is to be provided for synchronous motors to avoid the motor pulling out of synchronism during rough weather and when turning.

1.2.3 Operation of the motor may be possible with a temporary overload. Such operation is to be limited so as to avoid any overheating damage.

1.2.4 Propulsion motor is to be designed so as to deliver a torque sufficient to permit a start from zero speed up to the maximal immersion depth.

1.2.5 Means are to be provided to limit the continuous input to the electric propulsion motor. This value is not to exceed the continuous full load torque for which motor and shafts are designed.

1.2.6 The plant as a whole is to have sufficient overload capacity to provide the torque and power needed during starting and manoeuvring conditions.

Locked rotor torque which may be required in relation to the operation of the vessel (e.g. for navigation in ice) is to be considered.

1.2.7 The electric motors and shaftline are to be constructed and installed so that, at any speed reached in service, all the moving components are suitably balanced.

2 Design of the propulsion plant

2.1 General

2.1.1 The electrical power for the propulsion system is to be supplied as required in Pt D, Ch 4, Sec 3, [3.2.3].

The minimum configuration of an electric propulsion plant consists of two batteries and one double winding electric motor.

2.1.2 When only one double winding electric motor is used, each stator winding is to be supplied by his own convertor.

2.1.3 Where parallel operation of batteries are necessary for propulsion, a switching device for separation of batteries is to be automatically activated, in case of short circuit or abnormally low voltage.

Where series operation of batteries are necessary for propulsion, automatic blocking of supply for services will be provided so as to avoid to supply these services with abnormally high voltage.

2.1.4 Plants having two or more static convertors or two or more motors on one propeller shaft are to be so arranged that any unit may be taken out of service and disconnected electrically, without affecting the operation of the others.

2.2 Power supply

2.2.1 Voltage variations and maximum voltage are to be maintained within the limits required in Ch 4, Sec 3.

2.2.2 In special conditions (e.g. during crash-stop manoeuvres), voltage variations, due to breaking operation, may exceed the limits stipulated in Ch 4, Sec 3 provided that other equipment operating on the same network is not unduly affected.

2.2.3 The electric plant is to be so designed as to prevent the harmful effects of electromagnetic interference generated by semiconductor convertors, in accordance with Ch 4, Sec 3.

2.3 Auxiliary machinery

2.3.1 When the installation has one or more lubrication systems, devices are to be provided to ensure the monitoring of the lubricating oil return temperature.

2.3.2 Propelling machinery installations with a forced lubrication system are to be provided with alarm devices which will operate in the event of oil pressure loss.

2.4 Electrical protection

2.4.1 Automatic disconnections of electric propulsion plants which adversely affect the manoeuvrability of the ship are to be restricted to faults liable to cause severe damage to the equipment.

2.4.2 The following protection of convertors is to be provided:

- protection against overvoltage in the supply systems to which convertors are connected
- protection against overcurrents in semiconductor elements during normal operation
- short-circuit protection.

2.4.3 Overcurrent protective devices in the main circuits are to be set sufficiently high so that there is no possibility of activation due to the overcurrents caused in the course of normal operation, e.g. during manoeuvring or in heavy seas.

2.4.4 Overcurrent protection may be replaced by automatic control systems ensuring that overcurrents do not reach values which may endanger the plant, e.g. by selective tripping or rapid reduction of the magnetic fluxes of the generators and motors.

2.4.5 In three-phase systems, phase-balance protective devices are to be provided for the motor circuit to disconnect the circuit concerned.

2.5 Adjustable excitation for propulsion motor

2.5.1 Each propulsion motor is to have its own exciter.

2.5.2 For plants where only one motor is foreseen, it is to be provided with a standby exciter, which it is easy to switch over to.

2.5.3 In the case of multi-propeller propulsion ships, only one standby exciter is to be provided. Switch-over operation is to be easy.

2.5.4 For the protection of field windings and cables, means are to be provided for limiting the induced voltage when the field circuits are opened. Alternatively, the induced voltage when the field circuits are opened is to be maintained at the nominal design voltage.

2.5.5 In excitation circuits, there is to be no overload protection causing the opening of the circuit, except for excitation circuits with semiconductor convertors.

2.5.6 Each exciter is to be supplied by a separate feeder.

3 Construction of rotating machines

3.1 Ventilation

3.1.1 When only one double winding electric motor is used, at least two fans are to be provided so that limited operation is possible in the event of one fan failing.

3.2 Protection against moisture and condensate

3.2.1 Machines and equipment which may be subject to the accumulation of moisture and condensate are to be provided with effective means of heating. The latter is to be provided for motors above 100 kW, in order to maintain the temperature inside the machine at about 3°C above the ambient temperature.

3.2.2 Provision is to be made to prevent the accumulation of bilge water, which is likely to enter inside the machine.

3.3 Rotating machines

3.3.1 Electrical machines are to be able to withstand the excess speed which may occur during operation of the ship.

3.3.2 The design of rotating machines supplied by static convertors is to consider the effects of harmonics.

3.3.3 The winding insulation of electrical machines is to be capable of withstanding the overvoltage which may occur in manoeuvring conditions.

3.3.4 The design of a.c. machines is to be such that they can withstand without damage a sudden short-circuit at their terminals under rated operating conditions.

3.3.5 The obtainable current and voltage of exciters and their supply are to be suitable for the output required during manoeuvring and overcurrent conditions, including short-circuit in the transient period, where applicable.

4 Control and monitoring

4.1 General

4.1.1 The control and monitoring systems, including computer based systems, are to be type approved, according to Ch 5, Sec 6.

4.2 Power plant control systems

4.2.1 The power plant control systems are to ensure that adequate propulsion power is available, by means of automatic control systems and/or manual remote control systems.

4.2.2 The automatic control systems are to be such that, in the event of a fault, the propeller speed and direction of thrust do not undergo substantial variations.

4.2.3 Failure of the power plant control system is not to cause complete loss of propulsion.

4.2.4 Where power-aided control (for example with electrical, pneumatic or hydraulic aid) is used for manual operation, failure of such aid is not to result in interruption of power to the propeller. Any such device is to be capable of purely manual local operation.

4.2.5 The control system is to include the following main functions:

- monitoring of the alarms: any event critical for the proper operation of an essential auxiliary or a main element of the installation requiring immediate action to avoid a breakdown is to activate an alarm
- speed of the propeller
- shutdown or slow down when necessary.

4.2.6 The risk of blackout due to electric propulsion operation is to be eliminated. At the request of the Society, a failure mode and effects analysis is to be carried out to demonstrate the reliability of the system.

4.3 Indicating instruments

4.3.1 In addition to the provisions of Part D, Chapter 5 of the Rules, instrument indicating power/energy available for propulsion is to be provided.

4.3.2 The instruments specified in [4.3.3] and [4.3.4] in relation to the type of plant are to be provided on the power control board or in another appropriate position.

4.3.3 The following instruments are required for each propulsion alternator, where applicable:

- an ammeter on each phase, or with a selector switch to all phases
- a voltmeter with a selector switch to all phases
- a wattmeter
- a tachometer or frequency meter
- a power factor meter or a var-meter or a field ammeter for each alternator operating in parallel
- a temperature indicator for direct reading of the temperature of the stator windings, for each alternator rated above 500 kW.

4.3.4 The following instruments are required for each a.c. propulsion motor:

- an ammeter on the main circuit
- an embedded sensor for direct reading of the temperature of the stator windings, for motors rated above 500 kW
- an ammeter on the excitation circuit for each synchronous motor, if applicable
- a voltmeter for the measurement of the voltage between phases of each motor supplied through a semiconductor frequency convertor, if applicable.

4.3.5 Where a speed measuring system is used for control and indication, the system is to be duplicated with separate sensor circuits and separate power supply.

4.3.6 A current indication is to be provided on the supply circuit for each propulsion semiconductor bridge.

4.4 Alarm system

4.4.1 The following requirements are applicable to the alarm system of electrical propulsion:

- Alarms circuits of electrical propulsion are to be connected to the main alarm system on board. As an alternative, the relevant circuit may be connected to a local alarm unit. In any case, a connection between the local alarm unit and the main alarm system is to be provided.
- The alarms can be arranged in groups, and shown in the control station. This is acceptable when a discrimination is possible locally.
- When the control system uses a computer based system, the requirements of Ch 5, Sec 3 are applicable, in particular, for the data transmission link between the alarm system and the control system.
- Individual alarms are considered as critical and are to be individually activated at the control stations, and acknowledged individually.
- Shutdown activation is to be considered as an individual alarm.

4.4.2 An alarm system is to be provided, in accordance with the requirements of Part D, Chapter 5. The system is to give an indication at the control positions when the parameters specified in [4.4] assume abnormal values or any event occurs which can affect the electric propulsion.

4.4.3 Where an alarm system is provided for other essential equipment or installations, the alarms in [4.4.2] may be connected to such system.

4.4.4 Critical alarms for propulsion are to be indicated to the control room separately.

4.4.5 The following alarms are to be provided, where applicable:

- high temperature of the cooling air of machines and semiconductor convertors provided with forced ventilation (see Note 1)
- reduced flow of primary and secondary coolants of machines and semiconductor convertors having a closed cooling system with a heat exchanger
- leakage of coolant inside the enclosure of machines and semiconductor convertors with liquid-air heat exchangers
- high winding temperature of propulsion motors, where required (see [4.3])
- low lubricating oil pressure of bearings for machines with forced oil lubrication
- tripping of protective devices against overvoltages in semiconductor convertors (critical alarm)
- tripping of protection on filter circuits to limit the disturbances due to semiconductor convertors

- tripping of protective devices against overcurrents up to and including short-circuit in semiconductor convertors (critical alarm)
- voltage unbalance of three-phase a.c. systems supplied by semiconductor frequency convertors
- earth fault for the main propulsion circuit (see Note 2)
- earth fault for excitation circuits of propulsion machines (see Note 3).

Note 1: As an alternative to the air temperature of convertors or to the airflow, the supply of electrical energy to the ventilator or the temperature of the semiconductors may be monitored.

Note 2: In the case of star connected a.c. generators and motors with neutral points earthed, this device may not detect an earth fault in the entire winding of the machine.

Note 3: This may be omitted in brushless excitation systems and in the excitation circuits of machines rated up to 500 kW. In such cases, lamps, voltmeters or other means are to be provided to detect the insulation status under operating conditions.

4.5 Reduction of power

4.5.1 An alarm for reduction of power is to be initiated in the following cases:

- low lubricating oil pressure of bearings of motors
- high winding temperature of motors
- fan failure in machines and convertors provided with forced ventilation, or failure of cooling system
- lack of coolant in machines and semiconductor convertors.

This alarm may lead to an automatic reduction of power.

4.5.2 When power is reduced automatically, this is to be indicated at the propulsion control position (critical alarm).

4.5.3 Switching-off of the semiconductors in the event of abnormal service operation is to be provided in accordance with the manufacturer's specification.

4.5.4 Safety functions

The following requirements are applicable to the safety system of electrical propulsion:

- As a general rule, safety function using external sensors such as temperature, pressure, overspeed, main cooling failure, or stop of converter by blocking impulse is to be confirmed by the automatic opening of the main circuit using a separate circuit.
- In order to avoid accidental stop of the propulsion line and limit the risk of blackout due to wire break, the tripping of the main circuit-breaker is to be activated by an emission coil with a monitoring of the line wire break.
- In the case of a single line propulsion system, the power limitation order is to be duplicated.
- As a general rule, when the safety stop is activated, it is to be maintained until local acknowledgement.

4.5.5 Converters

For converters, parameters according to Tab 1, Tab 2 and Tab 3 are to be monitored or controlled.

4.5.6 Propulsion electric motor

For propulsion electric motors, parameters according to Tab 3 are to be monitored or controlled.

4.5.7 All parameters listed in the tables of this item are considered as a minimum requirement for unattended machinery spaces.

Some group alarms may be locally detailed on the corresponding unit (for instance loss of electronic supply, failure of electronic control unit, etc.).

Table 1 : Motor converter

Symbol convention H = High, HH = High high, G = Group alarm L = Low, LL = Low low, I = Individual alarm X = Function is required, R = Remote	Monitoring		Automatic control				
			Motor			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down **(1)**	Control	Standby Start	Stop
Short-circuit current I max	I			X			
Overvoltage	G			X			
Undervoltage	G			X			
Phase unbalanced	I						
Communication circuit, control circuits, power supplies, watchdog of control system according to supplier's design	G			X			
Speed sensor system failure	G					X **(2)**	
Overspeed	I			X			

(1) May be manual or with automatic order.
(2) Automatic switch-over to the redundant speed sensor system.

Table 2 : Converter cooling circuit

Symbol convention H = High, HH = High high, G = Group alarm L = Low, LL = Low low, I = Individual alarm X = Function is required, R = Remote	Monitoring		Automatic control				
			Motor			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down **(1)**	Shut-down **(1)**	Control	Standby Start	Stop
Air cooling temperature high	I	R					
Cooling pump pressure or flow low	G	R					
						X	
Cooling fluid temperature high	G						
Leak of cooling medium	G						
			X				
Temperature sensor failure (short-circuit, open circuit, supply failure)	G						
(1) May be manual or with automatic order.							

Table 3 : Propulsion electric motor

Symbol convention H = High, HH = High high, G = Group alarm L = Low, LL = Low low, I = Individual alarm X = Function is required, R = Remote	Monitoring		Automatic control				
			Motor			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down **(1)**	Shut-down **(1)**	Control	Standby Start	Stop
Automatic tripping of overload and short-circuit protection on excitation circuit, where applicable	G, H			H			
Loss of excitation, where applicable	G			X			
Winding current unbalanced	G						
Harmonic filter supply failure	I						
Interface failure with power management system	I		X				
Earthing failure on stator winding and stator supply	I	R					
Temperature of winding on phase 1, 2, 3	G	R					
	I, H		X				
	I, HH			X			
Motor cooling air temperature	I, H	R					
Cooling pump pressure or flow	G, L	R					
			X				
						X	
Cooling fluid temperature	G, H						
Leak of cooling medium	G						
			X				
Temperature sensor failure (short-circuit, open circuit, supply failure)	G						
Motor bearing temperature	G, H	R					
Bearing lubrication oil pressure (for self-lubricated motor, when the speed is under the minimum RPM specified by the manufacturer, shutdown is to be activated)	I, L	R					
			X				
						X	
Bearing lubrication oil pressure	G, L						
Shaft reduction gear bearing temperature	I, H						
Shaft reduction gear lubricating oil temperature	I, H						
Shaft reduction gear bearing pressure	I, L						
				X			
(1) May be manual or with automatic order.							

5 Installation

5.1 Ventilation of spaces

5.1.1 Loss of ventilation to spaces with forced air cooling is not to cause loss of propulsion. To this end, two sets of ventilation fans are to be provided, one acting as a standby unit for the other. Equivalent arrangements using several independently supplied fans may be considered.

5.2 Cable runs

5.2.1 Instrumentation and control cables are to comply with the requirements of Ch 5, Sec 5 of the Rules.

5.2.2 Where there is more than one propulsion motor, all cables for any one machine are to be run as far as is practicable away from the cables of other machines.

5.2.3 Cables which are connected to the slip rings of synchronous motors are to be suitably insulated for the voltage to which they are subjected during manoeuvring.

6 Tests

6.1 Test of rotating machines

6.1.1 The test requirements are to comply with Ch 4, Sec 4.

6.1.2 For rotating machines, related to electrical propulsion, a test program is to be submitted to the Society for approval.

6.1.3 In relation to the evaluation of the temperature rise, it is necessary to consider the supplementary thermal losses induced by harmonic currents in the stator winding. To this end, two methods may be used:

- direct test method, when the electric propulsion motor is being supplied by its own frequency convertor, and/or back to back arrangement according to the supplier's facility
- indirect test method as defined in Ch 4, App 1; in this case, a validation of the estimation of the temperature excess due to harmonics is to be documented. A justification based on a computer program calculation may be taken into consideration, provided that validation of such program is demonstrated by previous experience.

SECTION 14 TESTING

1 General

1.1 Rule application

1.1.1 Before a new installation, or any alteration or addition to an existing installation, is put into service, the electrical equipment is to be tested in accordance with articles [3], [4] [5] and with Pt D, Ch 5, Sec 6 if needed, to the satisfaction of the Surveyor in charge.

1.2 Insulation-testing instruments

1.2.1 Insulation resistance may be measured with an instrument applying a voltage of at least 500 V. The measurement will be taken when the deviation of the measuring device is stabilised.

Note 1: Any electronic devices present in the installation are to be disconnected prior to the test in order to prevent damage.

1.2.2 For high voltage installation, the measurement is to be taken with an instrument applying a voltage adapted to the rated value and agreed with the Society.

2 Type approved components

2.1

2.1.1 The following components are to be type approved or in accordance with [2.1.2]:

- electrical cables
- pressure hull penetration
- transformers
- main electrical batteries
- rotating machines
- electrical convertors for essential services
- switching devices (circuit-breakers, contactors, disconnectors, etc.) and overcurrent protective devices
- sensors, alarm panels, electronic protective devices, automatic and remote control equipment, actuators, safety devices for installations intended for essential services (steering, propulsion machinery, etc.), electronic speed regulators for main or auxiliary engines
- computers used for tasks essential to safety.
- public address system, excluding loudspeakers.

2.1.2 Case-by-case approval based on submission of adequate documentation and execution of tests may also be granted, at the discretion of the Society.

3 Insulation resistance

3.1 Lighting and power circuits

3.1.1 The insulation resistance between all insulated poles (or phases) and earth and, where practicable, between poles (or phases), is to be at least 1 MΩ in ordinary conditions.

The installation may be subdivided to any desired extent and appliances may be disconnected if initial tests give results less than that indicated above.

3.2 Internal communication circuits

3.2.1 Circuits operating at a voltage of 50 V and above are to have an insulation resistance between conductors and between each conductor and earth of at least 1 MΩ.

3.2.2 Circuits operating at voltages below 50 V are to have an insulation resistance between conductors and between each conductor and earth of at least 0,33 MΩ.

3.2.3 If necessary, any or all appliances connected to the circuit may be disconnected while the test is being conducted.

3.3 Switchboards

3.3.1 The insulation resistance between each busbar and earth and between each insulated busbar and the busbar connected to the other poles (or phases) of each main switchboard, section board, etc. is to be not less than 1 MΩ.

3.3.2 The test is to be performed before the switchboard is put into service with all circuit-breakers and switches open, all fuse-links for pilot lamps, earth fault-indicating lamps, voltmeters, etc. removed and voltage coils temporarily disconnected where otherwise damage may result.

3.4 Generators and motors

3.4.1 The insulation resistance of generators and motors, in normal working condition and with all parts in place, is to be measured and recorded.

3.4.2 The test is to be carried out with the machine hot immediately after running with normal load.

3.4.3 The insulation resistance of generator and motor connection cables, field windings and starters is to be at least 1 MΩ.

4 Earth

4.1 Electrical constructions

4.1.1 Tests are to be carried out, by visual inspection or by means of a tester, to verify that all earth-continuity conductors and earthing leads are connected to the frames of apparatus and to the hull, and that in socket-outlets having earthing contacts, these are connected to earth.

4.2 Metal-sheathed cables, metal pipes or conduits

4.2.1 Tests are to be performed, by visual inspection or by means of a tester, to verify that the metal coverings of cables and associated metal pipes, conduits, trunking and casings are electrically continuous and effectively earthed.

5 Operational tests

5.1 Generating sets and their protective devices

5.1.1 Generating sets are to be run at full rated load to verify that the following are satisfactory:

- electrical characteristics
- commutation (if any)
- lubrication
- ventilation
- noise and vibration level.

5.1.2 Suitable load variations are to be applied to verify the satisfactory operation under steady state and transient conditions (see Ch 4, Sec 4, [2]) of:

- voltage regulators
- speed governors.

5.1.3 Generating sets intended to operate in parallel are to be tested over a range of loading up to full load to verify that the following are satisfactory:

- parallel operation
- sharing of the active load
- sharing of the reactive load (for a.c. generators).

Synchronising devices are also to be tested.

5.1.4 The satisfactory operation of the following protective devices is to be verified:

- overspeed protection
- overcurrent protection (see Note 1)
- load-shedding devices
- any other safety devices.

For sets intended to operate in parallel, the correct operation of the following is also to be verified:

- reverse-power protection for a.c. installations (or reverse-current protection for d.c. installations)
- minimum voltage protection.

Note 1: Simulated tests may be used to carry out this check where appropriate.

5.1.5 The correct operation of the different configuration of electrical power source is to be tested. A test program is to be submitted to the Society.

5.2 Main electrical batteries

5.2.1 Main electrical batteries are to be tested as follows:

- good operation of battery room ventilation
- verification of the battery monitoring system
- H2 monitoring system
- full charging test
- capacity evaluation.

5.3 Switchgear

5.3.1 All switchgear is to be loaded and, when found necessary by the attending Surveyor, the operation of overcurrent protective devices is to be verified (see Note 1).

Note 1: The workshop test is generally considered sufficient to ensure that such apparatus will perform as required while in operation.

5.4 Consuming devices

5.4.1 Electrical equipment is to be operated under normal service conditions (though not necessarily at full load or simultaneously) to verify that it is suitable and satisfactory for its purpose.

5.4.2 Motors and their starters are to be tested under normal operating conditions to verify that the following are satisfactory:

- power
- operating characteristics
- commutation (if any)
- speed
- direction of rotation
- alignment.

5.4.3 The remote stops foreseen are to be tested.

5.4.4 Lighting fittings, heating appliances etc. are to be tested under operating conditions to verify that they are suitable and satisfactory for their purposes (with particular regard to the operation of emergency lighting).

5.5 Communication systems

5.5.1 Communication systems, order transmitters and mechanical engine-order telegraphs are to be tested to verify their suitability.

5.6 Installations in areas with a risk of explosion

5.6.1 Installations and the relevant safety certification are to be examined to ensure that they are of a type permitted in the various areas and that the integrity of the protection concept has not been impaired.

5.7 Voltage drop

5.7.1 Where it is deemed necessary by the attending Surveyor, the voltage drop is to be measured to verify that the permissible limits are not exceeded (see Ch 4, Sec 3, [8.11.4]).

5.8 Electrical pressure hull penetration

5.8.1 A test pressure of all electrical pressure hull penetration is to be done to verify the tightness of this penetration.

APPENDIX 1 INDIRECT TEST METHOD FOR SYNCHRONOUS MACHINES

1 General

1.1 Test method

1.1.1 The machine is to be subject to the three separate running tests specified below (see Fig 1) when:

- the machine is complete (with covers, heat exchangers, all control devices and sensors)
- the exciter circuit is connected to its normal supply or to a separate supply having the same characteristics, and
- the supply is fitted with the necessary measuring instruments.

a) Test No.1: No load test at rated voltage and current on rotor, stator winding in open circuit

The temperature rise of the stator winding depends, in such a case, on the magnetic circuit losses and mechanical losses due to ventilation, where:

- $\Delta ts1$ is the stator temperature rise
- $\Delta tr1$ is the rotor temperature rise.

b) Test No.2: Rated stator winding current with the terminals short-circuited

The temperature of the stator winding depends on the thermal Joule losses and mechanical losses, as above, where:

- $\Delta ts2$ is the stator temperature rise
- $\Delta tr2$ is the rotor temperature rise, which for test No.2 is negligible.

c) Test No.3: Zero excitation

The temperature of all windings depends on the mechanical losses due to friction and ventilation, where:

- $\Delta ts3$ is the stator temperature rise
- $\Delta tr3$ is the rotor temperature rise.

Note 1: The synchronous electric motor is supplied at its rated speed by a driving motor. The temperature balance will be considered as being obtained, when the temperature rise does not vary by more than 2°C per hour.

1.1.2 Temperature measurements of the stator winding can be based on the use of embedded temperature sensors or measurement of winding resistance. When using the resistance method for calculation of the temperature rise, the resistance measurement is to be carried out as soon as the machine is shut down.

The rotor temperature rise is obtained by calculation of rotor resistance:

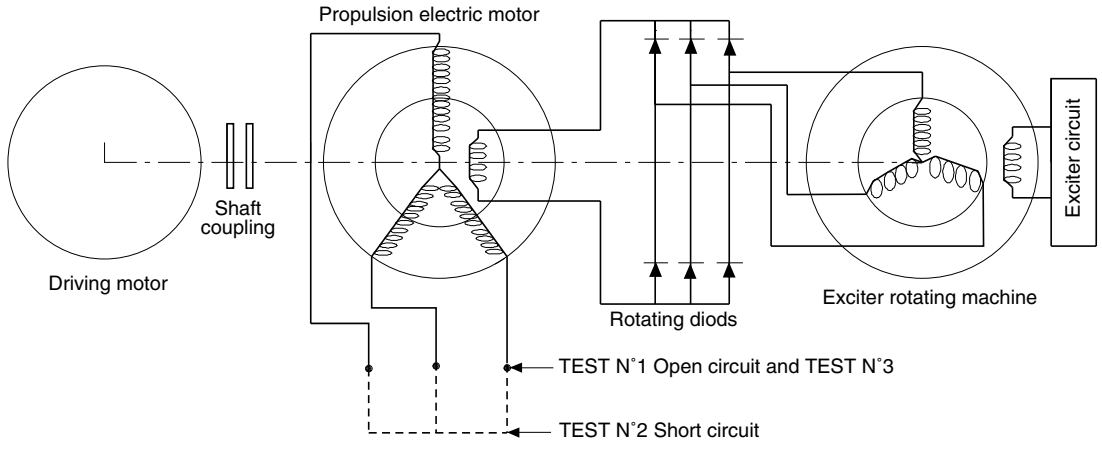
$R_{rotor} = U/I_r$

where U and I are the voltage and current in the magnetic field winding.

The following parameters are recorded, every 1/2 hour:

- temperature sensors as well as the stator current and voltage
- the main field voltage and current
- the bearing temperatures (embedded sensor or thermometer), and the condition of cooling of the bearings, which are to be compared to those expected on board.

Figure 1 : Schematic diagram used for the test



1.1.3 The tests described above allow the determination of the final temperature rise of stator and rotor windings with an acceptable degree of accuracy.

- The temperature rise of the stator winding is estimated as follows:

  Δt stator = $\Delta ts1 + \Delta ts2 - \Delta ts3$

  Δt stator winding is to be corrected by the supplementary temperature rise due to current harmonics evaluated by the manufacturer
- Considering that in test No.1 the magnetic field winding current Irt is different from the manufacturer's estimated value Ir (due to the fact that the cos φ in operation is not equal to 1), the temperature rise of the rotor is to be corrected as follows:

  Δt rotor = ($\Delta tr1 - \Delta tr3$) x (rated loading conditions Ir/ test loading conditions Irt)^2 + $\Delta tr3$

1.1.4 In the indirect method, a possible mutual influence of the temperature rise between the stator and the rotor is not taken into consideration. The test results may be representative of the temperature rise on board ship, but a margin of 10 to 15°C is advisable compared with the permitted temperature of the Rules and the measure obtained during tests.

Part D
Systems

Chapter 5
AUTOMATION

SECTION 1 **GENERAL REQUIREMENTS**

SECTION 2 **DESIGN REQUIREMENTS**

SECTION 3 **COMPUTER BASED SYSTEMS**

SECTION 4 **CONSTRUCTIONAL REQUIREMENTS**

SECTION 5 **INSTALLATION REQUIREMENTS**

SECTION 6 **TESTING**

SECTION 1 GENERAL REQUIREMENTS

1 General

1.1 Field of application

1.1.1 The following requirements apply to automation systems, installed on all submarines, and intended for essential services as defined in Pt A, Ch 1, Sec 1, [1.2.1].

1.1.2 This Chapter is intended to avoid that failures or malfunctions of automation systems associated with essential and non-essential services cause danger to other essential services.

1.2 Regulations and standards

1.2.1 The regulations and standards applicable are those defined in Ch 4, Sec 1.

1.3 Definitions

1.3.1 Unless otherwise stated, the terms used in this Chapter have the definitions laid down in Ch 4, Sec 1 or in the IEC standards. The following definitions also apply:

- Alarm indicator

  Indicator which gives a visible and/or audible warning upon the appearance of one or more faults to advise the operator that his attention is required

- Alarm system

  System intended to give a signal in the event of abnormal running condition

- Application software

  Software performing tasks specific to the actual configuration of the computer based system and supported by the basic software

- Automatic control

  Control of an operation without direct or indirect human intervention, in response to the occurrence of predetermined conditions

- Automation systems

  Systems including automatic control systems and monitoring systems (see Part D, Chapter 1)

- Basic software

  Minimum software, which includes firmware and middleware, required to support the application software

- Cold standby system

  Duplicated system with a manual commutation or manual replacement of cards which are live and non-operational. The duplicated system is to be able to achieve the operation of the main system with identical performance, and be operational within 10 minutes

- Computer based system

  System of one or more computers, associated software, peripherals and interfaces, and the computer network with its protocol

- Control station

  Group of control and monitoring devices by means of which an operator can control and verify the performance of equipment

- Control system

  System by which an intentional action is exerted on an apparatus to attain given purposes

- Expert system

  Intelligent knowledge-based system that is designed to solve a problem with information that has been compiled using some form of human expertise

- Fail safe

  Design property of an item in which the specified failure mode is predominantly in a safe direction with regard to the safety of the submarine, as a primary concern

- Full redundant

  Used to describe an automation system comprising two (identical or non-identical) independent systems which perform the same function and operate simultaneously

- Hot standby system

  Used to describe an automation system comprising two (identical or non-identical) independent systems which perform the same function, one of which is in operation while the other is on standby with an automatic changeover switch

- Instrumentation

  Sensor or monitoring element

- Integrated system

  System consisting of two or more subsystems having independent functions connected by a data transmission network and operated from one or more workstations

- Local control

  Control of an operation at a point on or adjacent to the controlled switching device

- Monitoring system

  System designed to observe the correct operation of the equipment by detecting incorrect functioning (measure of variables compared with specified value)

- Qualified components

  Components which have been subject to a series of test defined by an international standard which demonstrates that the components are able to sustain the environmental conditions prevailing onboard

- Redundancy

  Existence of more than one means for performing a required function

- Remote control

  Control from a distance of apparatus by means of an electrical or other devices

- Safety system

  System intended to limit the consequence of failure and is activated automatically when an abnormal condition appears. Manual activation will be considered on the case by case basis

- Software

  Program, procedures and associated documentation pertaining to the operation of the computer system.

1.4 General

1.4.1 The automation systems and components, as indicated in Ch 4, Sec 14, [2], are to be chosen among the list of type approved products.

They are to be approved on the basis of the applicable requirements of these Rules and in particular those stated in this Chapter, or qualified according to an equivalent international standard.

Case-by-case approval may also be granted at the discretion of the Society, based on submission of adequate documentation and subject to the satisfactory outcome of any required tests.

1.4.2 Essential services shall be provided with effective means for its operation and control.

1.4.3 Failure of automation systems is to generate an alarm.

1.4.4 Detailed indication, alarm and safety requirements regarding automation systems for individual machinery and installations are to be found in tables located in Part D, Chapter 2 and Part D, Chapter 3.

Each row of these tables is to correspond to one independent sensor.

2 Documentation

2.1 General

2.1.1 Before the actual construction is commenced, the Manufacturer, Designer or Shipbuilder is to submit to the Society the documents (plans, diagrams, specifications and calculations) requested in this Section.

The list of documents requested is to be intended as guidance for the complete set of information to be submitted, rather than an actual list of titles.

The Society reserves the right to request the submission of additional documents in the case of non-conventional design or if it is deemed necessary for the evaluation of the system, equipment or components.

Plans are to include all the data necessary for their interpretation, verification and approval.

Unless otherwise agreed with the Society, documents for approval are to be sent in triplicate if submitted by the Shipyard and in four copies if submitted by the equipment supplier. Documents requested for information are to be sent in duplicate.

In any case, the Society reserves the rights to require additional copies, when deemed necessary.

Electronic document may be submitted under special agreement (see Part D, Chapter 1).

2.2 Documents to be submitted

2.2.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Documentation
1	I	The general specification for the automation of the submarine
2	A	The detailed specification of the essential service systems
3	A	The list of components used in the automation circuits, and references (Manufacturer, type, etc.)
4	I	Instruction manuals
5	I	Test procedures for control, alarm and safety systems
6	A	A general diagram showing the monitoring and/or control positions for the various installations, with an indication of the means of access and the means of communication between the positions as well as with the engineers
7	A	The diagrams of the supply circuits of automation systems, identifying the power source
8	A	The list of monitored parameters for alarm/monitoring and safety systems
9	A	Diagram of the engineers' alarm system

(1) A = to be submitted for approval
I = to be submitted for information.

Table 2 : Computer based system documentation

No.	I/A (1)	Documentation
1	I	System description, computer software; see [2.3.2]
2	A	System description, computer hardware; see [2.3.3]
3	I	System reliability analysis; see [2.3.4]
4	I	User interface description; see [2.3.5]
5	I	Test programs; see [2.3.6]
(1) A = to be submitted for approval I = to be submitted for information.		

2.3 Documents for computer based system

2.3.1 General

For computer based systems, the documents listed in Tab 2 are to be submitted.

2.3.2 System description, computer software

This documentation is to contain:

- a list of all main software modules installed per hardware unit with names and version numbers
- a description of all main software which is to include at least:
  - a description of basic software installed per hardware unit, including communication software, when applicable
  - a description of application software.

2.3.3 Description of computer hardware

The documentation to be submitted is to include:

- hardware information of importance for the application and a list of documents that apply to the system
- the supply circuit diagram
- a description of hardware and software tools for equipment configuration
- the information to activate the system
- general information for trouble shooting and repair when the system is in operation.

2.3.4 System reliability analysis

The documentation to be submitted is to demonstrate the reliability of the system by means of appropriate analysis such as:

- a failure mode analysis describing the effects due to failures leading to the destruction of the automation system. In addition, this documentation is to show the consequences on other systems, if any. This analysis is appraised in accordance with the IEC Publication 60812, or a recognised standard
- test report /life test
- MTBF calculation
- any other documentation demonstrating the reliability of the system.

2.3.5 User interface description

The documentation is to contain:

- a description of the functions allocated to each operator interface (keyboard/screen or equivalent)
- a description of individual screen views (schematics, colour photos, etc.)
- a description of how menus are operated (tree presentation)
- an operator manual providing necessary information for installation and use.

2.3.6 Test programs

The following test programs are to be submitted:

- software module/unit test
- software integration test
- system validation test
- on-board test.

Each test program is to include:

- a description of each test item
- a description of the acceptance criteria for each test.

2.4 Documents for type approval of equipment

2.4.1 Documents to be submitted for type approval of equipment are listed hereafter:

- a request for type approval from the manufacturer or his authorized representative
- the technical specification and drawings depicting the system, its components, characteristics, working principle, installation and conditions of use and, when there is a computer based system, the documents listed in Tab 2
- any test reports previously prepared by specialised laboratories.

3 Environmental and supply conditions

3.1 General

3.1.1 General

The automation system is to operate correctly when the power supply is within the range specified in Ch 4, Sec 2.

3.1.2 Environmental conditions

The automation system is to be designed to operate satisfactorily in the environment in which it is located. The environmental conditions are described in Ch 4, Sec 2.

3.1.3 Failure behaviour

The automation system is to have non-critical behaviour in the event of power supply failure, faults or restoration of operating condition following a fault. If a redundant power supply is used, it must be taken from an independent source.

3.2 Power supply conditions

3.2.1 Electrical power supply

The conditions of power supply to be considered are defined in Ch 4, Sec 2.

4 Materials and construction

4.1 General

4.1.1 The choice of materials and components is to be made according to the environmental and operating conditions in order to maintain the proper function of the equipment.

4.1.2 The design and construction of the automation equipment is to take into account the environmental and operating conditions in order to maintain the proper function of the equipment.

4.2 Type approved components

4.2.1 See Ch 4, Sec 14.

SECTION 2 DESIGN REQUIREMENTS

1 General

1.1

1.1.1 All control systems dedicated to essential services shall be independent or designed such that failure of one system does not degrade the performance of another system.

1.1.2 Safety functions are to be independent of normal control and monitoring systems.

1.1.3 Control, monitoring and safety systems are to have self-check facilities. In the event of failure, an alarm is to be activated.

In particular, failure of the power supply of the automation system is to generate an alarm.

1.1.4 When a computer based system is used for control, alarm or safety systems, it is to comply with the requirements of Ch 5, Sec 3.

1.1.5 The automatic change-over switch of a hotstandby system is to operate independently of both systems. When change-over occurs, no stop of the installation is necessary and the latter is not to enter undefined or critical states.

1.1.6 When systems under control are required to be duplicated and in separate compartments, this is also to apply to control elements within computer based systems.

2 Power supply of automation systems

2.1 General

2.1.1 Automation systems are to be supplied either by two separate feeders, each one coming from a separate network (see Note 1), or through a UPS with an autonomy sufficient to recover the normal supply.

Note 1: The design is to be such as to prevent the loss of an essential service in case of single failure.

Note 2: When the loss of power leads to a loss of the function during more than 10 minutes, the supply through a UPS is required.

2.1.2 The capacity of the stand-by power supply is to be sufficient to allow the normal operation of the automation systems for at least half an hour.

2.1.3 Failure of any power supply to an automation system is to generate an audible and visual alarm.

2.1.4 Power supplies are to be protected against short circuit and overload for each independent automation system.

Power supplies are to be isolated.

3 Control systems

3.1 General

3.1.1 The transfer from one control mode to another should be achieved without any alteration of the operation of the control system

3.2 Local control

3.2.1 Each system is to be able to be operated from a position located so as to enable, as far as practicable, visual control of operation. For detailed instrumentation for each system, refer to Part D, Chapter 2 and Part D, Chapter 3.

The local control may be waived where an other control system is available.

3.3 Remote control systems

3.3.1 When several control stations are provided, control of machinery is to be possible at one station at a time.

3.3.2 At each location there shall be an indicator showing which location is in control of the propulsion machinery.

3.3.3 Remote control is to be provided with the necessary instrumentation, in each control station, to allow effective control (correct function of the system, indication of control station in operation, alarm display).

3.3.4 When transferring the control location, no significant alteration of the controlled equipment is to occur. Transfer of control is to be protected by an audible or visual warning and acknowledged by the receiving control location. The main control location is to be able to take control without acknowledgement.

3.4 Automatic control systems

3.4.1 Automatic starting, operational and control systems shall include provisions for manually overriding the automatic controls, unless an independent control system is available.

Note 1: The purpose of the independent control system is to limit the risk of common mode of failure with the automated control system.

3.4.2 Automatic control is to be stable in the range of the controller in normal working conditions.

3.4.3 Automatic control is to have instrumentation to verify the correct function of the system.

4 Control of propulsion machinery

4.1 Remote control

4.1.1 The requirements mentioned in Article [3] are to be applied for propulsion machinery.

4.1.2 The design of the remote control system shall be such that in case of its failure an alarm will be given.

4.1.3 Indicators shall be fitted on the control platform.

4.1.4 The main propulsion machinery shall be provided with an emergency stopping device on the control room which shall be independent of the navigation control system.

This emergency stopping device may consist of a simple and clearly marked control device, for example a push-button. This fitting is to be capable of suppressing the propeller thrust, whatever the cause of the failure may be.

4.2 Remote control from control platform

4.2.1 Remote control of the propulsion machinery shall be possible only from one location at a time; at such locations interconnected control positions are permitted.

4.2.2 The system shall include means to prevent the propelling thrust from altering significantly, when transferring control from one location to another.

4.2.3 Remote starting of the propulsion machinery is to be automatically inhibited if a condition exists which may damage the machinery, e.g. shaft turning gear engaged, drop of lubrication oil pressure or brake engaged.

4.2.4 As a general rule, the control room panels are not to be overloaded by alarms and indications which are not required.

4.3 Automatic control of propulsion and manoeuvring units

4.3.1 When the power source actuating the automatic control of propelling units fails, an alarm is to be triggered.

5 Remote control of valves

5.1

5.1.1 The following requirements are applicable to valves whose failure could impair essential services.

5.1.2 Failure of the power supply is not to permit a valve to move to an unsafe condition.

5.1.3 An indication is to be provided at the remote control station showing the actual position of the valve or whether the valve is fully open or fully closed.

5.1.4 The control of steering gear system is to be arranged according to the requirements given in Ch 3, Sec 7.

5.1.5 Control of ballast system is to be arranged according to the requirements given in Ch 3, Sec 5, [7.3.3] and Ch 3, Sec 5, [7.4.3].

5.2 Control of pressure hull valves

5.2.1 Control of ballast system is to be arranged according to the requirements given in Ch 3, Sec 5, [6.4.2], item f).

6 Alarm system

6.1 General requirements

6.1.1 Alarms are to be visual and audible and are to be clearly distinguishable, in the ambient noise and lighting in the normal position of the personnel, from any other signals.

6.1.2 Sufficient information is to be provided for proper handling of alarms.

6.1.3 The alarm system is to be of the self-check type; failure within the alarm system, including the outside connection, is to activate an alarm. The alarm circuits are to be independent from each other. All alarm circuits are to be protected so as not to endanger each other.

6.1.4 The response values of automation equipment must be so coordinated with each other that, when a threshold is reached, a warning is initiated, followed, after a certain warning period or if the process variable continues to change at a preset speed, by the actuation of safety devices.

6.2 Alarm functions

6.2.1 Alarm activation

Alarms are to be activated when abnormal conditions appear in the machinery, which need the intervention of personnel on duty, and on the automatic change-over, when standby machines are installed.

An existing alarm is not to prevent the indication of any further fault.

6.2.2 Acknowledgement of alarm

The acknowledgment of an alarm consists in manually silencing the audible signal and additional visual signals (e.g. rotating light signals) while leaving the visual signal on the active control station. Acknowledged alarms are to be clearly distinguishable from unacknowledged alarms. Acknowledgement should not prevent the audible signal to operate for new alarm.

Alarms shall be maintained until they are accepted and visual indications of individual alarms shall remain until the fault has been corrected, when the alarm system shall automatically reset to the normal operating condition.

Acknowledgement of alarms is only to be possible at the active control station.

Alarms, including the detection of transient faults, are to be maintained until acknowledgement of the visual indication.

Acknowledgement of visual signals is to be separate for each signal or common to a limited group of signals. Acknowledgement is only to be possible when the user has visual information on the alarm condition for the signal or all signals in a group.

6.2.3 Locking of alarms

Manual locking of separate alarms may be accepted when this is clearly indicated.

Locking of alarm and safety functions in certain operating modes (e.g. during start-up or trimming) is to be automatically disabled in other modes.

6.2.4 Time delay of alarms

It is to be possible to delay alarm activation in order to avoid false alarms due to normal transient conditions (e.g. during start-up or trimming).

7 Safety system

7.1 Design

7.1.1 System failures

A safety system is to be designed so as to limit the consequence of failures.

The safety system is to be of the self-check type; as a rule, failure within the safety system, including the outside connection, is to activate an alarm.

7.2 Standby systems

7.2.1 For the automatic starting system of the standby units, the following requirements are to be applied:

- faults in the electrical or mechanical system of the running machinery are not to prevent the standby machinery from being automatically started
- when a machine is on standby, ready to be automatically started, this is to be clearly indicated at its control position
- the change-over to the standby unit is to be indicated by a visual and audible alarm
- means are to be provided close to the machine, to prevent undesired automatic or remote starting (e.g. when the machine is being repaired).

7.3 Testing

7.3.1 The safety systems are to be tested in accordance with the requirements in Ch 5, Sec 6.

SECTION 3 COMPUTER BASED SYSTEMS

1 General requirements

1.1 General

1.1.1 The characteristics of the system are to be compatible with the intended applications, under normal and abnormal process conditions. The response time for alarm function is to be less than 5 seconds.

1.1.2 When systems under control are required to be duplicated and in separate compartments, this is also to apply to control elements within computer based systems.

1.1.3 As a rule, computer based systems intended for essential services are to be type approved.

1.2 System type approval

1.2.1 The type approval is to cover the hardware and basic software of the system. The type approval requirements are detailed in Ch 5, Sec 6. A list of the documents to be submitted is provided in Ch 5, Sec 1.

1.3 System operation

1.3.1 The system is to be protected so that authorized personnel only can modify any setting which could alter the system.

1.3.2 Modification of set points or parameters is to be possible without complex operations such as compilation or coded data insertion.

1.3.3 Program and data storage of the system is to be designed so as not to be altered by environmental conditions, as defined in Ch 4, Sec 2, [1], or loss of the power supply.

1.4 System reliability

1.4.1 System reliability is to be documented as required in Ch 5, Sec 1, [2.3.4].

1.5 System failure

1.5.1 A self-monitoring device is to be implemented so as to check the proper function of hardware and software in the system. This is to include a self-check facility of input /output cards, as far as possible.

1.5.2 The failure and restarting of computer based systems should not cause processes to enter undefined or critical states.

1.6 System redundancy

1.6.1 If it is demonstrated that the failure of the system, which includes the computer based system, leads to a disruption of the essential services, a secondary independent means, of appropriate diversity, is to be available to restore the adequate functionality of the service.

2 Hardware

2.1 General

2.1.1 The construction of systems is to comply with the requirements of Ch 5, Sec 4.

2.2 Housing

2.2.1 The housing of the system is to be designed to face the environmental conditions, as defined in Ch 4, Sec 2, [1], in which it will be installed. The design will be such as to protect the printed circuit board and associated components from external aggression. When required, the cooling system is to be monitored, and an alarm activated when the normal temperature is exceeded.

2.2.2 The mechanical construction is to be designed to withstand the vibration levels defined in Ch 4, Sec 2, depending on the applicable environmental condition.

3 Software

3.1 General

3.1.1 The basic software is to be developed in consistent and independent modules.

A self-checking function is to be provided to identify failure of software module.

When hardware (e.g. input /output devices, communication links, memory, etc.) is arranged to limit the consequences of failures, the corresponding software is also to be separated in different software modules ensuring the same degree of independence.

3.1.2 Basic software is to be type approved according to Ch 5, Sec 6, [2.3].

3.1.3 Application software is to be tested in accordance with Ch 5, Sec 6, [3.3].

3.1.4 Loading of software, when necessary, is to be performed in the aided conversational mode.

3.2 Software development quality

3.2.1 Software development is to be carried out according to a quality plan defined by the builder and records are to be kept. International standard (e.g. ISO 9000-3, ISO/IEC 12207), is to be taken as guidance for the quality procedure. The quality plan is to include the test procedure for software and the results of tests are to be documented.

4 Data transmission link

4.1 General

4.1.1 The performance of the network transmission medium (transfer rate and time delay) is to be compatible with the intended application.

4.1.2 When the master /slave configuration is installed, the master terminal is to be indicated on the other terminals.

4.2 Hardware support

4.2.1 The data transmission is to be self-checked, regarding both the network transmission medium and the interfaces/connections.

The data communication link is to be automatically started when power is turned on, or restarted after loss of power.

4.2.2 The choice of transmission cable is to be made according to the environmental conditions. Particular attention is to be given to the level characteristics required for electromagnetic interferences.

4.2.3 The installation of transmission cables is to comply with the requirements stated in Ch 4, Sec 11. In addition, the routing of transmission cables is to be chosen so as to be in less exposed zones regarding mechanical, chemical or EMI damage.

4.2.4 The coupling devices are to be designed, as far as practicable, so that in the event of a single fault, they do not alter the network function. When a failure occurs, an alarm is to be activated.

Addition of coupling devices is not to alter the network function.

Hardware connecting devices are to be chosen, when possible, in accordance with international standards.

When a computer based system is used with a non-essential system and connected to a network used for essential systems, the coupling device is to be of an approved type.

4.3 Transmission software

4.3.1 The transmission software is to be so designed that alarm or control data have priority over any other data. For control data, the transmission time is not to jeopardise efficiency of the functions.

4.3.2 The transmission protocol is preferably to be chosen among international standards.

4.3.3 A means of transmission control is to be provided and designed so as to verify the completion of the data transmitted (CRC or equivalent acceptable method). When corrupted data is detected, the number of retries is to be limited so as to keep an acceptable global response time. The duration of the message is to be such that it does not block the transmission of other stations.

4.4 Transmission operation

4.4.1 When a hardware or software transmission failure occurs, an alarm is to be activated. A means is to be provided to verify the activity of transmission and its proper function (positive information).

4.5 Redundant network

4.5.1 Where two or more essential services are using the same network, redundant networks are required according to the conditions mentioned in [1.6.1].

Fault tolerant networks may be considered as an alternative (e.g. use of loops).

4.5.2 Switching of redundant networks from one to the other is to be achieved without alteration of the performance.

4.5.3 When not in operation, the redundant network is to be permanently monitored, so that any failure of either network may be readily detected. When a failure occurs in one network, an alarm is to be activated.

4.5.4 In redundant networks, the two networks are to be mutually independent. Failure of any common components is not to result in any degradation in performance.

4.5.5 When redundant data communication links are required, they are to be routed separately, as far as practicable.

5 Man-machine interface

5.1 System functional indication

5.1.1 A means is to be provided to verify the activity of the system, or subsystem, and its proper function.

5.1.2 A visual and audible alarm is to be activated in the event of malfunction of the system, or subsystem. This alarm is to be such that identification of the failure is simplified.

5.2 Input devices

5.2.1 Input devices are to be positioned such that the operator has a clear view of the related display.

The operation of input devices, when installed, is to be logical and correspond to the direction of action of the controlled equipment.

The user is to be provided with positive confirmation of action.

Control of essential functions is only to be available at one control station at any time. Failing this, conflicting control commands are to be prevented by means of interlocks and /or warnings.

5.2.2 When keys are used for common/important controls, and several functions are assigned to such keys, the active function is to be recognisable.

If use of a key may have unwanted consequences, provision is to be made to prevent an instruction from being executed by a single action (e.g. simultaneous use of two keys, repeated use of a key, etc.).

Means are to be provided to check validity of the manual input data into the system (e.g. checking the number of characters, range value, etc.).

5.2.3 If use of a push button may have unwanted consequences, provision is to be made to prevent an instruction from being executed by a single action (e.g. simultaneous use of two push buttons, repeated use of push buttons, etc.). Alternatively, this push button is to be protected against accidental activation by a suitable cover, or use of a pull button, if applicable.

5.3 Output devices

5.3.1 VDU's (video display units) and other output devices are to be suitably lighted and dimmable when installed in the control room. The adjustment of brightness and colour of VDU's is to be limited to a minimum discernible level.

When VDU's are used for alarm purposes, the alarm signal, required by the Rules, is to be displayed whatever the other information on the screen. The alarms are to be displayed according to the sequence of occurrence.

When alarms are displayed on a colour VDU, it is to be possible to distinguish alarm in the event of failure of a primary colour.

The position of the VDU is to be such as to be easily readable from the normal position of the personnel on watch. The size of the screen and characters is to be chosen accordingly.

When several control stations are provided in different spaces, an indication of the station in control is to be displayed at each control station. Transfer of control is to be effected smoothly and without interruption to the service.

5.4 Workstations

5.4.1 The number of workstations at control stations is to be sufficient to ensure that all functions may be provided with any one unit out of operation, taking into account any functions which are required to be continuously available.

5.4.2 Multifunction workstations for control and display are to be redundant and interchangeable.

5.4.3 The choice of colour, graphic symbols, etc. is to be consistent in all systems on board.

5.5 Computer dialogue

5.5.1 The computer dialogue is to be as simple and self-explanatory as possible.

The screen content is to be logically structured and show only what is relevant to the user.

Menus are to be organised so as to have rapid access to the most frequently used functions.

5.5.2 A clear warning is to be displayed when using functions such as alteration of control condition, or change of data or programs in the memory of the system.

5.5.3 A 'wait' indication is to warn the operator when the system is executing an operation.

6 Integrated systems

6.1 General

6.1.1 Operation with an integrated system is to be at least as effective as it would be with individual, stand alone equipment.

6.1.2 Failure of one part (individual module, equipment or subsystem) of the integrated system is not to affect the functionality of other parts, except for those functions directly dependant on information from the defective part.

6.1.3 A failure in connection between parts, cards connections or cable connections is not to affect the independent functionality of each connected part.

6.1.4 Alarm messages for essential functions are to have priority over any other information presented on the display.

7 Expert system

7.1

7.1.1 The expert system software is not to be implemented on a computer linked with essential functions.

7.1.2 Expert system software is not to be used for direct control or operation, and needs human validation by personnel on watch.

8 System testing

8.1

8.1.1 The system tests are to be carried out according to Ch 5, Sec 6.

8.1.2 All alterations of a system (hardware and software) are to be tested and the results of tests documented.

9 System maintenance

9.1

9.1.1 System maintenance is to be planned and documented. Changes in configuration, hardware and software are to be documented. The relevant documents and backups are to be prepared when the system is delivered.

SECTION 4 CONSTRUCTIONAL REQUIREMENTS

1 General

1.1 General

1.1.1 Automation systems are to be so constructed as:

- to withstand the environmental conditions the environmental conditions, as defined in Ch 4, Sec 2, [1], in which they operate
- to have necessary facilities for maintenance work.

1.2 Materials

1.2.1 Materials are generally to be of the flame-retardant type.

1.2.2 Connectors are to be able to withstand standard vibrations, mechanical constraints and corrosion conditions as given in Ch 5, Sec 6.

1.3 Component design

1.3.1 Automation components are to be designed to simplify maintenance operations. They are to be so constructed as to have:

- easy identification of failures
- easy installation and safe handling in the event of replacement of parts (plug and play principle) without impairing the operational capability of the system, as far as practicable
- facility for adjustment of set points or calibration
- test point facilities, to verify the proper operation of components.

1.4 Environmental and supply conditions

1.4.1 The environmental and supply conditions are specified in Ch 5, Sec 1. Specific environmental conditions are to be considered for air temperature and humidity, vibrations, corrosion from chemicals and mechanical or biological attacks.

2 Electrical and/or electronic systems

2.1 General

2.1.1 Electrical and electronic equipment is to comply with the requirements of Part D, Chapter 4 and Part D, Chapter 5.

2.1.2 A separation is to be done between any electrical components and liquids, if they are in a same enclosure. Necessary drainage will be provided where liquids are likely to leak.

2.1.3 When plug-in connectors or plug-in elements are used, their contacts are not to be exposed to excessive mechanical loads. They are to be provided with a locking device.

2.1.4 All replaceable parts are to be so arranged that it is not possible to connect them incorrectly or to use incorrect replacements. Where this not practicable, the replacement parts as well as the associated connecting devices are to be clearly identified. In particular, all connection terminals are to be properly tagged. When replacement cannot be carried out with the system on, a warning sign is to be provided.

2.1.5 Forced cooling systems are to be avoided. Where forced cooling is installed, an alarm is to be provided in the event of failure of the cooling system.

2.1.6 The interface connection is to be so designed to receive the cables required. The cables are to be chosen according to Ch 4, Sec 3.

2.2 Electronic system

2.2.1 Printed circuit boards are to be so designed that they are properly protected against the normal aggression expected in their environment.

2.2.2 Electronic systems are to be constructed taking account of electromagnetic interferences.

Special precautions are to be taken for:

- measuring elements such as the analogue amplifier or analog/digital converter, and
- connecting different systems having different ground references.

2.2.3 The components of electronic systems (printed circuit board, electronic components) are to be clearly identifiable with reference to the relevant documentation.

2.2.4 Where adjustable set points are available, they are to be readily identifiable and suitable means are to be provided to protect them against changes due to vibrations and uncontrolled access.

2.2.5 The choice of electronic components is to be made according to the normal environmental conditions, in particular the temperature rating.

2.2.6 All stages of fabrication of printed circuit boards are to be subjected to quality control. Evidence of this control is to be documented.

2.2.7 Burn-in tests or equivalent tests are to be performed.

2.2.8 The programmable components are to be clearly tagged with the program date and reference.

Components are to be protected against outside alteration when loaded.

2.3 Electrical system

2.3.1 Cables and insulated conductors used for internal wiring are to be at least of the flame-retardant type, and are to comply with the requirements in Part D, Chapter 4.

2.3.2 If specific products (e.g. oil) are likely to come into contact with wire insulation, the latter is to be resistant to such products or properly shielded from them, and to comply with the requirements in Part D, Chapter 4.

3 Pneumatic systems

3.1

3.1.1 Pneumatic automation systems are to comply with Ch 3, Sec 5.

3.1.2 Pneumatic circuits of automation systems are to be independent of any other pneumatic circuit on board.

4 Hydraulic systems

4.1

4.1.1 Hydraulic automation systems are to comply with Ch 3, Sec 5.

4.1.2 Suitable filtering devices are to be incorporated into the hydraulic circuits.

4.1.3 Hydraulic circuits of automation systems are to be independent of any other hydraulic circuit on board.

5 Automation consoles

5.1 General

5.1.1 Automation consoles are to be designed on ergonomic principles. Handrails or other efficient means are to be fitted for safe operation of the console.

5.2 Indicating instruments

5.2.1 The operator is to receive feed back information on the effects of his orders.

5.2.2 Indicating instruments and controls are to be arranged according to the logic of the system in control. In addition, the operating movement and the resulting movement of the indicating instrument are to be consistent with each other.

5.2.3 The instruments are to be clearly labelled. When installed in the control room, all lighted instruments of consoles are to be dimmable, where necessary.

5.2.4 Indicating instruments are to be designed and inscribed in such way that they can be read quickly and clearly.

5.3 VDU's and keyboards

5.3.1 VDU's in consoles are to be located so as to be easily readable from the normal position of the operator. The environmental lighting is not to create any reflection which makes reading difficult.

5.3.2 The keyboard is to be located to give easy access from the normal position of the operator. Special precautions are to be taken to avoid inadvertent operation of the keyboard.

SECTION 5 INSTALLATION REQUIREMENTS

1 General

1.1

1.1.1 Automation systems are to be installed taking into account the:

- maintenance requirements (test and replacement of systems or components)
- influence of EMI. The IEC 60533 standard is to be taken as guidance
- environmental conditions corresponding to the location in accordance with Ch 4, Sec 1 and Ch 4, Sec 3, [6].

1.1.2 Control stations are to be arranged for the convenience of the operator.

1.1.3 Automation components are to be properly fitted. Screws and nuts are to be locked, where necessary.

2 Sensors and components

2.1 General

2.1.1 The location and selection of the sensor is to be done so as to measure the actual value of the parameter. Temperature, vibration and EMI levels are to be taken into account. When this is not possible, the sensor is to be designed to withstand the local environment.

2.1.2 The enclosure of the sensor and the cable entry are to be appropriate to the space in which they are located.

2.1.3 Means are to be provided for testing, calibration and replacement of automation components. Such means are to be designed, as far as practicable, so as to avoid perturbation of the normal operation of the system.

2.1.4 A tag number is to identify automation components and is to be clearly marked and attached to the component. These tag numbers are to be collected on the instrument list mentioned in Ch 5, Sec 1, Tab 1.

2.1.5 Electrical connections are to be arranged for easy replacement and testing of sensors and components. They are to be clearly marked.

2.1.6 Low level signal sensors are to be avoided. When installed they are to be located as close as possible to amplifiers, so as to avoid external influences. Failing this, the wiring is to be provided with suitable EMI protection and temperature correction.

2.2 Temperature elements

2.2.1 Temperature sensors, thermostats or thermometers are to be installed in a thermowell of suitable material, to permit easy replacement and functional testing. The thermowell is not to significantly modify the response time of the whole element.

2.3 Level switches

2.3.1 Level switches fitted to flammable oil tanks, or similar installations, are to be installed so as to reduce the risk of fire.

3 Cables

3.1 Installation

3.1.1 Cables are to be installed according to the requirements in Ch 4, Sec 12, [7].

3.1.2 Suitable installation features such as screening and/or twisted pairs and/or separation between signal and other cables are to be provided in order to avoid possible interference on control and instrumentation cables.

3.1.3 Specific transmission cables (coaxial cables, twisted pairs, etc.) are to be routed in specific cable-ways and mechanically protected to avoid loss of any important transmitted data. Where there is a high risk of mechanical damage, the cables are to be protected with pipes or equivalent.

3.1.4 The cable bend radius is to be in accordance with the requirements of Ch 4, Sec 12, [7.2].

For mineral insulated cables, coaxial cables or fibre optic cables, whose characteristics may be modified, special precautions are to be taken according to the manufacturer's instructions.

3.2 Cable terminations

3.2.1 Cable terminations are to be arranged according to the requirements in Part D, Chapter 4. Particular attention is to be paid to the connections of cable shields. Shields are to be connected only at the sensor end when the sensor is earthed, and only at the processor end when the sensor is floating.

3.2.2 Cable terminations are to be able to withstand the identified environmental conditions (shocks, vibrations, salt mist, humidity, etc.).

3.2.3 Terminations of all special cables such as mineral insulated cables, coaxial cables or fibre optic cables are to be arranged according to the manufacturer's instructions.

4 Pipes

4.1

4.1.1 For installation of piping circuits used for automation purposes, see the requirements in Ch 3, Sec 5.

4.1.2 Hydraulic and pneumatic piping for automation systems is to be marked to indicate its function.

5 Automation consoles

5.1 General

5.1.1 Consoles or control panels are to be located so as to enable a good view of the process under control, as far as practicable. Instruments are to be clearly readable in the ambient lighting.

5.1.2 The location is to be such as to allow easy access for maintenance operations, as far as practicable.

5.1.3 Shock absorbers are to be installed for all consoles and switchboards fitted onboard, according to service notation requirements, where necessary.

SECTION 6 TESTING

1 General

1.1 General

1.1.1 Automation systems are to be tested for type approval, at works and on board, when required. Tests are to be carried out under the supervision of a Surveyor of the Society.

1.1.2 The type testing conditions for electrical, control and instrumentation equipment, computers and peripherals are described in Article [2].

1.1.3 Automation systems are to be inspected at works, according to the requirements of [3], in order to check that the construction complies with the Rules.

1.1.4 Automation systems are to be tested when installed on board and prior to sea trials, to verify their performance and adaptation on site, according to Article [4].

2 Type approval

2.1 General

2.1.1 The following requirements are applicable, but not confined, to all electrical, control and instrumentation systems which are intended to be type approved for use in marine applications. In particular, they apply to control, protection, safety devices and internal communication.

2.1.2 The necessary documents to be submitted, prior to type testing, are listed in Ch 5, Sec 1, [2.4.1]. The type approval of automation systems refers to hardware type approval or software type approval, as applicable.

2.2 Hardware type approval

2.2.1 Hardware type approval of automation systems is obtained subject to the successful outcome of the tests described in Tab 1.

Vibration and salt mist testing may be performed on different specimens, where applicable.

Table 1 : Type tests

No.	Test	Procedure **(6)**	Test parameters	Other information
1	Visual inspection	–	–	• drawings, design data
2	Performance test	Manufacturer performance test programme based upon specification and relevant rule requirement	• standard atmosphere conditions • temperature: 25°C ± 10°C • relative humidity: 60% ± 30% • air pressure: 96 KPa ± 10 KPa	• confirmation that operation is in accordance with the requirements specified for particular automatic systems or equipment • checking of self-monitoring features • checking of specified protection against an access to the memory • checking against effect of unerroneous use of control elements in the case of computer systems
3	Power supply failure	–	• 3 interruptions during 5 minutes • switching- off time 30 s each case	• verification of the specified action of the equipment on loss and restoration of supply in accordance with the system design
4a	Electric A.C. power supply variations	–	COMBINATION Voltage variation permanent / Frequency variation permanent + 6% / + 5% + 6% / – 5% – 10% / – 5% – 10% / + 5% voltage transient / frequency transient 1,5 s / 5 s + 20% / + 10% – 20% / – 10%	

No.	Test	Procedure **(6)**	Test parameters	Other information
4b	Electric D.C. power supply variations	–	Voltage tolerance continuous: ± 10% Voltage cyclic variation: 5% Voltage ripple: 10% Electric battery supply: • + 40% to – 25% for equipment connected to the battery during full charging • + 20% to – 25% for equipment connected to the battery during partial charging	
4c	Pneumatic and hydraulic power supply variations	–	Pressure: ± 20% Duration: 15 minutes	
5	Dry heat	IEC Publication 60068-2-2	• Temperature: 55°C ± 2°C Duration: 16 hours, or • Temperature: 70°C ± 2°C Duration: 2 hours (see **(1)**)	• equipment operating during conditioning and testing • functional test during the last hour at the test temperature
6	Damp heat	IEC Publication 60068-2-30 Test Db	Temperature: 55°C Humidity: 95% Duration: 2 cycles (12 + 12 hours)	• measurement of insulation resistance before test • equipment operating during the complete first cycle and switched off during second cycle except for functional test • functional test during the first 2 hours of the first cycle at the test temperature and during the last 2 hours of the second cycle at the test temperature • recovery at standard atmosphere conditions • insulation resistance measurements and performance test
7	Vibration	IEC Publication 60068-2-6 Test Fc	• 2 Hz ± 3/0 Hz to 13,2 Hz amplitude: ± 1mm • 13,2 Hz to 100 Hz acceleration: ± 0,7 g For severe vibration conditions such as, e. g., on diesel engines, air compressors, etc.: • 2,0 Hz to 25 Hz amplitude: ± 1,6 mm • 25 Hz to 100 Hz acceleration: ± 4,0 g Note: Very special conditions may exist for example on exhaust manifolds of diesel engines especially for medium and high speed engines. Values may be required to be in these cases: • 40 Hz to 2000 Hz • acceleration: ± 10,0 g at 600°C	• duration 90 minutes at 30 Hz in case of no resonance condition • duration 90 minutes at each resonance frequency at which $Q \geq 2$ is recorded • during the vibration test, operational conditions are to be demonstrated • tests to be carried out in three mutually perpendicular planes • it is recommended as a guidance that Q does not exceed 5 • duration 120 minutes if sweep test is chosen in case several resonance frequencies are detected close to each other

No.	Test	Procedure **(6)**	Test parameters	Other information
8	Inclination	IEC Publication 60092-504	Static 22,5°	a) inclined to the vertical at an angle of at least 22,5° b) inclined to at least 22,5° on the other side of the vertical and in the same plane as in a) c) inclined to the vertical at an angle of at least 22,5° in plane at right angles to that used in a) d) inclined to at least 22,5° on the other side of the vertical and in the same plane as in c) Note: The period of testing in each position should be sufficient to fully evaluate the behaviour of the equipment
			Dynamic 22,5°	Using the directions defined in a) to d) above, the equipment is to be rolled to an angle of 22,5° each side of the vertical with a period of 10 seconds The test in each direction is to be carried out for not less than 15 minutes
9	Insulation resistance	Rated supply voltage / Test voltage Un ≤ 65 V: 2 x Un min. 24 V Un > 65V: 500 V	Minimum insulation resistance before / after 10 Mohms / 1,0 Mohms 100 Mohms / 10 Mohms	• insulation resistance test is to be carried out before and after: damp heat test, cold test and salt mist test • between all circuits and earth • on the supply terminals where appropriate Note: Certain components, e. g. for EMC protection, may be required to be disconnected for this test
10	High voltage	Rated voltage Un Up to 65 V 66 V to 250 V 251 V to 500 V 501 V to 690 V	Test voltage (A.C. voltage 50 or 60Hz) 2 x Un + 500 V 1500 V 2000 V 2500 V	• separate circuits are to be tested against each other and all circuits connected with each other tested against earth • printed circuits with electronic components may be removed during the test • period of application of the test voltage: 1 minute Note: Certain components, e. g. printed circuits with electronic components, may be required to be disconnected for this test
11	Cold	IEC Publication 60068-2-1	• Temperature: +5°C ± 3°C Duration: 2 hours, or • Temperature: –25°C ± 3°C Duration: 2 hours (see **(2)**)	• initial measurement of insulation resistance • equipment not operating during conditioning and testing except for operational test • operational test during the last hour at the test temperature • insulation resistance measurement and the operational test after recovery
12	Salt mist	IEC Publication 60068-2-52 Test Kb	Four spraying periods with a storage of seven days after each	• initial measurement of insulation resistance and initial functional test • equipment not operating during conditioning • functional test on the 7th day of each storage period • insulation resistance measurement and operational test after recovery (see **(3)**)

No.	Test	Procedure **(6)**	Test parameters	Other information
13	Electrostatic discharge	IEC 61000-4-2	Contact discharge: 6 kV Air discharge: 8 kV Interval between single discharges: 1 sec. No. of pulses: 10 per polarity According to level 3 severity standard	• to simulate electrostatic discharge as may occur when persons touch the appliance • the test is to be confined to the points and surfaces that can normally be reached by the operator • performance criterion B (see **(4)**)
14	Radiated Radio Frequency	IEC 61000-4-3	Frequency range: 80 MHz to 2 GHz Modulation**: 80% AM at 1000Hz Field strength: 10V/m Frequency sweep rate: $\leq 1{,}5.10^{-3}$ decades/s (or 1% / 3 sec) According to level 3 severity standard	• to simulate electromagnetic fields radiated by different transmitters • the test is to be confined to the appliances exposed to direct radiation by transmitters at their place of installation • performance criterion A (see **(5)**) ** If, for tests of equipment, an input signal with a modulation frequency of 1000 Hz is necessary, a modulation frequency of 400 Hz should be chosen
15	Conducted Audio Frequency	IEC 60533	A.C.: • Frequency range: rated frequency to 200th harmonic • Test voltage (rms): 10% of supply to 15th harmonic reducing to 1% at 100th harmonic and maintain this level to the 200th harmonic, max. 2 W D.C.: • Frequency range: 50 Hz - 10 kHz • Test voltage (rms) :10% of supply but at least 3 V, max. 2 W	• to simulate distortions in the power supply system generated, for instance, by electronic consumers and coupled in as harmonics • method of the test in accordance with IEC 945, clause 10.2 of the 3rd edition • performance criterion A (see **(5)**)
16	Conducted Radio Frequency	IEC 61000-4-6	Frequency range: 150 kHz - 80 MHz Amplitude: 3 V rms (see **(7)**) Modulation***: 80% AM at 1000 Hz Frequency sweep range: $\leq 1{,}5.10^{-3}$ decades/s (or 1% / 3sec.) According to level 2 severity standard	• to simulate electromagnetic fields coupled as high frequency into the test specimen via the connecting lines • performance criterion A (see **(5)**) *** If, for tests of equipment, an input signal with a modulation frequency of 1000 Hz is necessary, a modulation frequency of 400 Hz should be chosen
17	Burst/ Fast Transients	IEC 61000-4-4	Single pulse time: 5ns (between 10% and 90% value) Single pulse width: 50 ns (50% value) Amplitude (peak): 2 kV line on power supply port/earth; 1 kV line/line on I/O data control and signal lines Pulse period: 300 ms Burst duration: 15 ms Duration/polarity: 5 min According to level 3 severity standard	• arcs generated when actuating electrical contacts • interface effect occurring on the power supply, as well as at the external wiring of the test specimen • performance criterion B (see **(4)**)
18	Surge / Slow Transient	IEC 61000-4-5	Pulse rise time: 1,2 µVs (between 10% and 90% value) Pulse width: 50 µVs (50% value) Amplitude (peak) : 1 kV line/earth; 0,5kV line/line Repetition rate: ≥ 1 pulse/min No of pulses: 5 per polarity Application: continuous According to level 3 severity standard	• to simulate interference generated, for instance, by switching “ON” or “OFF” high power inductive consumers • test procedure in accordance with figure 10 of the standard for equipment where power and signal lines are identical • performance criterion B (see **(4)**)

No.	Test	Procedure **(6)**	Test parameters	Other information
19	Radiated Emission	CISPR 16-1, 16-2	• For equipment installed in the bridge and deck zone: Frequency range (MHz): / Limits (dBµV/m): 0,15 - 0,30: 80- 50 0,30 - 30: 50- 34 30 - 2000: 54 except for: 156 - 165: 24 • For equipment installed in the general power distribution zone: Frequency range (MHz): / Limits (dBµV/m): 0,150 - 0,168: 80 - 75 0,168 - 30: 75 - 50 30 - 100: 60 - 54 100 - 2000: 54 except for: 156 - 165: 24	• procedure in accordance with the standard but distance 3 m between equipment and antenna
20	Conducted Emission	CISPR 16-1, 16-2	• For equipment installed in the bridge and deck zone: Frequency range: / Limits (dBµV): 10 - 150 kHz: 96 - 50 150 - 350 kHz: 60 - 50 0,35 - 30 MHz: 50 • For equipment installed in the general power distribution zone: Frequency range: / Limits (dBµV): 10 - 150 kHz: 120 - 69 150 - 500 kHz: 79 0,50 - 30 MHz: 73	
21	Flame retardant	IEC 60092-101 or IEC 60695-2-2	Flame application: 5 times 15 s each Interval between each application: 15 s	• the burnt out or damaged part of the specimen by not more than 60mm long

(1) Equipment to be mounted in consoles, housing etc. together with other equipment are to be tested with 70°C.

(2) For equipment installed in non-weather protected locations or cold locations, test is to be carried out at –25°C.

(3) Salt mist test is to be carried out for equipment installed in weather exposed areas.

(4) Performance criterion B: (for transient phenomena): The Equipment Under Test shall continue to operate as intended after the tests. No degradation of performance or loss of function is allowed as defined in the technical specification published by the Manufacturer. During the test, degradation or loss of function or performance which is self recoverable is however allowed but no change of actual operating state or stored data is allowed.

(5) Performance criterion A (for continuous phenomena): The EUT shall continue to operate as intended during and after the test. The degradation of performance or loss is allowed as defined in the technical specification published by the Manufacturer.

(6) Column 3 indicates the testing procedure which is normally to be applied. However, equivalent testing procedure may be accepted by the Society provided that what is required in the other columns is fulfilled.

(7) For equipment installed on the bridge and deck zone, the test levels shall be increased to 10V rms for spot frequencies in accordance with IEC 60945 at 2,3,4,6.2, 8.2, 12.6, 16.5, 18.8, 22, 25 MHz.

Reset of the automation system is accepted between each test, where necessary.

2.2.2 The following additional tests may be required, depending on particular manufacturing or operational conditions:

- mechanical endurance test
- temperature shock test (e.g. 12 shocks on exhaust gas temperature sensors from 20°C ± 5°C to maximum temperature of the range)
- immersion test
- oil resistance test
- shock test.

The test procedure is to be defined with the Society in each case.

2.3 Software type approval

2.3.1 Software type approval consists of evaluation of the development quality and verification of test results.

Documents in accordance with Ch 5, Sec 1, [2] are required.

Repetition of unit tests, integration tests or validation tests is required to verify the consistency of test results.

Certificate may be issued at the request of the manufacturer when approval is granted.

3 Acceptance testing

3.1 General

3.1.1 Acceptance tests are generally to be carried out at the manufacturer's facilities before the shipment of the equipment, when requested.

Acceptance tests refer to hardware and software tests as applicable.

3.2 Hardware testing

3.2.1 Hardware acceptance tests include, where applicable:

- visual inspection
- operational tests and, in particular:
  - tests of all alarm and safety functions
  - verification of the required performance (range, calibration, repeatability, etc.) for analogue sensors
  - verification of the required performance (range, set points, etc.) for on/off sensors
  - verification of the required performance (range, response time, etc.) for actuators
  - verification of the required performance (full scale, etc.) for indicating instruments
- endurance test (burn-in test or equivalent)
- high voltage test
- hydrostatic tests.

Additional tests may be required by the Society.

3.2.2 Final acceptance will be granted subject to:

- the results of the tests listed in [3.2.1]
- the type test report or type approval certificate.

3.3 Software testing

3.3.1 Software acceptance tests of computer based systems are to be carried out to verify their adaptation to their use on board, and concern mainly the application software.

3.3.2 The software modules of the application software are to be tested individually and subsequently subjected to an integration test. The test results are to be documented and to be part of the final file. It is to be checked that:

- the development work has been carried out in accordance with the plan
- the documentation includes the proposed test, the acceptance criteria and the result.

Repetition tests may be required to verify the consistency of test results.

3.3.3 Software acceptance will be granted subject to:

- examination of the available documentation
- a functional test of the whole system.

The Society may ask for additional tests of systems which are part of safety systems or which integrate several functions.

4 On board tests

4.1 General

4.1.1 On board tests are to be carried out on automation systems associated with essential services to verify their compliance with the Rules, by means of visual inspection and the performance and functionality according to Tab 2.

When completed, automation systems are to be such that a single failure, for example loss of power supply, is not to result in a major degradation of the propulsion or steering of the ship. In addition, a blackout test is to be carried out to show that automation systems are continuously supplied.

Upon completion of on board tests, test reports are to be made available to the Surveyor.

Table 2 : On board tests

Equipment	Nature of tests
Electronic equipment	Main hardware functionality
Analogue sensors	Signal calibration, trip set point adjustment
On/off sensors	Simulation of parameter to verify and record the set points
Actuators	Checking of operation in whole range and performance (response time, pumping)
Reading instruments	Checking of calibration, full scale and standard reference value

Part D
Systems

Chapter 6
COMMUNICATION AND NAVIGATING

SECTION 1 COMMUNICATION SYSTEM

SECTION 2 NAVIGATING AND LOCATING EQUIPMENT

SECTION 3 SIGNALISATION

SECTION 1 COMMUNICATION SYSTEM

1 General

1.1 Application

1.1.1 The communication related to weapons or military operation is not covered by these Rules.

1.1.2 The failure of communication elements is not to endanger the reception and transmission of distress messages

2 Documentation

2.1 Documents to be submitted

2.1.1 In addition to the documents mentioned in Pt D Ch 4, Sec 1, Tab 1, and the requirements in Pt D, Ch 5, Sec 1, [2.1.1], documents according to Tab 1 are to be submitted.

3 Design requirements

3.1 General

3.1.1 Transmission protocol is to be according to a recognised international standard, such as the National Marine Electronic Association and international marine interface Standard IEC 61162.

3.1.2 Regardless of their type, size and function or range of service, submarines are to be equipped with various means of internal and external communication.

3.2 internal communication

3.2.1 A telephone link independent of the main power supply system (e.g. sound powered telephone) is to be provided between the control room and the propulsion local control place and between the fin bridge and the control room.

3.2.2 For public address and general alarm system, see Ch 4, Sec 3, [3.10] and Ch 4, Sec 3, [3.11].

3.3 Surface communication

3.3.1 Submarines are to be equipped with at least one two-channel VHF transmitter/receiver, one of the channels of which must operate on safety channel 16-VHF, while the other is used as a “working channel” for communication.

3.3.2 Additional means of communication may be required by the Naval Authority.

4 Testing

4.1 Product approval

4.1.1 Approval of products involved in the function of external communication are subject to the approval of the Naval Authority.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Documentation
1	A	Specifications of the external communication systems
2	A	Diagram of communication system
3	A	Diagram of local area network and hardware characteristics
4	A	Diagram of computer network and hardware characteristics
5	A	Communication software description of local area network (Protocol characteristics...)
6	A	List of data to be transmitted on internal network and priority level
7	I	Specifications of the external communication systems
8	A	List of data to be transmitted on external network and priority level
9	A	Communication software description of external network including software in receiving station ashore (Protocol characteristics...)
10	A	Test program of the communication equipment and systems, including test method for the integration of all the communication equipment (additional to the test procedure for type approval)
(1) A = to be submitted for approval I = to be submitted for information.		

SECTION 2 NAVIGATING AND LOCATING EQUIPMENT

1 General

1.1 Application

1.1.1 All submarines are to be fitted with navigation and positioning equipment in accordance with the hereunder requirements.

1.2 Operational assumptions

1.2.1 All equipment necessary for navigating and positioning the submarine is to be designed and constructed so as to work properly in the environmental conditions specified for the submarine.

1.3 Regulations, guidelines, standards

1.3.1 The requirements are based, as far as practicable, on the understanding that the applicable regulations and guidelines issued by the International Maritime Organisation are complied with, in particular:

a) Regulations 15 to 28, Chapter V of the 1974 "International Convention for the Safety of Life at Sea" (SOLAS) and applicable amendments

b) International Regulations for Preventing Collisions at Sea and all other relevant Regulations relating to Radiotelegraphy, Radiotelephony and Safety of Navigation required by Chapters IV and V of SOLAS 1974, as amended

c) IMO A.694: 1991, General requirements for shipborne radio equipment forming part of the global maritime distress and safety system (GMDSS) and for electronic navigational aids

d) IMO Performance Standards for navigational equipment and related navigational aids applicable to:

- gyrocompasses and or inertial navigation system (Resolution A.424)
- radar equipment (Resolutions A.222, A.278, A.477, MSC.64 (67) Annex 4)
- ARPA (Resolution A.422, A.823 (19))
- speed and distance measuring equipment (Resolution A.478, A.824, MSC.96 (72))
- echo sounding equipment (Resolution A.224, MSC.74 (69) Annex 4)
- electronic navigational aids – general requirements (Resolution A.574)
- rate-of-turn indicators (Resolution A.526).

1.3.2 The requirements and guidelines of the following international standards are to be complied with, as far as practicable:

- IEC 60872: ARPA – Operational and performance requirements – Methods of testing and required test results
- IEC 60936: Shipborne radar – Operational and performance requirements – Methods of testing and required test results
- IEC 61023: Marine speed and distance measuring equipment (SDME) – Operational and performance requirements – Methods of testing and required test results
- IEC 61174: Electronic chart display and information system (ECDIS) - Operational and performance requirements - Methods of testing and required test results
- ISO 8728 Ships and Marine technology - Gyro-compasses.

1.3.3 Additional requirements may be imposed by the national authority with whom the submarine is registered and/or by the Administration within whose territorial jurisdiction it is intended to operate.

1.4 Definitions

1.4.1 Terms used in the requirements are defined below:

- Alarm: a visual and audible signal indicating an abnormal situation
- ARPA: automatic radar plotting aid
- Control room: that area from which the navigation and control of the submarine is operated
- Display: means by which a device presents visual information to the navigator, including conventional instrumentation
- Ergonomics: application of the human factor in the analysis and design of equipment, work and working environment
- Field of vision: angular size of scene that can be observed from a position on the submarine bridge or in the control room periscope or optronical mast

- Fin bridge: place from where the submarine may be controlled when the submarine is navigating in surface
- Navigation: all tasks relevant for deciding, executing and maintaining course and speed in relation to waters and traffic
- Navigator: person navigating, operating navigational equipment and manoeuvring the submarine
- NAVTEX: an international maritime radio telex system sponsored by IMO and IHO, which automatically receives the broadcast telex information such as navigational, meteorological warnings and search and rescue (SAR) alerts on a 24-hour watch basis
- Normal conditions: when all systems and equipment related to navigation operate within design limits, and environmental conditions such as weather and traffic do not cause excessive workload to the officer of the watch
- Officer of the watch: person in charge of safe navigating, personal safety, operating of control room equipment and manoeuvring of the submarine
- Radar plotting: the whole process of target detection, tracking, calculation of parameters and display of information
- Tracking: process of observing the sequential changes in the position of a target, to establish its motion
- Workstation: position at which one or several tasks constituting a particular activity are carried out.

2 Documentation

2.1 Documents to be submitted

2.1.1 Documents according to Tab 1 are to be submitted.

2.1.2 Additional plans and specifications are to be submitted for approval, if requested by the Society.

3 Control room instrumentation and controls

3.1 General

3.1.1 The instrumentation and controls for navigation and traffic surveillance/manoeuvring are to be arranged to enable the officer of the watch with the crew to:

a) determine and plot the submarine's position, course, track, speed and immersion

b) analyse the traffic situation

c) decide on collision avoidance manoeuvres on surface

d) alter course

e) change speed

f) monitor course, speed, track, propeller revolutions, rudders angle and depth under the keel and immersion

g) record navigational data in the navigation log book (may be manually recorded from data available at the workstation)

h) detect the traffic in surface by the mean of acoustic sensors or others, before surfacing.

3.2 Safety of navigation: collision-grounding

3.2.1 Optical surveillance is to be possible by periscope, or equivalent device (see Pt D, Ch 3, Sec 4, [2.1.1]).

3.2.2 If a track control system is provided, it shall be monitored by an off course alarm addressed to the navigator, in case of malfunction. This alarm is to be derived from an independent system from the automatic steering system.

The navigator is to be given an alarm in the event of deviation from the planned route and /or planned depth.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Documentation
1	A	General arrangement of the control room and control consoles or panels
2	A	General arrangement of fin bridge
3	A	List and specification of navigational equipment and references
4	A	Functional diagram showing relation between navigational equipment
5	A	List of alarms and instrumentation located in control room
6	A	Diagram of alarm system
7	A	Diagram of electrical power supply to navigation system
8	A	Test program including test method for the integration of all the navigation, communication and alarm system
9	I	List of intended area of operation of the ship
(1) A = to be submitted for approval I = to be submitted for information.		

3.3 Surface navigation

3.3.1 As a minima for safe navigation, submarines are to be provided with the following navigational equipment:

a) position fixing system appropriate to the intended surface areas

b) a 9 GHz radar

c) nautical charts and nautical publications to plan and display the submarine route for the intended voyage and to plot and monitor positions throughout the voyage.

An electronic chart display and information system (ECDIS) is also accepted as meeting the chart carriage requirements of this item c)

d) two gyrocompass systems or equivalent devices (inertial navigation system)

e) a speed log system

f) an echo sounding system.

3.3.2 The following indicators are to be provided at the fin bridge:

a) a pelorus or compass bearing device, or other means to take bearings

b) a gyrocompass (or equivalent device) heading repeater

c) a speed repeater.

3.3.3 The navigation equipment required for navigation in surface may be dismounted when the submarine is navigating in depth.

3.4 Depth navigation

3.4.1 As a minima for safe navigation, submarines are to be provided with the following navigational equipment:

a) two gyrocompass systems or equivalent devices (inertial navigation system)

b) a speed log system

c) two depth indicators

d) an echo sounding system.

3.4.2 The two depth indicators are to be operated independently of each other. Each system is to have an independent power supply and its own pressure pick-up.

3.4.3 The accuracy of one of these two depth indicators is to be 1% minimum at nominal diving depth. The accuracy should not be significantly affected by pressure variations.

4 Design and reliability

4.1 General

4.1.1 Where computerised equipment, as listed in [3.3], is interconnected through a computer network, failure of the network is not to prevent individual equipment from performing its individual functions.

4.2 Power supply

4.2.1 For power supply of navigating equipment, see Ch 4, Sec 3, [3.2.5] and Ch 4, Sec 3, [3.2.6].

4.3 Environmental conditions

4.3.1 Shipborne navigational equipment, as listed in [3.3], specified in IMO Publication 978-88-04E "PERFORMANCE STANDARDS FOR NAVIGATIONAL EQUIPMENT" is to be capable of continuous operation under the conditions of various sea states, vibration, humidity, temperature and electromagnetic interference likely to be experienced in the ship in which it is installed.

5 Ergonomical recommendations

5.1 Lighting

5.1.1 The lighting required on the control room should be designed so as not to impair the vision of the officer on watch. Lighting used in areas and close to equipment requiring illumination during navigation, is to be such as not to impair the night vision adaptatione.g. red lighting. In the fin bridge, such lighting is to be arranged so that it cannot be mistaken for a navigation light by an other ship. It is to be noted that red lighting is not to be fitted over chart table so as to avoid possible confusion in colour discrimination.

5.2 Control room space heating/cooling

5.2.1 Unless otherwise justified, control room spaces are to be provided with heating and air cooling systems. System controls are to be readily available for the officer of the watch.

5.3 Personnel's safety

5.3.1 There are to be no sharp edges or protuberances on the surfaces of the instruments and equipment installed on the control room which could cause injury to the navigator.

5.3.2 Sufficient handrails or the equivalent are to be fitted inside the control room or around instruments and equipment therein for safety in bad weather.

5.3.3 Adequate means are to be made for anti-slip of the floor, whether it is dry or wet.

5.3.4 Where provision for seating is made in the control room, means for securing are to be provided, having regard to storm conditions.

6 Testing

6.1 Tests

6.1.1 Documentary evidence in the form of certification and/or test results is to be submitted to the satisfaction of the Society. Where acceptable evidence is not available, the requirements of Ch 5, Sec 6 are applicable, as far as practicable.

6.1.2 Shipboard tests and sea trials are to be carried out in accordance with the test procedures submitted for approval in advance to the Society. Tests and trials are to be performed under the supervision of the Surveyors.

6.1.3 After fitting on board, the installations are to be submitted to tests deemed necessary to demonstrate correct operation. Some tests may be carried out at quay side, while others are to be effected at sea trials.

SECTION 3 SIGNALISATION

1 General

1.1 Application

1.1.1 Submarines are to be fitted with:

- a whistle and its control device
- a signal lamp and its control device
- navigating lights.

1.1.2 Navigating lights are to be, as far as practicable, in line with COLREG, and subject to the approval of the Naval Authority.

1.1.3 Submarines navigation lights may be fitted with a diming system.

1.1.4 Submarines navigation lights may be dismounted when the submarine is navigating in depth.

1.1.5 For installations on board, see Ch 4, Sec 3, [3.9].

RULES FOR THE CLASSIFICATION OF NAVAL SUBMARINES

Part E
Fire Safety and Human Occupancy

Chapters **1 2 3**

CHAPTER 1 FIRE PROTECTION

CHAPTER 2 ATMOSPHERE CONTROL

CHAPTER 3 EMERGENCY AND RESCUE INSTALLATIONS

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Part E
Fire Safety and Human Occupancy

Chapter 1
FIRE PROTECTION

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SECTION 1 GENERAL

1 Application

1.1 General

1.1.1 The requirements of this Chapter apply to naval submarines.

1.2 Exemptions

1.2.1 The Society may, if the position of spaces and/or of rooms is such as to render the application of any specific requirement of this Chapter unreasonable or unnecessary, exempt from those requirements individual submarines.

1.3 Documentation to be submitted

1.3.1 The interested party is to submit to the Society the documents listed in Tab 1.

1.4 Type approved products

1.4.1 The following materials, equipment, systems or products in general used for fire protection, are to be type approved by the Society, except for special cases for which an authorisation of use may be given by the Society for individual ships on the basis of suitable documentation or ad hoc tests:

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Document **(2)**
1	A	Structural fire protection showing the purpose and category of the various spaces of the submarine, the fire rating of bulkheads and decks, means of closings of openings in A class divisions, and completed with the indication of material of other bulkhead and of ceilings and lining
2	A	Natural and mechanical ventilation systems showing the penetrations on A class divisions, location of dampers, means of closing, arrangements of air conditioning rooms
3	A	Automatic fire detection systems and manually operated call points
4	A	Arrangement of fixed fire-extinguishing systems **(2)**
5	A	Fire-fighting equipment
6	A	Electrical diagram of the fixed gas fire-extinguishing systems, fixed fire detection systems, fire alarm and emergency lighting
7	A	Electrical diagram of power control and position indication circuits for fire devices
8	I	General arrangement plan
9	A	Fire control plan
10	A	Flooding fighting plan
11	A	Atmosphere control documentation
12	A	Rescue arrangement documentation
13	A	Dangerous gases elimination documentation
14	A	Emergency breathing air drawings

(1) A: to be submitted for approval, in four copies
I: to be submitted for information, in duplicate.

(2) Plans are to be schematic and functional and to contain all information necessary for their correct interpretation and verification such as:

- service pressures
- capacity and head of pumps and compressors, if any
- materials and dimensions of piping and associated fittings
- volumes of protected spaces, for gas and foam fire-extinguishing systems
- surface areas of protected zones for pressure water-spraying, low expansion foam fire-extinguishing systems
- capacity, in volume and/or in mass, of vessels or bottles containing the extinguishing media or propelling gases, for gas, foam fire-extinguishing systems
- type, number and location of nozzles of extinguishing media for gas, pressure water-spraying, foam fire-extinguishing systems.

All or part of the information may be provided, instead of on the above plans, in suitable operation manuals or in specifications of the systems.

a) fire-resisting and fire-retarding divisions (bulkheads or decks) and associated doors

b) materials for pipes penetrating A class divisions (where they are not of steel or other equivalent material)

c) materials for oil or fuel oil pipes (where they are not of steel or copper and its alloys)

d) bulkhead or deck penetrations for electrical cables passing through A class divisions

e) materials with low flame spread characteristic including paints, varnishes and similar, when they are required to have such characteristic

f) non-combustible materials

g) non-readily igniting materials for primary deck coverings

h) fixed foam fire-extinguishing systems and associated foam-forming liquids

i) flexible pipes and expansion bellows of non-conventional material for any type of fluid

j) nozzles for fixed pressure water-spraying fire-extinguishing systems for machinery spaces and for weapon rooms

k) portable fire-extinguishers

l) fixed watermist fire-extinguishing systems with or without additives

m) sensing heads for automatic fire alarm and fire detection systems

n) fixed fire detection and alarm systems

o) fixed gas detection systems

p) portable gas detection systems

q) fire dampers.

The Society may request type approval for other materials, equipment, systems or products required by the applicable provisions for ships or installations of special types.

On the agreement of the Naval Authority, the Society may also issue a type approval certificate based on other standards recognised by the Naval Authority, and accept this certificate in equivalence of the type approval certificates issued for the classification of not military steel ships.

2 Definitions

2.1 Accommodation spaces

2.1.1 Accommodation spaces are those spaces used for public spaces, corridors, stairs, lavatories, cabins, offices, hospitals, meeting rooms.

2.2 A class divisions

2.2.1 A class divisions are those divisions formed by bulkheads and decks which comply with the following criteria:

a) they are constructed of steel or other equivalent material

b) they are suitably stiffened

c) they are insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C above the original temperature, within the time listed below:

- class "A-15".....15 minutes
- class "A-0".....0 minutes

d) they are so constructed as to be capable of preventing the passage of smoke and flame to the end of the one-hour standard fire test, and

e) the Society required a test of a prototype bulkhead or deck in accordance with the "Fire Test Procedures Code" (see [2.6]) to ensure that it meets the above requirements for integrity and temperature rise

f) the bulkhead thickness shall be at least thickness of a prototype tested bulkhead.

2.2.2 The products indicated in Tab 2 may be installed without testing or approval.

2.3 C class divisions

2.3.1 C class divisions are constructed of approved non-combustible materials. They need meet neither requirements relative to the passage of smoke and flame nor limitations relative to the temperature rise. Combustible veneers are permitted provided they meet the other relevant requirements of this Chapter.

Table 2 : Products installed without testing or approval

Classification	Product description
class A-0 bulkhead	A steel bulkhead with dimensions not less than the minimum dimensions given below: • thickness of plating: 4 mm • stiffeners 60 x 60 x 5 mm spaced at 600 mm or structural equivalent
class A-0 deck	A steel bulkhead with dimensions not less than the minimum dimensions given below: • thickness of plating: 4 mm • stiffeners 95 x 65 x 7 mm spaced at 600 mm or structural equivalent
class A-0 door	A steel [watertight] door, of at least 4 mm thickness, fitted with a symmetrical latch system, when its gas tightness or watertightness is required by this Rules.

2.4 Control stations

2.4.1 Control stations are those spaces in which the ship's radio or main navigating equipment are located or where the fire recording or fire control equipment is centralized.

The spaces containing naval systems for detection, command, communication, combat or weapon control/operation, bridge for command, defence, operation or planning rooms and spaces containing centralised ship's operation are assimilated as a control station. Control room is considered as one control station.

2.5 Fire Safety Systems Code

2.5.1 "Fire Safety Systems Code" means the International Code for Fire Safety Systems as adopted by the Maritime Safety Committee of the IMO by Resolution MSC.98(73).

2.6 Fire Test Procedures Code

2.6.1 "Fire Test Procedures Code" means the "International Code for Application of Fire Test Procedures", as adopted by the Maritime Safety Committee of the IMO by Resolution MSC.61 (67).

2.7 Flashpoint

2.7.1 Flashpoint is the temperature in degrees Celsius (closed cup test) at which the product will give off enough flammable vapour to be ignited, as determined by an approved flashpoint apparatus.

2.8 Galley

2.8.1 Spaces containing any electrically heated cooking plate or hot plate for keeping food warm with a power of more than 5 kW are to be regarded, for the purpose of Ch 1, Sec 5, as galleys.

2.9 Low flame spread

2.9.1 A low flame spread means that the surface thus described will adequately restrict the spread of flame, this being determined in accordance with the "Fire Test Procedures Code" (see [2.6]).

2.9.2 Non-combustible materials are considered as low flame spread. However, due consideration will be given by the Society to the method of application and fixing.

2.10 Machinery spaces

2.10.1 Machinery spaces are the following spaces:

a) Diesel engine room:

spaces containing mainly engines used for electrical power generation

b) Propulsion room:

spaces containing electrical motors used for main propulsion

c) Auxiliary machinery spaces:

- other spaces than those listed above containing propulsion machinery, fuel cells systems, fuel oil units, internal combustion engines, oil filling stations, refrigerating, ventilation and air conditioning machinery, and similar spaces, pumps, steering gear equipment, air compressor units, oxygen production units and trunks serving to such spaces
- rooms containing section switchboards and electrical equipment not fitted with a fire-extinguishing system (see Ch 1, Sec 6, [2.3.1].

2.11 Machinery spaces category A

2.11.1 Machinery spaces are the diesel engine rooms where the aggregate total power output is not less than 375 kW.

2.12 Non-combustible material

2.12.1 Non-combustible material is a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C, this being determined in accordance with the "Fire Test Procedures Code (see [2.6]). Any other material is a combustible material.

2.12.2 In general, products made only of glass, concrete, ceramic products, natural stone, masonry units, common metals and metal alloys are considered as being non-combustible and may be installed without testing and approval.

2.13 Pantries

2.13.1 Pantries may contain:

a) coffee automats, toasters, dishwashers, microwave ovens, water boilers and similar appliances

b) electrically heated cooking plates and hot plates for keeping food warm, each with a maximum power of 5 kW.

A dining room containing such appliances is not regarded as a pantry.

2.14 Public spaces

2.14.1 Public spaces are those portions of the accommodation which are used for dining rooms, lounges, recreational areas and similar permanently enclosed spaces.

2.15 Service spaces

2.15.1 Service spaces are those spaces used for galleys, pantries, lockers, storerooms, laundries, laboratories, workshops other than those forming part of the machinery spaces, and similar spaces and trunks to such spaces.

2.16 Steel or other equivalent material

2.16.1 Steel or other equivalent material means any non-combustible material which, by itself or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable exposure to the standard fire test (e.g., aluminium alloy with appropriate insulation).

2.17 Standard fire test

2.17.1 The standard fire test is one in which the specimens of the relevant bulkheads and decks are exposed in a test furnace to temperatures corresponding approximately to the standard time-temperature curve. The test methods shall be in accordance with the Fire Test Procedures Code (see [2.6])

2.18 Weapon room

2.18.1 Weapon rooms are the spaces used for the storage of submarine weapons.

SECTION 2 PREVENTION OF FIRE

1 Probability of ignition

1.1 Arrangements for fuel oil, lubrication oil and other flammable oils

1.1.1 Limitation in the use of oils as fuel

See Pt D, Ch 3, Sec 5, [16.2.1].

1.1.2 Arrangements for fuel oil

See Pt D, Ch 3, Sec 5.

1.1.3 Arrangements for lubricating oil

See Pt D, Ch 3, Sec 5.

1.1.4 Arrangements for other flammable oils

See Pt D, Ch 3, Sec 5.

1.2 Use of gaseous fuel for domestic purpose

1.2.1 The use of gaseous fuel for domestic purpose is not allowed.

1.3 Miscellaneous items of ignition sources and ignitability

1.3.1 Waste receptacles

All waste receptacles shall be constructed of non-combustible materials with no openings in the sides or bottom.

1.3.2 Insulation surfaces against oil penetration

In spaces where penetration of oil products is possible, the surface of insulation shall be impervious to oil or oil vapours.

1.3.3 Primary deck coverings

Primary deck coverings, if applied within accommodation and service spaces and control stations, shall be of approved material which will not readily ignite, this being determined in accordance with the Fire Test Procedures Code (see Ch 1, Sec 1, [2.6]).

2 Fire growth potential

2.1 Control of air supply and flammable liquid to the space

2.1.1 Closing appliances and stopping devices of ventilation

a) Closing appliances of ventilation system shall be capable of being closed locally from outside the spaces or group of spaces of same category being ventilated.

The controls are to be easily accessible as well as prominently and permanently marked and are to indicate whether the shut-off is open or closed.

b) Main closing appliances without remote-controlled shall be able to totally isolate the space at least 2 minutes after the fire detection triggering.

c) Except if in compliance with the requirement above, main closing appliances controls are also to be remote-controlled from one control position located in accommodation spaces or in control stations. Main closing appliances are to comprise at least diesel engine room ventilation closing appliances and main battery rooms ventilation closing appliances

d) Power ventilation fans shall be capable of being stopped locally.

e) Power ventilation fans are also to be remote-controlled from one control position situated in one control station.

2.1.2 Means of control in diesel engine room

In addition to the requirements of [2.1.1], the following requirements are applicable for the diesel engine room:

- means of control for the supply of flammable liquids are to be provided to control the supply of fuel oil from the feed fuel tank to the diesel engine
- the controls required above shall be located outside the space concerned so they will not be cut off in the event of fire in the space they serve
- in diesel engine room, controls to close off ventilation ducts and pipes are to be installed with due regard to the hot gases produced by a fire in the space concerned.

2.2 Fire protection materials

2.2.1 Use of non-combustible materials

a) Insulating materials

Except in refrigerated compartments, insulating materials shall be non-combustible. Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems, need not be of non-combustible materials, but they shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame-spread characteristics.

Cold service means refrigeration systems and chilled water piping for air conditioning systems.

b) Ceilings and linings

Except in refrigerated compartments, all linings, grounds, ceilings shall be of non combustible materials. Partial bulkheads or decks used to subdivide a space for utility shall also be of non-combustible material.

2.2.2 Use of combustible materials

a) General

Non-combustible bulkheads, ceilings and linings fitted in accommodation and service spaces may be faced with combustible surface materials in accordance with item b).

Note 1: Painted cork used for anti-condensation purposes is not required to have low-flame spread characteristics but is to be protected by an intumescent paint.

b) Low flame spread characteristics of surfaces

The following surfaces shall have low flame spread characteristics in accordance with the Fire Test Procedures Code:

1) exposed surfaces (deck, ceilings and bulkheads) of all spaces of a ship

2) surfaces including grounds in concealed or inaccessible spaces in all spaces of a ship.

The evaluation of the flame-spread characteristic of the boundary linings of the ships has to be performed for the layers combinations forming the coating

3 Smoke generation potential and toxicity

3.1 Paints and other finishes

3.1.1 Paints and other finishes used on exposed interior surfaces shall not be capable of producing excessive quantities of smoke and toxic products, this being determined in accordance with the Fire Test Procedures Code.

4 Prevention of explosion

4.1 Weapon rooms

4.1.1 The naval authority requirements are to be taken into account in order to avoid any explosion risks in the weapon room.

4.2 Main Batteries

4.2.1 Hydrogen level detectors are to be fitted in the main battery compartment. Its location is to be determined after checking of the formation of air pockets possibility.

SECTION 3 SUPPRESSION OF FIRE: DETECTION AND ALARM

1 General

1.1 Minimum number of detectors

1.1.1 Where a fixed fire detection and fire alarm system is required for the protection of spaces, at least one detector complying with the requirements given in Article [7] shall be installed in each such space.

2 Initial and periodical tests

2.1 General

2.1.1 The function of fixed fire detection and fire alarm systems required by the relevant Sections of this Chapter shall be tested under varying conditions of ventilation after installation.

2.1.2 The function of fixed fire detection and fire alarm systems shall be periodically tested to the satisfaction of the Society by means of equipment producing hot air at the appropriate temperature, or smoke or aerosol particles having the appropriate range of density or particle size, or other phenomena associated with incipient fires to which the detector is designed to respond.

3 Protection of machinery spaces

3.1 Installation

3.1.1 A fixed fire detection and fire alarm system complying with the relevant provisions given in Article [7] shall be installed in machinery spaces.

3.2 Design

3.2.1 Fire detection

The fixed fire detection and fire alarm system required in [3.1.1] shall be so designed and the detectors so positioned as to detect rapidly the onset of fire in any part of those spaces and under any normal conditions of operation of the machinery and variations of ventilation as required by the possible range of ambient temperatures.

The detection system shall initiate audible and visual alarms in sufficient places to ensure that the alarms are heard and observed in the control room.

4 Protection of accommodation, service spaces and control stations

4.1 General

4.1.1 A fixed fire detection and fire alarm system in accordance with Article [7] should be so installed and arranged as to provide smoke detection in service spaces and accommodation spaces. Spaces having little or no fire risk such as voids, sanitary spaces, and similar spaces need not be fitted with a fixed fire detection and alarm system. Smoke detectors need not be fitted in the galley but requirement [4.2] is to be applied. Fire detectors are not needed in permanently manned spaces such as control stations.

4.2 Protection of the galley

4.2.1 Heat detection

One heat detector complying with the relevant provisions given in Article [7] is to be installed in the galley exhaust duct.

4.2.2 Manually operated call point

One manually operated call point complying with the relevant provisions given in Article [7] is to be located at the exit of the galley.

5 Protection of weapon rooms

5.1 Smoke detection

5.1.1 Smoke detectors complying with the relevant provisions given in Article [7] are to be installed in weapon rooms. However, others hazard detection systems can be added according to the Naval Authorities requirements.

6 Protection of battery space

6.1 Smoke detection

6.1.1 Smoke detectors complying with the relevant provisions given in Article [7] are to be installed in battery ventilation ducts.

7 Fixed fire detection and fire alarm systems design

7.1 Engineering specifications

7.1.1 General requirements

a) Any required fixed fire detection and fire alarm system with manually operated call points shall be capable of immediate operation at all times.

b) The fire detection system shall not be used for any other purpose, except that the temperature measurement system can be connected to the fire detection control panel.

c) The system and equipment shall be suitably designed to withstand supply voltage variation and transients, ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered in ships.

d) Fire detection systems shall be fitted with a zone address identification capability and so arranged that:

1) means are provided to ensure that any fault (e.g. power break, short-circuit, earth) occurring in the loop will not render the whole loop ineffective

Note 1: Loop means an electrical circuit linking detectors of various sections in a sequence and connected (input and output) to the indicating unit(s).

2) all arrangements are made to enable the initial configuration of the system to be restored in the event of failure (electrical, electronic, computational)

3) the first initiated fire alarm will not prevent any other detector from initiating further fire alarms

4) no loop will pass through a space twice. When this is not practical, the part of the loop which by necessity passes through the space for a second time shall be so installed at the maximum possible distance from other parts of the loop.

7.1.2 Sources of power supply

There shall be not less than two sources of power supply for the electrical equipment used in the operation of the fire detection and fire alarm system. Furthermore the feeders shall feed the control panel through buffer battery. The supply shall be provided by separate feeders reserved solely for that purpose. Such feeders shall run to an automatic change-over switch situated in or adjacent to the control panel for the fire detection system.

The main feeders of both sources shall run from the main switchboards to the change-over switch without passing through any other distributing switchboard.

7.1.3 Component requirements

a) Detectors

1) Detectors shall be operated by heat, smoke or other products of combustion, flame, or any combination of these factors. Detectors operated by other factors indicative of incipient fires may be considered by the Society provided that they are no less sensitive than such detectors. Flame detectors shall only be used in addition to smoke or heat detectors

2) Smoke detectors shall operate within sensitivity limits to the satisfaction of the Society having regard to the avoidance of detector insensitivity or oversensitivity

3) Heat detectors shall be certified to operate before the temperature exceeds 78°C but not until the temperature exceeds 54°C, when the temperature is raised to those limits at a rate less than 1°C per minute. At higher rates of temperature rise, the heat detector shall operate within temperature limits to the satisfaction of the Society having regard to the avoidance of detector insensitivity or oversensitivity

4) At the discretion of the Society, the permissible temperature of operation of heat detectors may be increased to 30°C above the maximum deckhead temperature in drying rooms and similar spaces of a normal high ambient temperature

5) All detectors shall be of a type such that they can be tested for correct operation and restored to normal surveillance without the renewal of any component.

7.1.4 Installation requirements

a) Sections

1) Detectors as well as manually operated call points shall be grouped into separate sections

Note 1: Section means group of fire detectors or manually operated call points as shown in the indicating unit(s) required in item a)3) of [7.1.5].

2) A loop of fire detectors which covers a control station, a service space or an accommodation space shall not include the diesel engine room or the propulsion room.

b) Positioning of detectors

1) Detectors shall be located for optimum performance. Positions near beams and ventilation ducts or other positions where patterns of air flow could adversely affect performance and positions where impact or physical damage is likely shall be avoided. In general, detectors which are located on the overhead shall be a minimum distance of 0,5 m away from bulkheads. Above requirements are not applicable for detectors located in ventilation ducts

2) The maximum spacing of detectors shall be in accordance with Tab 1. The Society may require or permit other spacings based upon test data which demonstrate the characteristics of the detectors.

c) Arrangement of electric wiring

1) Electrical wiring which forms part of the system should be so arranged as to avoid galley, diesel engine room and propulsion room, and other enclosed spaces of high fire risk except where it is necessary to provide for fire detection or fire alarm in such spaces or to connect to the appropriate power supply

2) A loop of fire detection systems shall be capable of operating even if the loop is damaged in one point by the fire.

Table 1 : Maximum spacing of detectors

Type of detector	Maximum floor area per detector	Maximum distance away from bulkheads
Smoke	55 m^2	4 m

7.1.5 System control requirements

a) Visual and audible fire signals

1) The activation of any detector or manually operated call point shall initiate a visual and audible fire signal at the control panel and indicating units

2) The control panel shall be located at the continuously manned damage control station

3) Indicating units shall, as a minimum, denote the space in which a detector is activated or a manually operated call point has been operated. One indicating unit shall be located in the control room

4) Clear information shall be displayed on or adjacent to each indicating unit about the space covered and the location of the sections

5) Power supplies and electric circuits necessary for the operation of the system shall be monitored for loss of power or fault conditions as appropriate. Occurrence of a fault condition shall initiate a visual and audible fault signal at the control panel which shall be distinct from a fire signal.

SECTION 4 SUPPRESSION OF FIRE: CONTROL OF SMOKE SPREAD

1 Protection of control stations

1.1 General

1.1.1 Practicable measures should be taken for control stations in order to ensure that visibility and freedom from smoke are such that, in the event of fire, the machinery and equipment contained therein may be supervised and continue to function effectively.

1.1.2 In case of fire outside control station, effective local closing arrangements should be provided by means of fire dampers or smoke dampers which are to be easily closed within the control station. Precautions are to be taken so that into the control stations, the members of crew being on watch have always access to a breathing air plug.

2 Release of smoke after fire

2.1 General

2.1.1 When surfacing, it should be possible to release smoke by means of diesel engine and/or ventilation fans.

2.2 Means of control

2.2.1 Means of control shall be located outside diesel engine room.

SECTION 5 SUPPRESSION OF FIRE: CONTAINMENT OF FIRE

1 Thermal and structural boundaries

1.1 Application

1.1.1 The following requirements are concerning only spaces located inside pressure hull. Pressure hull itself is not concerned by this section.

1.2 Thermal and structural subdivision

1.2.1 Submarines shall be subdivided into spaces by thermal and structural divisions having regard to the fire risk of the space.

1.2.2 Internal bulkheads which are not required to be A class bulkheads by [1.4] and [1.5] are to be at least C class bulkheads.

1.2.3 In approving structural fire protection details, the Society shall have regard to the risk of heat transmission at intersections and terminal points of required thermal barriers.

1.3 Definitions

1.3.1 Types of spaces

- control stations and equivalent spaces
- accommodation spaces
- service spaces
- galley
- propulsion room
- tanks and auxiliary machinery spaces having little or no fire risk
- tanks forming part of the ship's structure except feed fuel tank
- battery compartments
- feed fuel tank
- diesel engine room
- weapon room.

1.4 Protection from high-risk spaces

1.4.1 Diesel engine room and feed fuel tank boundaries

The Diesel engine room and the feed fuel tank are to be generally separated from other adjacent spaces by A-15 class structural gastight bulkheads and decks. When adjacent spaces are located under the diesel engine room, the deck can be reduced to A-0 class. When adjacent spaces are auxiliary machinery spaces, bulkheads and decks can also be reduced to A-0 class.

1.4.2 Propulsion room boundaries

Propulsion room is to be generally separated from other adjacent spaces by A-15 class structural gastight bulkheads and decks. When adjacent spaces are located under the propulsion room, the deck can be reduced to A-0 class. When adjacent spaces are auxiliary machinery spaces, bulkheads and decks can also be reduced to A-0 class.

1.4.3 Galley boundaries

Galley is to be generally separated from other adjacent spaces by A-15 class structural gastight bulkheads and decks. When adjacent spaces are located under the galley, the deck can be reduced to A-0 class. When adjacent spaces are auxiliary machinery spaces, bulkheads and decks can also be reduced to A-0 class.

1.5 Zones to be protected from fire risk

1.5.1 Accommodation spaces and control stations

The zone containing accommodation spaces and control stations is to be generally protected from adjacent zone by A-0 class bulkheads and decks. This zone may also contain other auxiliary machinery spaces or service spaces of negligible fire risk.

1.5.2 Battery compartment

The battery space is to be protected by at least A-0 class bulkheads and decks.

1.5.3 Weapon room

The weapon room is to be protected by at least A-0 class bulkheads and decks. Alternative arrangements (either structural or operational) to prevent flame propagation into weapon room may be considered.

2 Penetration in fire-resisting divisions

2.1 Penetrations in A class divisions

2.1.1 Unless otherwise specified, where A class divisions are penetrated, such penetrations shall be tested in accordance with the Fire Test Procedure Code.

2.1.2 A ventilation duct penetrating an A class division accordingly to the provisions of [4.3] need not to be tested.

2.1.3 Where A class divisions are penetrated by electrical cables, such penetrations shall always be tested in accordance with the Fire Test Procedure Code.

2.2 Pipes penetrating A class divisions

2.2.1 Where A class divisions are penetrated by pipes, such penetrations shall be tested in accordance with the Fire Test Procedures code. However the following arrangement, if adequately justified and installed, may be dispensed with the fire test:

a) the pipe penetration is made of steel or other equivalent material having a thickness of at least 3 mm and a length of at least 200 mm (preferably divided into 100 mm on each side of the fire division)

b) the pipe penetration is suitably insulated by extension of the insulation at the same level of the division

c) the pipe is connected to the ends of the sleeve by flanges or coupling; or any clearance between pipe and sleeve is made tight by means of non combustible or other suitable material.

2.2.2 Uninsulated metallic pipes penetrating "A" class divisions are to be of a material having a melting temperature which exceeds 950°C for "A-0" class divisions.

2.2.3 Where the Society may permit the conveying of oil or combustible liquids through accommodation and service spaces, the pipes conveying combustible liquids are to be of a material approved by the Society having regard to the fire risk. The pipes conveying combustible liquids through weapon room shall be limited in number and fitted with welded connection.

3 Protection of openings in fire-resisting divisions

3.1 Doors in fire-resisting divisions

3.1.1 The fire resistance of doors shall be equivalent to that of the division in which they are fitted, this being determined in accordance with the Fire Test Procedures Code. Doors and door frames in A class divisions shall be constructed of steel.

3.1.2 Doors fitted in boundary bulkheads of machinery spaces shall be reasonably gas-tight. These doors shall normally be kept closed.

3.1.3 Fire-resisting doors shall be provided with system signalling their closed position in the control room. Kitchen doors may be exempted from this requirement as well as doors visible from control stations permanently manned.

4 Ventilation systems

4.1 Duct and dampers

4.1.1 Introduction

A summary of ventilation systems requirements is available in Pt D, Ch 3, Sec 5, [14.3].

4.1.2 Ducts material

Ventilation ducts shall be of non-combustible material. However, short ducts, not generally exceeding 5 m in length and with a free cross-sectional area not exceeding 0,03 m^2, need not be non-combustible, subject to the following conditions:

a) the ducts are made of a material which has low flame spread characteristics

b) the ducts are only used at the end of the ventilation device, and should comply with ducts penetrations requirements through A class divisions (See [4.3]).

Flexible bellows of combustible material may be used for connecting fans to the ducting. If flexible bellows of combustible material are used in other positions, they are to be kept as a minimum and preferably made of a material which has low flame spread characteristics.

4.1.3 Arrangements to be tested

The following arrangements shall be tested in accordance with the Fire Test Procedures Code:

a) fire dampers or equivalent systems, including their relevant means of operation. However, the test is not required where fire dampers having a thickness of at least 3 mm in steel, are directly joined to ventilation ducts by means of riveted or screwed flanges or by welding

b) duct penetrations through A class divisions. However, the test is not required where steel sleeves are in accordance with [4.3] and are directly joined to ventilation ducts by means of riveted or screwed flanges or by welding.

4.2 Arrangements of ducts

4.2.1 General arrangement

Fire dampers are to be fitted so that the fire can be concealed in its space or group of spaces of origin. The part of the ventilation system serving the machinery spaces is to be capable of being isolated with fire dampers from accommodation, service spaces or control stations. In the event of fire, precautions are to be taken so that the following group of spaces are always supplied with the breathing air system, except if the fire began inside:

- control stations
- accommodation spaces.

4.2.2 Ducts passing through the diesel engine room or through the galley

Ducts passing through the diesel engine room or through the galley without serving these spaces are to be constructed of steel and are to comply with one of the following requirements:

a) either automatic fire dampers or equivalent systems are fitted close to the boundaries penetrated, or

b) the ducts are constructed to A-15 standard within the diesel engine room or through the galley.

4.2.3 Galley ducts arrangement

If there is an air inlet duct serving the galley, a fire damper is to be fitted inside to protect other spaces from a fire in the galley.

Where they pass through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges shall be constructed of steel. Each exhaust duct shall be fitted with:

a) a grease trap readily removable for cleaning

b) a fire damper located in the lower end of the duct which is automatically and remotely operated

c) arrangements, operable from a position close to the entrance, outside the galley, for operating fire damper and shutting off the exhaust fans (if dedicated to the galley).

4.2.4 Ventilation of battery compartments

The part of the ventilation system serving the diesel engine room is to be capable of being isolated with fire dampers.

Ventilation outlet ducts coming from battery spaces are to be connected directly to the foul air system.

4.3 Details of duct penetrations

4.3.1

a) Where a thin plated duct passes through A class bulkheads or decks, the opening shall be lined with a steel sheet sleeve having a thickness of at least 3 mm and a total length of at least 200 mm. When passing through bulkheads, this length should be divided preferably into 100 mm on each side of the bulkhead. When passing through decks, the part of this length laid on the lower side of the decks pierced is to be minimum 150 mm.

For ducts with a free cross-sectional area exceeding 0,02 m^2, these ducts, or sleeves lining such ducts, are to be suitably insulated by extension of the insulation at the same level of the division.

Equivalent penetration protection may be provided to the satisfaction of the Society, and

b) Ducts with a free cross-sectional area exceeding 0,075 m^2 shall be fitted with fire dampers in addition to the requirements of the preceding item a).Fire dampers are not required where ducts pass through spaces surrounded by A class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they pierce.

Each fire damper shall be:

- operated manually, from both sides of the bulkhead or the deck separating two manned spaces
- easily accessible
- provided with an indicator showing whether the damper is open or closed
- capable of being closed in less than 2 minutes after fire alarm triggering.

The fire dampers may be capable of being closed manually or remotely.

Note 1: Where they are placed behind ceilings or linings, these ceilings or linings shall be provided with an inspection door on which a plate reporting the identification number of the fire damper is provided. The fire damper identification number shall also be placed on any remote controls required.

4.3.2 With reference to the requirements of [4.3.1], the following applies:

The term “free cross-sectional area” means, even in the case of a pre-insulated duct, the area calculated on the basis of the inner diameter of the duct.

SECTION 6 SUPPRESSION OF FIRE: FIRE FIGHTING

1 General

1.1 Application

1.1.1 In this Section, fire-extinguishing arrangements in different types of spaces are described in [2], [3], [4] and [5]. Details for the design of portable fire extinguishers are given in Article [6] and details for the design of fixed fire-extinguishing systems are given in Article [7].

2 Fire-extinguishing arrangements in machinery spaces

2.1 Machinery spaces arrangement

2.1.1 General

a) The arrangement of machinery spaces is to be such that safe storage and handling of flammable liquids is ensured.

b) All spaces where oil-consuming installations, settling tanks or daily service fuel tanks are located are to be easily accessible and well ventilated.

c) Where leakage of flammable liquids may occur during normal service or routine maintenance work, special arrangement is to be made to prevent these fluids from reaching other parts of the machinery where danger of ignition may arise.

d) Materials used in machinery spaces are not normally to have properties increasing the fire potential of these rooms. Neither combustible nor oil-absorbing materials are to be used as flooring, bulkhead lining, ceiling or deck in the control room, machinery spaces or rooms where oil tanks are located. Where penetration of oil products is possible, the surface of the insulation is to be impervious to oil or oil vapours.

2.2 Diesel engine room

2.2.1 Fixed fire-extinguishing systems

Diesel engine room shall be provided with one of the following fixed fire-extinguishing systems:

a) a fixed gas fire-extinguishing system complying with the provisions of [7.2]

b) a fixed pressure water-mist fire-extinguishing system complying with the provisions of [7.3].

2.2.2 Additional fire-extinguishing arrangements

a) There shall be provided a sufficient number of portable foam extinguishers or equivalent. There are at least two such extinguishers close to the access door.

b) There shall be at least one CO_2 extinguisher if any electric switchboards or section board are fitted inside compartment.

2.3 Propulsion room

2.3.1 Fixed fire-extinguishing systems

Propulsion room shall be provided with gas fire-extinguishing system for the protection of the following cabinets:

a) propulsion switchgear cabinet

b) propulsion converter cabinets.

Note 1: This electrical cabinets are to be fitted with a system of injection of gas fire-extinguishing directly inside, without opening their doors.

2.3.2 Additional fire-extinguishing arrangements

There shall be at least two portable CO_2 extinguishers or equivalent in each such space.

2.4 Auxiliary machinery spaces

2.4.1 Fixed fire-extinguishing systems

If located in an auxiliary machinery space, battery head cubicles shall be provided with fixed gas fire-extinguishing systems complying with the provisions of [7.2].

2.4.2 Additional fire-extinguishing arrangements

There shall be at least one CO_2 extinguisher in the proximity of any electric switchboard or section board.

3 Fire-extinguishing arrangements in control stations, accommodation and service spaces

3.1 Arrangement of portable fire extinguishers

3.1.1 Accommodation spaces, service spaces and control stations shall be provided with portable fire extinguishers of appropriate types and in sufficient number to the satisfaction of the Society.

The number and the type of portable fire extinguishers required for the above-mentioned spaces are to be as follows:

- in accommodation spaces: at each deck, two foam extinguishers or equivalent, located at each end of the corridor
- in the control room: one CO_2 extinguisher or equivalent

- in the proximity of any electric switchboard or section board having a power of 20 kW and upwards: at least one CO_2 extinguisher

Note 1: This electrical cabinets are to be fitted with a system of injection of gas fire-extinguishing directly inside, without opening their doors.

- in the galley: at least one CO_2 extinguisher or equivalent.

3.1.2 Portable fire extinguishers shall be located near the entrance of the protected space.

4 Fire-extinguishing arrangements in weapon room

4.1 Fixed fire-extinguishing system

4.1.1 The fire-extinguishing arrangement in weapon rooms shall be defined by the Naval Authority, considering the specificities of weapons contained in this space.

4.2 Arrangement of portable fire extinguishers

4.2.1 There shall be at least one portable CO_2 extinguisher or equivalent and one portable foam extinguisher or equivalent in the weapon room.

5 Fire-extinguishing arrangements in main battery compartments

5.1 Fixed fire-extinguishing system

5.1.1 Main battery compartments shall be provided with a fixed gas fire-extinguishing system, complying with the provisions of [7.2].

6 Portable fire extinguishers

6.1 Type and design

6.1.1 Portable fire extinguishers required in Articles [2], [3] and [4] shall comply with the requirements of [6.2].

6.2 Engineering specifications

6.2.1 Fire extinguisher

a) Safety requirements

Fire extinguishers are not permitted if they contain an extinguishing medium which, in the opinion of the Society, either by itself or under the expected conditions of use, gives off toxic gases in such quantities as to endanger persons or which is an ozone depleting substance.

b) Quantity of medium

1) The fire extinguishing capability of a fire extinguisher shall be at least equivalent to that of a 9 l fluid extinguisher.

Each carbon dioxide extinguisher is to have normally a capacity of at least 5 kg.

Note 1: However, for first intervention purposes, it is possible to use carbon dioxide extinguishers of capacity 2 kg in auxiliary machinery spaces, in the galley and in the accommodation spaces corridor.

2) Other fire extinguishers may be accepted if considered equivalent by the Society.

7 Fixed fire-extinguishing systems

7.1 Types of fixed fire-extinguishing systems

7.1.1 A fixed fire extinguishing system required in Articles [2], [4] and [5] shall comply with the requirements of this Article.

7.1.2 Where a fixed fire-extinguishing system not required by this Chapter is installed, it shall meet the relevant requirements of this Chapter.

7.1.3 Fire-extinguishing systems using Halon 1211, 1301, and 2402 and perfluorocarbons shall be prohibited.

7.1.4 In general, the Society shall not permit the use of steam as a fire-extinguishing medium in fixed fire-extinguishing systems.

7.2 Fixed gas fire-extinguishing systems

7.2.1 General

a) Fire-extinguishing medium

1) Fixed gas fire-extinguishing systems are permitted only for the protection of unoccupied spaces. Protected spaces are to be capable of being rendered gastight where a fixed gas fire-extinguishing system is used. Openings which may admit air to, or allow gas to escape from, a protected space shall be capable of being closed from outside the protected space

2) CO_2 or other gas can be used as fire-extinguishing medium. The use of a fire-extinguishing medium other than CO_2 which, in the opinion of the Society or the Naval Authority, either by itself or under the expected condition of use gives off toxic or narcotic gas in such quantities as to endanger persons is forbidden. In any case when a fixed gas fire extinguishing system is installed the provisions of this Article shall be complied with

3) Where the quantity of the fire-extinguishing medium is required to protect more than one space, the quantity of medium available need not be more than the largest quantity required for any one space so protected

4) Means shall be provided for the crew to safely check the quantity of medium in the containers

5) Containers for the storage of fire-extinguishing medium and associated pressure components shall be designed to pressure codes of practice to the satisfaction of the Society, having regard to their locations and maximum ambient temperatures expected in service.

b) Installation requirements

1) The piping for the distribution of fire-extinguishing medium shall be arranged and discharge nozzles so positioned that a uniform distribution of medium is obtained

2) Except as otherwise permitted by the Society, pressure containers required for the storage of fire-extinguishing medium, shall be located outside protected spaces. The room containing fire extinguishing medium bottles are to fitted with an efficient mechanical ventilation system

3) The storage of the fire extinguishing medium is not permitted within spaces which may contain air/flammable gas mixtures.

c) System control requirements

1) The necessary pipes for conveying fire-extinguishing medium into protected spaces shall be provided with control valves so marked as to indicate clearly the space to which the pipes are led. Suitable provision shall be made to prevent inadvertent release of the medium into the space

The pipes shall not pass through accommodation spaces and refrigerated spaces

Control valves are to be capable of local operation. The open or closed position of control valves is to be indicated

2) The means of control of any fixed gas fire-extinguishing system shall be readily accessible, simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in a protected space. At each location there shall be clear instructions relating to the operation of the system having regard to the safety of personnel

3) Automatic release of fire-extinguishing medium shall not be permitted.

7.2.2 High-pressure carbon dioxide systems - General

a) Quantity of fire extinguishing medium

1) The quantity of carbon dioxide shall be sufficient to lower the oxygen rate to 13% in the protected space

2) For the purpose of this item the volume of free carbon dioxide shall be calculated at 0,56 m^3/kg

3) The fixed piping system shall be such that 85% of the gas can be discharged into the space within 2 minutes.

b) Controls

Carbon dioxide systems shall comply with the following requirements:

- two separate controls shall be provided for releasing carbon dioxide into a protected space and to ensure the activation of the alarm. One control shall be used for opening the valve of the piping which convey the gas into the protected space and a second control shall be used to discharge the gas from its storage containers, and
- the two controls shall be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box shall be a break-glass-type enclosure conspicuously located adjacent to the box.

7.2.3 High-pressure carbon dioxide systems - Details

a) The system is to be designed for an ambient temperature range of 0°C to 55°C, as a rule.

b) Containers for the storage of the fire extinguishing medium are to be designed and tested in accordance with the relevant requirements of Pt D, Ch 3, Sec 3.

c) Piping and accessories are to generally satisfy the relevant requirements of Pt D, Ch 3, Sec 5.

d) Steel piping systems: for systems where carbon dioxide is stored at ambient temperature, the thickness of steel pipes is not to be less than the values given in Tab 1.

Slightly smaller thicknesses may be accepted provided they comply with the standards of the Naval Authority.

The thickness of threaded pipes is to be measured at the bottom of the thread.

e) Copper piping systems: for systems where carbon dioxide is stored at ambient temperature, the thickness of copper pipes is not to be less than the values given for steel pipes in Tab 1.

When copper pipes are used, the part of copper piping located inside the protected space is to be reduced to the minimum. Furthermore, pipe joints are subject to particular attention of the Society.

The thickness of threaded pipes is to be measured at the bottom of the thread.

f) Pipes are to be appropriately protected against corrosion. Steel pipes are to be, at least, zinc or paint coated, except those fitted in machinery spaces, upon acceptance of the Society.

g) After mounting onboard, and in complement to tests and inspections at the Manufacturer's workshop, as per requirements of Pt D, Ch 3, Sec 5, carbon dioxide pipes and their accessories are to undergo the following tests:

- pipe length between bottles and master valves:

  hydraulic test, at the workshop or on board, at 128 bar. When the hydraulic test is carried out at the workshop, at least test with inert gas or air, at 7 bar, is to be carried on board
- pipe length between master valves and nozzles:

  hydraulic test on board with inert gas or air at 7 bar
- the master valves are to undergo an hydraulic test at 128 bar.

Table 1 : Minimum wall thickness for steel pipes for CO_2 fire-extinguishing systems

External diameter of pipes (mm)	Minimum wall thickness, in mm	
	From bottles to distribution station	From distribution station to nozzles
10,2 - 17,2	2,6	2,1
21,3 - 26,9	3,2	2,6
30,0 - 48,3	4,0	3,2
51,0 - 60,3	4,5	3,6

7.3 Fixed water-mist fire-extinguishing system

7.3.1 Main requirements

Equivalent water-based fire-extinguishing systems for machinery spaces are to be approved by the Society accounting the guidelines annexed to IMO MSC/Circ. 1165. Water-based fire-extinguishing systems for machinery spaces approved by the Society accounting the guidelines annexed to IMO MSC/Circ.668 as revised by IMO MSC/Circ.728 may also be used until 10 June 2010.

7.3.2 Specific requirements for submarines

Paragraph 11 of IMO MSC/Circ.668 as revised by IMO MSC/Circ.728 Annex and paragraph 12 of IMO MSC/Circ. 1165 Annex is replaced by the following requirement:

- the system shall be available for immediate use and capable of continuously supplying water for at least 10 minutes in order to prevent re-ignition or fire spread within that period of time
- the average water distribution is to be at least 0,5 $l/m^3/min$
- nozzles are to be positioned in areas clear of obstacles. The minimal distance between a nozzle and its nearest obstacle is to be minimum 1meter. If both above conditions are not satisfied, additional nozzles could be required, in order to optimise the water distribution. Flow per nozzle could be lowered in these areas but, in this case, total flow of the system is to be increased.

7.4 Water pumps for water-based fire-extinguishing systems

7.4.1 Pumps required for the provision of water for fire-extinguishing systems

The sources of power and controls of pumps required by [7.3] shall be installed outside the space or spaces protected by such systems and shall be so arranged that a fire in the space or spaces protected will not put any such system out of action.

SECTION 7 SUPPRESSION OF FIRE: STRUCTURAL INTEGRITY

1 Material of hull, structural bulkheads and decks

1.1 General

1.1.1 The hull, structural bulkheads and decks shall be constructed of steel or other equivalent material. For the purpose of applying the definition of steel or other equivalent material as given in Ch 1, Sec 1, [2.16], the "applicable fire exposure" shall be according to the integrity and insulation standards given in Ch 1, Sec 5.

2 Machinery spaces

2.1 Floor plating

2.1.1 The floor plating of normal passageways in the diesel engine room and in the propulsion room are to be made of steel.

Part E

Fire Safety and Human Occupancy

Chapter 2

ATMOSPHERE CONTROL

SECTION 1 GAS MONITORING

SECTION 2 OXYGEN PRODUCTION

SECTION 3 DANGEROUS GASES ELIMINATION

SECTION 4 EMERGENCY BREATHING AIR SUPPLY

SECTION 1 GAS MONITORING

1 General

1.1 Principle

1.1.1 Generally speaking, devices concerned by the present Chapter are to ensure to the personnel the services required for safety during the maximum duration of a normal mission to which is added the specified survival period.

1.2 Definitions

1.2.1 Normal mission

The normal mission is the standard mission used for designing the submarine.

1.2.2 Refuge compartment

A refuge compartment is a space intended for use during the survival period in the case where pressure hull is flooded. For specific requirements about these compartments, see also Pt F, Ch 1, Sec 6.

2 Breathing atmosphere control

2.1 General

2.1.1 The breathing atmosphere is to be efficiently ventilated, in order to obtain a homogeneous atmosphere.

2.1.2 The composition, pressure and temperature of the breathing atmosphere, especially where dangerous gases are likely to be emitted are to be the subject of the utmost attention.

2.1.3 The materials used in the inner spaces and likely to be in contact with the atmosphere, such as coatings, adhesives and lubricants should be selected in order not to give off toxic, irritant or disagreeable gases or which may become so after passing through the regeneration system.

2.2 Monitoring devices

2.2.1 Environmental conditions

It must be possible to check at least the pressure and the temperature of the compartments at will. The use of mercury pressure gauges and thermometers is not permitted.

2.2.2 Gas analysis

Suitable devIces are to be provided to allow the breathing atmosphere composition on board to be checked, that is:

a) an oxygen monitoring device

b) a carbon dioxide monitoring device

c) a carbon monoxide monitoring device

d) an hydrogen monitoring device.

2.2.3 Calibration

A calibration system of the checking devices by means of known and stable mixtures, or a device of equivalent reliability is to be provided for.

2.2.4 Operation time

Operation of the monitoring devices is to be ensured for the whole duration of the mission, and during survival period, if possible. If not, test tubes can be used for the duration of the survival period.

2.2.5 Alarm

An alarm system is to be provided to come into operation automatically in case of failure of the automatic control, if any, or where the permissible limits are reached whether these limits concern the composition, or the temperature of the breathing mixture.

Thresholds are to be fixed as per STANAG or internationally recognized standards requested by the Naval Authority, to the following parameters:

a) minimum oxygen partial pressure

b) maximum oxygen partial pressure

c) maximum carbon dioxide partial pressure

d) maximum carbon monoxide rate

e) maximum hydrogen rate: 2% or less.

2.2.6 Hydrogen monitoring: specific requirements

In addition to the hydrogen monitoring on board, a hydrogen content is to be monitored continuously in the battery spaces. The position of th

e measuring points is to be fixed considering the local conditions.

The hydrogen measuring system is to be supplied by an uninterrupted power supply.

SECTION 2 OXYGEN PRODUCTION

1 Oxygen supply system

1.1 Definitions

1.1.1 Normal mission

The normal mission is the standard mission used for designing the submarine.

1.1.2 Refuge compartment

A refuge compartment is a space intended for use during the survival period in the case where pressure hull is flooded. For specific requirements about these compartments, see also Pt F, Ch 1, Sec 6.

1.1.3 Standard temperature and pressure

Standard temperature is 0°C and standard pressure is 1013 mbar.

1.2 Main requirements

1.2.1 General

An oxygen supply system is to be installed to replace the oxygen consumed from the atmosphere in the submarine. This oxygen supply system can be made either with oxygen containers, as described in Article [2], or with oxygen candles, as described in Article [3]. The use of other types of oxygen supply systems is to be submitted for review to the Society on a case-by-case basis and subject to the approval of the Naval Authority.

1.2.2 Operation time

Oxygen is to be provided for the maximum duration of a normal mission to which is added the specified survival period.

1.2.3 Design

During the normal mission, the oxygen supply system is to be designed by calculating a minimum consumption rate at 20°C, on the basis of a reference consumption rate of at least value mentioned in a reference standard.

1.2.4 Oxygen partial pressure range

In normal conditions, the oxygen partial pressure is to be maintained, as far as practicable, between pressure values mentioned in a reference standard.

2 Oxygen containers

2.1 Main requirements

2.1.1 General

When the oxygen supply system uses oxygen containers as the main source of oxygen supply, oxygen containers are to comply with this Article.

2.1.2 Containers arrangement

The oxygen may be stored in bottles or containers either as a compressed gas or in the liquid state.

2.1.3 Liquid oxygen

Liquid oxygen is to be used with caution. In particular, heat insulated tanks are to be provided to collect accidental leakage of liquid oxygen and to avoid thermal stresses on the pressure resistant structure.

2.1.4 Container valves and drain cocks

Each compressed gas container is to be protected by a shut-off valve and a drain cock. Means are to be provided in order to prevent accidental release of this valve.

2.1.5 Piping

Piping and accessories are to generally satisfy the relevant requirements of Pt D, Ch 3, Sec 5.

2.1.6 Containers location

Oxygen containers are to be located, if possible, outside the pressure hull.

2.1.7 Oxygen metering devices

Manually operated oxygen metering devices are to be equipped with a container shut-off valve and a device for controlling the flow rate. A flow-rate indicator has to be fitted. Metering devices are to be equipped with a manually operated bypass.

3 Oxygen candles

3.1 Main requirements

3.1.1 When the oxygen supply system uses oxygen candles as the main source of oxygen supply, oxygen candles are to comply with this Article.

3.1.2 Working of oxygen candles is based on the decomposition of a chlorate. The chemical reaction is exothermic with water production. The necessary provisions are to be taken to dissipate the heat produced by the reaction.

SECTION 3 DANGEROUS GASES ELIMINATION

1 General

1.1 Definitions

1.1.1 Normal mission

The normal mission is the standard mission used for designing the submarine.

1.1.2 Refuge compartment

A refuge compartment is a space intended for use during the survival period in the case where pressure hull is flooded. For specific requirements about these compartments, see also Pt F, Ch 1, Sec 6.

1.1.3 Standard temperature and pressure

Standard temperature is 0°C and standard pressure is 1013 mbar.

2 Carbon dioxide elimination

2.1 Main requirements

2.1.1 General

Carbon dioxide elimination is to be performed by means of chemical products, which can be:

a) for carbon dioxide absorption processes: soda lime granules, lithium hydroxide or barium lime, for example. Attention is to be paid to the decrease of efficiency of these absorbents in dry air

b) for carbon dioxide adsorption processes: monoethanolamine, diethanolamine or zeolites (molecular sieves), for example. These processes necessitate particular precautions and means to store or to reject the captured carbon dioxide. Carbon dioxide adsorption units are to be submitted for review to the Society on a case-by-case basis and subject to the approval of the Naval Authority.

2.1.2 Operation time

Chemical products used for carbon dioxide elimination are to be supplied for use during the maximum duration of a normal mission to which is added the specified survival duration period.

2.1.3 Design

During the normal mission, the carbon dioxide elimination system is to be designed by calculating a minimum production rate at 20°C, on the basis of a reference production rate of at least 20l/h per person at standard temperature and standard pressure.

In a work enclosure, a higher production rate may be determined by actual experience in terms of the nature of the work to be performed by the personnel.

2.1.4 Carbon dioxide partial pressure range

In normal conditions, the carbon dioxide partial pressure is to be maintained, as far as practicable, below 0,01 bar.

2.1.5 Dust filter

The carbon dioxide elimination unit is to be fitted with a dust filter of non-combustible material.

3 Elimination of other dangerous gases

3.1 Main requirements

3.1.1 General

Dangerous gases, such as toxic, flammable, corrosive or biologically active gases may be found in small concentrations in the breathing atmosphere.

3.1.2 All necessary provisions should be taken to reduce dangerous emissions from their origins to a minimum when selecting the materials, installations and work procedures. In particular instruments containing mercury are to be forbidden inside manned enclosures.

3.1.3 Dangerous emissions are removed by absorption, adsorption or oxidation. The removal products used may be, for example: activated carbon, soda lime or other alkaline compounds.

Carbon monoxide and hydrogen may be removed by catalytic burners. Low temperature catalytic burners are to be preferably used in order to avoid the possible formation of toxic derivatives due to decomposition of certain gases.

SECTION 4 EMERGENCY BREATHING AIR SUPPLY

1 Design

1.1 Main requirements

1.1.1 Air capacity

The emergency breathing air system is to be supplied by compressed air system (see Pt D, Ch 3, Sec 5, [11.3.2]). Emergency breathing air systems/appliances, are to be designed to ensure that in an emergency all persons on board have sufficient breathing air while the submarine is rising, or being brought, to the surface, subject to a duration mentioned in safety assessment. This duration should not be less than 1 hour, except if a relevant analysis is developed in safety assessment. Reference consumption rate shall be defined as per Stanag or internationally recognized standards requested by the Naval Authority.

1.1.2 Redundancy

The emergency breathing air system should comprise at least one line delivering air in all manned spaces into the submarine. The breathing line is fed by at least two pressure reducing units supplied through master valves by separate air groups located in two separate compartments. Section valves are to be so arranged as to allow a partial using of the emergency breathing air system in case of fire.

1.1.3 Set in operation

The emergency breathing air system is operated by opening one of the master valves. Each master valve is to be able to be easily opened. Manometers are to be fitted where master valve is operated.

1.1.4 Emergency breathing air appliances

Breathing air intakes and associated face masks are to be provided in sufficient quantity in different locations, so as to have at least a minimum number of them in each space corresponding to the maximal number of persons normally located in it. The total number of breathing air intakes and associated masks is to be superior to the number of persons on board. They are to be distributed in the following way:

- in each watch station, there should be a sufficient quantity of them for the number of persons being on watch
- near each berth, there should be one air intake and one mask
- other emergency breathing air intakes are to be distributed throughout the submarine, the maximum spacing between two adjacent breathing air intakes being 5 m.

Part E

Fire Safety and Human Occupancy

Chapter 3

EMERGENCY AND RESCUE INSTALLATIONS

SECTION 1 FLOODING FIGHTING

SECTION 2 EMERGENCY BLOWING

SECTION 3 EMERGENCY LIGHTENING

SECTION 4 RESCUE ARRANGEMENTS

SECTION 1 FLOODING FIGHTING

1 General

1.1 Application

1.1.1 This Section deals with the following items:

- sea water leakage detection
- means in order to recover pressure hull integrity.

1.2 Principle

1.2.1 Most common causes of ingress of seawater into a submarine are leakages from sea water pipes. Considering the flow of sea water which can be very important with external pressure, these leakages shall be rapidly detected before that volume of additional water prevents the submarine from surfacing. The submarine shall be equipped of sea water leakage detection system and of a fast and efficient closing of safety shut-off valves.

2 Sea water leakage detection

2.1 Design

2.1.1 Principle

Flooding is detected by the means of bilge level detectors or flow detectors inside sea water pipes.

2.1.2 Level detectors

Detectors and associated wiring and systems shall be able to work in immersed conditions.

They shall be able to work within trim and list conditions of submarine.

They must be efficiently protected against shocks and/or any intrusion of external objects that may disturb normal working of detector.

Detectors shall be of a type approved by the Society.

2.1.3 Flow detectors

Their aim is to trigger automatic closing of relevant safety shut-off valves. Reliability of these systems shall be proved through analysis. Such detectors shall be of a type approved by the Society.

2.2 Arrangement

2.2.1 Location of detectors

Compartments containing piping likely to withstand immersion pressure shall be fitted with leakage detectors.

2.2.2 Number and location of level detectors inside compartment

Sufficient number of detectors shall be implemented on adequate locations inside compartment in order to be able to detect sea water leakage independently from trim and list.

2.3 Control and monitoring

2.3.1 Information location

Detectors shall send information to a centralized system. Information shall be available where:

- shut-off safety valves remote means of closing are located
- emergency lightening and blowing controls are located
- steering remote controls are located
- engine order telegraph is located.

2.3.2 Type of signals delivered by level detectors

Level detectors may be common to bilge and flooding systems. In that case they deliver two types of signals:

- default level: indicates there is presence of water in compartment and that bilge pump starting is needed
- incident level: indicates water level reached in compartment involves that flooding fighting actions are needed (see safety analysis).

3 Safety shut-off valve closing

3.1

3.1.1 Hydraulic or compressed air fluid shall be used for power actuators of safety shut-off valves.See Pt D, Ch 3, Sec 5, [6.2.3] and Pt D, Ch 3, Sec 5, [6.4.2].

SECTION 2 EMERGENCY BLOWING

1 General

1.1 Definition

1.1.1 Emergency distributor

This device enables the passage of air contained in air receivers used for emergency blowing to ballast.

1.1.2 Emergency blowing valve

Non return valve enabling inlet of compressed air into ballast.

1.1.3 Emergency air bottles

Storage receivers for compressed air dedicated to emergency blowing.

1.2 Application

1.2.1 This Section deals with:

- air supply dedicated to emergency blowing
- piping systems involved in emergency blowing
- remote control system of emergency blowing.

1.3 Peculiar point

1.3.1 Whenever use of emergency blowing is forbidden on some range of immersion values, this information must be communicated to Naval Authority, including reactions to be undertaken in case of flooding while inside this range of immersion.

2 Design

2.1 Emergency air bottles

2.1.1 Emergency air bottles are to be built with requirements mentioned in Pt D, Ch 3, Sec 3.

2.2 Emergency distributors

2.2.1 Emergency distributors shall be type approved. See also Pt A, Ch 1, Sec 2, [3.3].

Compressed air shall be used for remote control of emergency blowing device.

3 Arrangement

3.1 Piping

3.1.1 Piping intended for emergency blowing are not to be used for other purpose.

3.1.2 Length of piping between air receivers and emergency blowing valve shall be as small as possible.

3.1.3 No isolating device is to be fitted between emergency air bottles and emergency distributor.

3.1.4 No air flexible and no air regulator are allowed between emergency air bottles and ballasts.

3.1.5 A control device shall be fitted in order to check that water has not accumulated upstream of emergency blowing valve.

3.2 Air capacity

3.2.1 Emergency bottles for emergency blowing shall not be used for other purpose. Any alternative design will have to be submitted to the satisfaction of the Society.

3.3 Effect of emergency blowing

3.3.1 Installation must be able to deliver air in ballast in sufficient quantity in order to provide calculated lightening for the submarine (see justification file of immersion versus speed diagram in Pt A, Ch 1, App 2) when submarine is positioned till accidental depth.

4 Control and monitoring

4.1 Remote control system

4.1.1 Energy source

Power for this installation shall be supplied by compressed air. In case of loss of this air source, a dedicated air storage receiver must be able to give enough energy to obtain one opening and one closing of all emergency blowing valves.

4.1.2 Required functions

Remote control must enable:

- blowing and cut-off air blowing in ballasts
- use of one half capacity or of the whole capacity of air blowing.

4.2 Monitoring

4.2.1 Pressure information and low level pressure signal on air receivers shall be implemented and available in control room. All air receivers involved in emergency air blowing are concerned, including remote air control receiver

4.2.2 The control of emergency blowing shall be located in control room.

SECTION 3 EMERGENCY LIGHTENING

1 General

1.1 Introduction

1.1.1 Emergency lightening through droppable weights may be used as an alternative of emergency blowing. This Section deals only with devices used in order to drop out safety weights.

2 Design

2.1 Piping and actuators

2.1.1 If remote control is needed, emergency weights dropping device shall generally use compressed air as source of energy. Any alternative design shall be submitted to the Society.

2.1.2 No flexible is allowed between emergency air bottles and devices used in order to drop out safety weight.

2.1.3 Piping design is to comply with requirements mentioned in Pt D, Ch 3, Sec 5, [11] (compressed air piping).

2.1.4 Whenever actuators are used, their design shall satisfy requirements mentioned in Pt D, Ch 3, Sec 3 (pressurized equipments).

2.2 Reliability

2.2.1 Dropping system shall prove good reliability on following functions:

- keeping the weights in their storage places in operational conditions of submarine
- dropping out weights till exceptional environment limits of platform attitude.

3 Arrangement

3.1 Droppable weight system

3.1.1 Droppable weight system arrangement shall fulfil following requirements:

- dropping out weights shall not induce excessive trim variation
- control system shall be easily reachable in control room
- dropping device must remain available even in case of main source of energy loss through a dedicated energy source.

SECTION 4 RESCUE ARRANGEMENTS

1 General

1.1 Introduction

1.1.1 Rescue arrangements are subject to the approval of the Naval Authority in each case. However, the rescue equipment, as described hereafter, is recommended. Alternatively, equivalent devices can be used.

1.2 Definitions

1.2.1 Dead man alarm

The dead man alarm system will give an alarm after a predefined time after which it has to be manually reset. The predefined time is determined by the Naval Authority.

1.2.2 Refuge compartment

A refuge compartment is a space intended to be used during the survival period when pressure hull is flooded. For specific requirements about these compartments, see also Pt F, Ch 1, Sec 6.

1.2.3 Survival period

The minimum survival period used for design of submarine and associated consumable goods. Duration of this period is specified by the Naval Authority.

2 Alert and localization

2.1 Description

2.1.1 The alert and localization are ensured by:

a) the release of a drifting and floating emitting buoy

b) the tripping of ultrasonic transducer (pinger) fixed to the submarine

c) pyrotechnics.

2.2 Drifting buoy

2.2.1 General

The drifting buoy used for localization may be fitted with a recorder box.

2.2.2 Composition

The drifting buoy is composed of 4 sub-assemblies:

a) a radio set emitting on the maritime distress frequency and on the SARSAT/COSPAS

b) a visual identification set: the buoy is orange-coloured. Information related to submarine are inscribed on float. In addition, the buoy is fitted with a luminous signalling

c) an electric supply set providing the energy required for buoy autonomy

d) a release set.

2.2.3 Buoy location

The buoy is to be located in a position not hindering its release.

2.2.4 Release system

Release is to be manually and automatically controlled. Automatic release should activate in case of flooding, or dead man alarm activation, or over-submersion. Corresponding activation limits for flooding and over-submersion are determined by the Naval Authority. Energy sources and control lines of release system should be duplicated.

2.3 Ultrasonic beacon

2.3.1 General

The ultrasonic distress beacon is fixed to the submarine hull. In order to aid the rescue vehicle to a position whereby it can achieve autonomous final homing, ultrasonic beacons should be capable of operating at common rescue vehicle response frequencies. The frequency is fixed by the Naval Authority.

2.3.2 This beacon should comply with the following requirements:

a) to have an acoustic emitting sub-assembly comprising a location indicating emitter and an emitter for guiding collective survival crafts

b) to be designed for self contained battery operation.

2.3.3 Control

The beacon should be activated automatically in the event of power failure or in the event of buoy release. It also should have a manual switch ON/OFF from inside the submarine, in each refuge compartment.

3 Survival

3.1 General

3.1.1 Principle

The survival devices located in each refuge compartment, if any, or in the submarine are:

a) devices for the atmosphere regeneration

b) the ventilation from the outside

c) food emergency stock, fresh water and garbage bags

d) medical supplies

e) emergency lighting

f) means of communication with rescue teams.

3.2 Atmosphere regeneration

3.2.1 Atmosphere regeneration devices are to comply with the applicable requirements of Ch 2, Sec 2 and Ch 2, Sec 3.

3.2.2 Oxygen production

a) Each refuge compartment, if any, or the whole submarine is to contain the necessary quantity of oxygen supply for use during the survival period, and

b) During the survival period, the reference consumption rate does not need to be more to 21,5l/h at Standard Temperature and Pressure, and

c) During the survival period, the oxygen partial pressure is to be maintained above 0,14 bar.

d) If the main and emergency sources are made with oxygen containers, the oxygen is to be stored in at least two separate units of bottles. In this case, each unit of oxygen bottles is to be connected to the inside of the vessel by a separate line.

e) When the oxygen supply system uses oxygen candles as the emergency of oxygen supply, oxygen candles are to comply with Ch 2, Sec 2, [3].

3.2.3 Dangerous gases elimination

a) Each refuge compartment, if any, or the whole submarine is to contain the necessary quantity of chemical products for carbon dioxide elimination during the survival period, and

b) During the survival period, the reference production rate can be lowered to limit value as described in a tandard accepted by the Naval Authority, and

c) During the survival period, the carbon dioxide partial pressures to be maintained, as far as practicable, below 0,03 bar.

3.3 Ventilation from the outside

3.3.1 The ventilation from the outside is performed by the inlet of fresh air passing through two loading columns (one for fresh air and the other one for foul air) in each refuge compartment. The implementation of this ventilation is to be possible from inside the submarine as well as from outside.

3.4 Food emergency stock

3.4.1 The food emergency stock and the fresh water supply is to be sufficient to the crew for the survival period duration.

3.5 Medical supplies

3.5.1 Medical supplies located in each refuge compartment should contain:

a) materials for initial management of fractures

b) materials for burn management

c) materials for management of lacerations and haemorrhage

d) miscellaneous stores, such as: analgesic medication, nasopharyngeal and/or oropharyngeal airways, eye-care materials

e) survival blankets.

3.6 Means of communication

3.6.1 Means of communication with rescue teams can be:

a) an emergency underwater telephone, and

b) a hammer.

4 Escape or rescue

4.1 General

4.1.1 The evacuation of the submarine can be ensured by the following facilities:

a) escape facilities, when the crew is able to evacuate by itself

b) rescue facilities, when an external appliance is necessary.

4.2 Escape

4.2.1 Escape trunk

When an escape trunk is requested by the Naval Authority, the scantling of the escape trunk structure is to be determined for 20 bar or the accidental diving depth pressure, if lower than 20 bar. Different design pressures may be considered, if explicitly required by the Naval Authority.

4.2.2 Escape facilities

Different types of escape facilities may be used in case of emergency:

a) Rush escape: at limited depth (30 m) in a flooded submarine, the crew is evacuating with a life jacket, after internal and external pressures have been balanced

b) Free escape: the crew members are equipped with survival suits as well as with the relevant inflation system for this equipment, thus allowing their escape from the trunk, after escape trunk pressurization (see Pt D, Ch 3, Sec 5, [11] for compressed air system design). They also are equipped with air pressure reducers in order to reduce the suits inflation air while crew escape is being performed through the trunk

c) Other facilities.

4.3 Rescue

4.3.1 The lifesaving using external facilities is made possible using a landing platform, directly accessible from the refuge compartment. The landing platform is designed for receiving a deep submergence rescue vehicle or an emergency chamber, to the satisfaction of the Naval Authority.

RULES FOR THE CLASSIFICATION OF NAVAL SUBMARINES

Part F
Additional Class Notations

Chapter **1**

CHAPTER 1 ADDITIONAL CLASS NOTATIONS

September 2016

Part F
Additional Class Notations

Chapter 1
ADDITIONAL CLASS NOTATIONS

SECTION 1 REF-STORE NOTATION

SECTION 2 HSE NOTATION

SECTION 3 AIP NOTATION

SECTION 4 COLLRES NOTATION

SECTION 5 ANCHORING NOTATION

SECTION 6 REFUGE COMPARTMENT

SECTION 1 REF-STORE NOTATION

1 General

1.1 Application

1.1.1 The additional class notation **REF-STORE** is assigned, to submarines with refrigerating installations related to preservation of ship's domestic supplies, complying with the requirement of this Chapter.

1.1.2 The requirements of this Chapter apply to refrigerating installations on ships. These requirements are specific to permanently installed refrigerating installations and associated arrangements and are to be considered additional to those specified in Pt D, Ch 3, Sec 4, which are mandatory for all ships with refrigerating installations.

1.2 Definitions

1.2.1 Direct cooling system

Direct cooling system is the system by which the refrigeration is obtained by direct expansion of the refrigerant in coils fitted on the walls and ceilings of the refrigerated chambers.

1.2.2 Indirect cooling system

Indirect cooling system is the system by which the refrigeration is obtained by brine or other secondary refrigerant, which is refrigerated by a primary refrigerant, circulated through pipe grids or coils fitted on the walls and ceilings of the refrigerated chambers.

1.2.3 Refrigerant

Refrigerant is a cooling medium which is used to transmit and maintain the cool in the refrigerated chamber.

1.2.4 Brine

Brine is a refrigerant constituted by a solution of industrial salts, which is normally used to cool the chambers in the indirect cooling systems, as secondary refrigerant. In general, in this Chapter, the word brine is also used to cover other types of secondary refrigerants, as for instance refrigerants based on glycol.

1.2.5 Refrigerating unit

A refrigerating unit includes one or more compressors driven by one or more prime movers, one condenser and all the associated ancillary equipment necessary to form an independent gas-liquid system capable of cooling refrigerated chambers.

When the installation includes a secondary refrigerant (brine), the refrigerating unit is also to include a brine cooler (evaporator) and a pump.

1.2.6 Refrigerated chamber

A Chamber may be a submarine's store space or any other ship service space for preservation or de-freezing of ship's domestic victuals.

2 Design criteria

2.1 Reference conditions

2.1.1 Design arrangements and temperature

The design arrangements of refrigerated and conditioned spaces for transport, preservation, de-freezing, processing, distribution of victuals, including incompatibility victuals preservation as well as appropriate space temperature to stowed victuals, are to comply with hygienic-healthful requirement of Naval Authority.

The refrigerating plants are to be designed according to temperatures requested by the Naval Authority and in accordance with the Administration requirements.

2.1.2 Environmental conditions

Unless otherwise indicated in the ship specification, the following environmental conditions are to be considered for the heat transfer and balance calculations and for the running rate of the refrigerating machinery as mentioned in normal conditions described in Pt B, Ch 1, Sec 3, [3] and Pt B, Ch 1, Sec 3, [4].

2.1.3 Operating conditions

The refrigerating plant inclusive of all machinery, equipment and accessories is to operate satisfactorily under the conditions indicated Pt B, Ch 1, Sec 3.

3 Documentation

3.1 Refrigerating installations

3.1.1 Plans to be submitted

The plans listed in Tab 1 are to be submitted as applicable.

The listed plans are to be constructional plans complete with all dimensions and are to contain full indication of types of materials employed.

Plans of equipment which are type approved by the Society need not be submitted, provided the types and model numbers are made available.

3.1.2 Calculations to be submitted

The calculations listed in Tab 2 are to be carried out in accordance with criteria agreed with the Society and are to be submitted.

Table 1 : Documents to be submitted

No.	A/I	Document
1	I	Detailed specification of the plant (refrigerating machinery and insulation) including the reference design and ambient conditions
2	I	General arrangement of refrigerated spaces including: • the intended purpose of spaces adjacent to refrigerated spaces • the arrangement of air ducts passing through refrigerated spaces • the arrangement of steelwork located in refrigerated spaces or in insulated walls • the arrangement of the draining system • the individual volume and the total volume of the refrigerated spaces
3	A	Drawings showing the thickness and methods of fastening of insulation on all surfaces in refrigerated spaces, including: • insulation material specification • hatch covers • doors • steel framing (pillars, girders, deck beams) • bulkhead penetrations • etc.
4	A	Cooling appliances in refrigerated spaces (coil grids, air coolers with air ducts and fans, etc.)
5	I	Characteristic curves of fans (capacity, pressure, power consumption)
6	A	Distribution of the thermometers and description of remote thermometer installation, if any, including: • detailed description of the apparatus with indication of the method and instruments adopted, measuring range, degree of accuracy and data regarding the influence of temperature variations on connection cables • electrical diagram of apparatus, with indication of power sources installed, characteristics of connection cables and all data concerning circuit resistance • drawings of sensing elements and their protective coverings and indicators, with specification of type of connections used
7	A	General arrangement and functional drawings of piping (refrigerant system, brine system if any, sea water system, defrosting system, etc.)
8	I	Characteristic curves of circulating pumps for refrigerant or brine (capacity, pressure, power consumption, etc.)
9	I	General arrangement of refrigerating machinery spaces (main data regarding prime movers for compressors and pumps, including source of power, are to be included in this drawing)
10	A	Electrical wiring diagram
11	A	Compressor main drawings (sections and crankshaft or rotors) with characteristic curves giving the refrigerating capacity
12	A	Drawings of main items of refrigerant system and pressure vessels, such as condensers, receivers, oil separators, evaporators, gas containers, etc.
13	A	Remote control, monitoring and alarm system (if any)
14	I	Operation manual for the refrigerating plant and for refrigerated containers, as applicable
Note 1: A = for Approval, I = for Information.		

Table 2 : Calculations to be submitted

No.	A/I	Item
1	I	Detailed calculation of the heat balance of the plant. The calculation is to take into account the minimum internal temperatures for which the classification is requested and the most unfavourable foreseen ambient conditions
Note 1: I = for Information.		

4 General technical requirements

4.1 Refrigeration of chambers

4.1.1 Refrigerating systems

Refrigeration of the chambers may be achieved by one of the following systems:

- direct cooling system
- air cooling system.

4.1.2 Cold distribution

a) The chambers may be refrigerated either by means of grids distributed on their walls or by means of air circulation on air coolers.

b) Grids and/or air coolers may be supplied either by brine or by a direct expansion system depending on the type of refrigerating system.

4.2 Refrigerating unit

4.2.1 Availability

The total refrigerating capacity of the plant is to be such as, in the most unfavourable conditions of external temperatures, it is possible to maintain, in the insulated spaces loaded with refrigerated goods, the temperature(s) for which the plant has been designed, with all refrigerating units, except one, working 24 h a day, if necessary.

4.3 Defrosting

4.3.1 Means are to be provided for defrosting air cooler coils, even when the refrigerated chambers are loaded to their maximum. Air coolers are to be fitted with trays and gutterways for gathering condensed water.

4.3.2 Arrangements are to be made to drain away the condensate even when the refrigerated chambers are loaded to their maximum. See [5.8] for specific requirements.

4.4 Prime movers and sources of power

4.4.1 Number of power sources

The motive power for each refrigerating unit is to be provided by at least two distinct sources. Each source is to be capable of ensuring the service of the plant under the conditions stated in [2.1.1], [2.1.2] and [2.1.3], without interfering with other essential services of the ship.

4.4.2 Electric motors

Where the prime movers of refrigerating units are electric motors, the electrical power is to be provided by at least two distinct generating sets.

4.5 Pumps

4.5.1 Minimum number of condenser pumps

a) At least one standby condenser circulating pump is to be provided; this pump is to be ready for use and its capacity is not to be less than that of the largest pump that it may be necessary to replace.

b) One of the condenser circulating pumps may be one of the ship's auxiliary pumps, provided its capacity is sufficient to serve the refrigerating plant working at maximum power without interfering with essential services of the ship.

4.6 Sea connections

4.6.1 Number and location of sea connections

a) Where an intermediate cooling medium is used, at least one standby brine circulating pump is to be provided; this pump is to be ready for use and its capacity is not to be less than that of the largest pump that it may be necessary to replace.

b) The same provision applies to any other type of plants in which the circulation of refrigerant is ensured by pumps.

4.6.2 Connections to other plants

Where the circulating pump(s) of the refrigerating plant is/are connected to the same circuit as other pumps, precautions are to be taken in the design and arrangement of piping so that the working of one pump does not interfere with another.

4.7 Refrigerating unit spaces

4.7.1 Arrangement

Refrigerating machinery spaces are to be provided with efficient means of ventilation and drainage and, unless otherwise allowed by the Society, are to be separated from the refrigerated spaces by means of gas-tight bulkheads.

Ample space is to be provided as practicable around the refrigerating machinery to permit easy access for routine maintenance and to facilitate overhauls, particularly in the case of condensers and evaporators.

4.7.2 Dangerous refrigerants in machinery spaces

Use of dangerous refrigerants in machinery spaces may be permitted in accordance with Pt D, Ch 3, Sec 6, [2.2.1].

5 Refrigerated chambers

5.1 Construction of refrigerated chambers

5.1.1 Bulkheads surrounding refrigerated chambers

a) Generally, the bulkheads of refrigerated chambers are to be of metallic construction; however, the bulkheads between two refrigerated spaces intended to contain goods of the same nature or having no contaminating effect need not be metallic.

b) The bulkheads are to be gas-tight.

c) Steels intended to be used for the construction of refrigerated chambers will be specially considered by Society.

5.1.2 Prefabricated chambers

Prefabricated chambers are to be of a robust construction, capable of withstanding the usual movements of a sea going vessel e.g. vibration, inclination, acceleration, etc.

They are to be fitted with suitable pressure equalising devices; these devices are to be so designed to allow the passage of air in either direction and remain closed in the absence of pressure differential.

The inner and outer surfaces of the prefabricated panels are to be covered with a suitable lining.

5.1.3 Closing devices

a) The closing devices of the accesses to refrigerated chambers, such as doors, hatch covers and plugs for loading or surveying are to be as far as possible gas-tight.

b) The ventilators of refrigerated chambers, if any, are to be fitted with gas-tight closing devices.

5.2 Penetrations

5.2.1 Penetration of pipes and ducts

Penetrations of pipes through watertight, gas-tight or fire-resistant decks and bulkheads are to be achieved by fitting glands suitable for maintaining the tightness and fire-resisting characteristics of the pierced structure.

5.2.2 Penetration of electrical cables

Where electrical wiring passes through refrigerated chambers, the relevant requirements of Pt D, Ch 4, Sec 2 are to be complied with.

5.3 Access to refrigerated spaces

5.3.1 Access doors to refrigerated chambers are to be provided with means of opening from inside even where they have been shut from outside.

5.3.2 A calling mean is to be installed inside the refrigerated chambers, in an accessible place on the lower part of one of the walls.

5.4 Insulation of refrigerated chambers

5.4.1 The insulation of refrigerated chambers shall comply with the following requirements:

a) The insulating material is to be non-hygroscopic. The insulating boards are to have satisfactory mechanical strength. Insulating materials and binders, if any, are to be odourless and so selected as not to absorb any of the odours of the goods contained in refrigerated chambers. The materials used for linings are to comply with the same provisions

b) Polyurethane and other plastic foams used for insulation are to be of a self-extinguishing type according to a standard acceptable by the Society. In general, these foams are not to be used without a suitable protective coating

c) The insulation together with its coating is normally to have low flame spread properties according to an accepted standard

d) Plastic foams of a self-extinguishing type, suitably lined, may also be used for insulation of piping and air ducts

e) When it is proposed to use foam prepared in situ, the detail of the process is to be submitted for examination before the beginning of the work

f) Prefabricated panels are to be of a design such that, when erected, the continuity of the insulation is ensured.

Possible gaps are to be filled with insulation material.

5.5 Protection of insulation

5.5.1 Insulation extension

The insulation and the lining are to be carefully protected from all damage likely to be caused by the goods contained in the chamber or by their handling.

5.5.2 Insulation strength

The insulation lining and the air screens with their supports are to be of sufficient strength to withstand the loads due to the goods liable to be carried in the refrigerated chambers.

Insulation linings are to be constructed and fitted so that they are airtight and provide an effective vapour barrier. The means of joining prefabricated panels are to have sufficient mechanical strength to maintain a vapour barrier on the inner and outer faces. All joints are to be sealed with a suitable gasket.

5.5.3 Removable panels

a) A sufficient number of removable panels are to be provided in the insulation, where necessary, to allow inspection of the bilges, bilge suctions, structural elements, vent and sounding pipes of tanks and other structures and arrangements covered by the insulation.

b) Where the insulation is covered with a protective lining, certain panels of this lining are to be provided with a suitable number of inspection openings fitted with watertight means of closing.

5.6 Miscellaneous requirements

5.6.1 Refrigerated chambers adjacent to oil or fuel tanks

a) An air space of at least 50 mm is to be provided between the top of fuel and lubricating oil tanks and the insulation, so designed as to allow leaks to drain to the bilges. Such air space may be omitted provided multiple sheaths of an odourless oil-resisting material are applied to the upper surface of tank tops. The total required thickness of sheathing depends on the tank construction, on the composition used and on the method of application.

b) In general, the sides of fuel and lubricating oil tanks are to be separated from refrigerated spaces by means of cofferdams. The cofferdams are to be vented, and air vents outlets are to be fitted with wire gauze which is easily removable for cleaning or renewal. The cofferdams may be omitted provided that multiple sheaths of an odourless oil-resisting material are applied on the tank side surface facing the refrigerated chambers. The total required thickness of this sheathing depends on the composition used and on the method of application.

5.6.2 Refrigerated chambers adjacent to high temperature spaces

The insulation of the walls to any space where an excessive temperature may arise, by accident or otherwise, is to be made of mineral wool or any equivalent material; wood chips, if any, are to be fireproof and separated from the plates on which they are fitted by means of insulating sheets.

5.6.3 Wooden structures

Wooden beams and stiffeners are to be insulated and strips of suitable insulating material are to be fitted between them and the metallic structures.

5.6.4 Metal fittings

All metal fittings (bolts, nuts, hooks, hangers, etc.) necessary for fitting of the insulation are to be galvanised or made in a corrosion-resistant material.

5.6.5 Equipment below the insulation

Arrangements are to be made whilst building in order to facilitate the examination in service of parts such as bilge suctions, scuppers, air and sounding pipes and electrical wiring which are within or hidden by the insulation.

5.7 Installation of the insulation

5.7.1 The following requirements shall be fulfilled:

a) Before laying the insulation, steel surfaces are to be suitably cleaned and covered with a protective coating of appropriate composition and thickness

b) The thickness of the insulation on all surfaces together with the laying process are to be in accordance with the approved drawings

c) The insulating materials are to be carefully and permanently installed; where they are of slab form, the joints are to be as tight as possible and the unavoidable crevices between slabs are to be filled with insulating material. Bitumen is not to be used for this purpose

d) Joints of multiple layer insulations are to be staggered

e) In applying the insulation to the metallic structures, any paths of heat leakage are to be carefully avoided.

5.8 Drainage of refrigerated spaces

5.8.1 General

All refrigerated spaces and trays under air coolers are to be fitted with means suitable for their continuous and efficient drainage.

5.8.2 Drain pipes

a) Drain pipes from refrigerating space cooler trays are to be fitted with liquid sealed traps provided with non-return valves which are easily accessible, even when the chamber is fully loaded.

b) Threaded plugs, blank flanges and similar means of closing of drain pipes from refrigerated spaces and trays of air coolers are not permitted.

c) Where means of closing of drain pipes are required by the Owner, these are to be easily checked and the controls are to be located in an accessible position on a deck above the maximum ship draft.

6 Refrigerants

6.1 General

6.1.1 Prohibited refrigerants

For restrictions on the selection of refrigerants, see Pt D, Ch 3, Sec 6, [2.2.1].

6.2 Rated working pressures

6.2.1 Pressure parts design pressure

a) The refrigerant design pressure is not to be less than the maximum working pressure of the installation or its parts, either in operation or at rest, whichever is the greater. No safety valve is to be set at a pressure higher than the maximum working pressure.

b) In general, the design pressure of the low pressure side of the system is to be at least the saturated vapour pressure of the refrigerants at 40°C. Due regard is to be paid to the defrosting arrangement which may increase the pressure on the low pressure system.

c) The design pressure of the high pressure side of the installation is to be based on the condenser working pressure while it operates with water cooling in tropical zones. In general, the rated working pressure is to be taken not less than the effective saturated vapour pressure at 50°C.

d) The design pressure of the system is also not to be lower than the values given in Tab 3.

Table 3 : Design working pressure

Refrigerant number	High pressure side	Low pressure side
R134a	1,3 MPa	1,1 MPa
R404a	2,0	1,7 MPa
R507	2,3	1,8 MPa
Note 1: Due to consideration is to be given to the values applicable to other refrigerants,		

7 Refrigerating machinery and equipment

7.1 Prime movers

7.1.1 General requirements

The electric motors driving the compressors, pumps or fans are to satisfy the relevant requirements of Pt D, Ch 4, Sec 4.

7.2 Common requirements for compressors

7.2.1 Casings

The casings of rotary compressors are to be designed for the design pressure of the high pressure side of the system indicated in Tab3.

7.2.2 Cooling

a) Air-cooled compressors are to be designed for an air temperature of 45°C.

b) For sea water cooling, a minimum inlet temperature of 32°C is to be applied. Unless provided with a free outlet, the cooling water spaces are to be protected against excessive overpressure by safety valves or rupture safety devices.

7.2.3 Safety devices

a) Stop valves are to be provided on the compressor suction and discharge sides.

b) A safety valve or rupture disc is to be arranged between the compressor and the delivery stop valve.

c) When the power exceeds 10 kW, the protection may consist of a pressure control device which automatically stops the machine in the event of overpressure. Details of the design of this device are to be submitted to the Society.

d) Compressors arranged in parallel are to be provided with check valves in the discharge line of each compressor.

e) Means are to be provided to indicate the correct direction of rotation.

7.3 Reciprocating compressors

7.3.1 Crankcase

a) When subjected to refrigerant pressure, compressor crankcases are to be either:
   - designed to withstand the rated working pressure of the LP side, or
   - fitted with safety valves designed to lift at a pressure not exceeding 0,8 times the crankcase test pressure; in this case, arrangements are to be made for the refrigerant to discharge to a safe place, or
   - protected against overpressures by means of devices likely to ensure a similar protection.

b) An oil level sight glass is to be fitted in the crankcase.

c) Means are to be provided to heat the crankcase when the compressor is stopped if the power of the compressor technically required such an arrangement.

7.4 Pressure vessels

7.4.1 General

The general requirements of Pt D, Ch 3, Sec 6, [2.1.2] are applicable.

7.4.2 Refrigerant receivers

a) The receivers are to have sufficient capacity to accumulate liquid refrigerant during changes in working conditions, maintenance and repairing.

b) Each receiver is to be fitted with suitable level indicators. Glass gauges, if any, are to be of the flat plate type and are to be heat resistant. All level indicators are to be provided with shut-off devices.

c) Each receiver that may be isolated from the system is to be provided with an adequate overpressure safety device.

7.4.3 Evaporators and condensers

a) All parts of evaporators and condensers are to be accessible for routine maintenance; where deemed necessary, efficient means of corrosion control are to be provided.

b) Safety valves are to be fitted on the shells of evaporators and condensers when the pressure from any connected pump may exceed their anticipated working pressure.

7.4.4 Air coolers

a) Air coolers are to be made of corrosion-resistant material or protected against corrosion by galvanizing.

b) Air coolers are to be provided with drip trays and adequate drains.

7.5 General requirements for piping

7.5.1 General

The general requirements of Pt D, Ch 3, Sec 6, [2.1.3] are applicable.

7.5.2 Piping arrangement

a) Pipelines are to be adequately supported and secured so as to prevent vibrations. Approved type flexible hoses may be used where necessary to prevent vibrations.

b) Provision is to be made for allowing thermal expansion and contraction of the piping system under all operating conditions. Approved type flexible hoses may be used where necessary for this purpose.

c) Where necessary, pipe insulation is to be protected from mechanical damage and is to be provided with an efficient vapour barrier which is not to be interrupted in way of supports, valves, fittings, etc.

7.6 Accessories

7.6.1 Oil separators

Oil separators with drains are to be fitted on the refrigerant lines. When a wire gauze is fitted, this is to be of material which cannot be corroded by the refrigerant.

7.6.2 Filters

a) Efficient filters are to be fitted at the suction of compressors and on the high pressure side of reducing valves. The filters of compressors may be incorporated in the crankcases, provided their filtering area is sufficient.

b) Filters are to be fitted with a wire gauze strainer which cannot be corroded by the refrigerant and allowing a sufficient flow area for the fluid. Small filters such as those of reducing valves are to be such that they can be easily removed without any disassembling of the pipes.

7.6.3 Dehydrators

An efficient dehydrator is to be fitted. The dehydrator is to be so designed and arranged that the drying product can be replaced without any disassembling of the pipes.

7.7 Refrigerating plant overpressure protection

7.7.1 General

a) The refrigerant circuits and associated pressure vessels are to be protected against overpressure by safety valves, rupture discs or equivalent arrangement. However, inadvertent discharge of refrigerant is to be prevented.

b) The safety devices are to be in such number and so located that there is no possibility that any part of the system may be isolated from a safety device. Where it is necessary to be able to isolate one of these devices from the system for maintenance purposes, the valves may be duplicated provided a change-over valve is arranged in such a way that when one device is isolated it is not possible to shut off the other.

c) Pressure vessels connected by pieces of pipe without valves may be considered as a single pressure vessel from the point of view of overpressure protection, provided that the interconnecting pipe does not prevent effective venting of the vessels.

7.7.2 Safety valves

a) Safety valve discharges are to be led to a safe place fitted with refrigerant concentration detectors.

b) Refrigerant pumps are to be fitted with safety valves at the discharge side. The valves may discharge at the pump suction side or at another suitable location.

c) After setting, safety valves are to be suitably protected against the possibility of inadvertent change of setting.

d) Safety valves are to lift at a pressure not more than 0,80 times the test pressure of the parts concerned.

8 Specific requirements for direct refrigerating systems

8.1 Specific requirements for air cooling systems and distribution and renewal of air in refrigerated spaces

8.1.1 Rated circulation

The air circulation system is to be so designed as to ensure as uniform as possible a distribution of air in refrigerated spaces.

8.1.2 Refrigerated air circulation systems

a) For air coolers, see [7.4.4].

b) Air coolers are to be designed for a maximum temperature difference between cooling medium and cooling air at the air cooler inlet of about 5°C for fruit cargoes and about 10°C for deep frozen goods.

c) The coils are to be divided into two sections, each capable of being easily shut off.

d) Means for defrosting the coils of the air coolers are to be provided. Defrosting by means of spraying with water is to be avoided.

e) Fans and their motors are to be arranged so as to allow easy access for inspection and repair and/or removal of the fans and motors themselves when the chambers are loaded with refrigerated goods. Where duplicate fans and motors are fitted and each fan is capable of supplying the quantity of air required, it is sufficient that easy access for inspection is provided.

f) The air circulation is to be such that delivery and suction of air from all parts of the refrigerated chambers are ensured.

g) The air capacity and the power of the fans are to be in proportion to the total heat to be extracted from the refrigerated chambers, due regard being given to the nature of the service.

9 Instrumentation, alarm, monitoring

9.1 General

9.1.1 Automation safety equipment

The automation safety equipment is to be of the fail-safe type and is to be so designed and installed as to permit manual operation. In particular, manual operation of the compressors is to be ensured in the event that any of the equipment is inoperable.

9.1.2 Regulation devices

Regulation devices such as motor-operated valves or thermostatic expansion valves are to be such that they can be isolated, thus allowing the plant to be manually operated should the need arise.

9.2 Instrumentation, alarm and monitoring arrangement

9.2.1 Compressors

Tab 4 summarises the minimum control and monitoring requirements for refrigerating compressors.

9.2.2 Refrigerating systems

Tab 5 summarises the minimum control and monitoring requirements for refrigerating systems.

Table 4 : Refrigerating compressors

Item	Indicator	Function			Comments
			Alarm	Automatic shutdown	
Refrigerant suction	pressure	low		X	At saturated temperature and
Refrigerant discharge	pressure	high		X	including intermediate stages
Refrigerant suction	temperature				For installations over 25 kW only
Refrigerant discharge	temperature				
Lubricating oil	pressure	low		X	
Lubricating oil	temperature				For installations over 25 kW only
Cooling water	temperature				For installations over 25 kW only
Cumulative running hours	hours				All screw compressors and installations over 25 kW only
Note 1: Shutdown is also to activate an audible and visual alarm, locally or at remote position.					

Table 5 : Refrigerating systems

Item	Indicator	Function			Comments
			Alarm	Automatic shutdown	
Chamber temperature	temperature		X		
Bilge level in refrigerated space		high	X		
Note 1: Audible and visual alarm to be activated locally or at remote position.					

10 Material tests, inspection and testing, certification

10.1 Material testing

10.1.1 The materials for the construction of the parts listed below are to be tested in compliance with the requirements of NR216 Materials:

- compressor crankshafts, couplings, connecting rods and piston rods
- compressor liners, cylinder heads and other parts subjected to pressure
- steel and copper tubing for evaporator and condenser coils and for pressure piping in general
- oil separators, intermediate receivers and other pressure vessels included in the gas circuit
- condensers and evaporators of shell type (tube or welded plate).

10.2 Shop tests

10.2.1 Individual pieces of equipment

Shop tests are to be carried out on pumps, electric motors and internal combustion engines forming parts of refrigerating installations, following procedures in accordance with the requirements applicable to each type of machinery. The relevant running data (capacity, pressure head, power and rotational speed, etc.) are to be recorded for each item.

10.2.2 Refrigerating unit

a) At least one refrigerating unit of each type installed on board is to be subjected to shop tests in order to ascertain its refrigerating capacity in the most unfavorable temperature conditions expected, or in other temperature conditions established by the Society.

b) Where the complete unit cannot be shop tested (for instance, in the case of direct expansion installations), only the compressors are to be tested according to procedures approved by the Society.

10.3 Pressure tests at the workshop

10.3.1 Strength and leak tests

Upon completion, all parts included in the suction and delivery branches of the refrigerant circuit are to be subjected to a strength and leak test.

The strength test is a hydraulic test carried out with water or other suitable liquid. The leak test is a test carried out with air or other suitable gas while the component is submerged in water at a temperature of approximately 30°C.

The components to be tested and the test pressure are indicated in Tab 6.

10.3.2 Condensers

Circulating water sides of condensers are to be subjected to a hydrostatic test at a pressure equal to 1,5 times the design pressure, but in no case less than 0,1 N/mm^2. They should be designed taking into account requirements mentioned in Pt D, Ch 3, Sec 5, [12.4.2] and Pt D, Ch 3, Sec 3 when submitted to immersion pressure.

Table 6 : Pressure tests

Component	Test pressure	
	Strength test	Leak test
Compressor cylinder blocks, cylinder covers, stop valves, pipes and other components (condensers, receivers, etc.) of the high pressure part of the circuit.	1,5 p_1	p_1
Compressor crankcases subjected to refrigerant pressure, stop valves, pipes and other components of the low pressure part of the circuit.	1,5 p_2	p_2
Where p_1 and p_2 are the design pressures indicated in [6.2] for high pressure and low pressure parts.		

10.4 Thermometers and manometers

10.4.1 The following requirements shall be fulfilled:

a) All thermometers recording the temperature of refrigerated spaces, the air temperature at the inlet and outlet of air coolers and the temperature at various points in the refrigerant circuit or in the brine circuit are to be carefully calibrated by the Manufacturer. The Society reserves the right to require random checks of the calibration

b) The accuracy of manometers and other measuring instruments is also to be checked before the commencement of the tests required in [10.5].

10.5 Shipboard tests

10.5.1 Pressure tests

After installation on board, and before operating, the plant is to be subjected to a test at the maximum working pressure determined as indicated in [6.2.1].

However, all pressure piping portions which have welded joints made on board are to be subjected to a strength test at a pressure equal to 1,5 times the rated working pressure before being insulated.

After the pressure test, and before charging with refrigerant, a vacuuming and a drying out of the complete refrigerating plant is to be carried out.

Air tightness of the refrigerated chambers is to be checked.

10.5.2 Tests of the ventilation system

After installation, the ventilation system is to be tested. The distribution of air in the various refrigerated spaces is to be checked.

10.5.3 Operational tests

a) Upon completion of the installation, each refrigerating plant is to be subjected to an operational test on board in order to check the proper operation of the machinery and the refrigerating capacity of the unit.

b) Before starting the actual test, the Surveyor will check at random that thermometers, pressure gauges and other instruments are in working order, calibrated and arranged as directed in each case by the Society.

c) All the refrigerating machinery is to be put into service and all chambers, closed and empty, are to be simultaneously cooled to the minimum expected temperature, i.e. the temperature required to be entered in the notation, or a lower temperature determined so that a difference of at least 20°C can be maintained between the average external temperature and the temperature in the refrigerated spaces. The expected temperature is to be maintained for a period of time sufficient to remove all the heat from the insulation.

d) The regulation of the refrigerating capacity of the plant may be effected by reducing the number of running compressors, by varying their rotational speed or even by running them intermittently.

e) The following data are to be recorded in the course of the test:

- temperatures in the refrigerated spaces, external air temperature and sea water temperature (in particular, at the outlet and inlet of the condensers)
- absorbed power and speed of the compressors and the temperatures and pressures which determine the running of the refrigerating machinery
- absorbed power of the motors driving the fans F_V and brine pumps F_P
- temperatures and pressures at various locations along the refrigerant circuits
- air temperatures at the inlet and outlet of air cooler.

f) Particular cases, e.g. when the test is carried out with very low external atmospheric temperatures which would require the temperature within the refrigerated spaces to be brought down below the above specified values, or where tests with empty chambers are not deemed sufficient/significant, will be specially considered by the Society. In particular, the following may be required:

- appropriate testing conditions, such as simulation with equivalent thermal loading or chamber heating, and/or
- a copy of the log book of the refrigerated chambers, including the temperature reading, after the first loaded voyage.

10.6 Defrosting system

10.6.1 The defrosting arrangements are also to be subjected to an operational test.

Instructions regarding the procedure to be followed for the operational test of the refrigerating plant on board will be given by the Society in each case.

SECTION 2 HSE NOTATION

1 General

1.1 Application

1.1.1 The additional class notation **HSE** is assigned to submarines that are verifying the health, safety and environmental regulations of the Naval Authority.

SECTION 3 AIP NOTATION

1 General

1.1 Definitions

1.1.1 AIP

AIP (Air Independent Propulsion) systems are systems producing electrical energy independently from outer air and dedicated to submarines propulsion.

AIP is not considered as being a redundant or a main means of producing energy but as an additional means.

Failure of the AIP should not lead to the loss of power supply of the essential services defined in Pt D, Ch 4, Sec 1.

The batteries on one side and the energy generating systems from nuclear reaction on the other side, are not part of the AIP according to the rules.

The AIP systems are composed of:

- an electric energy production system (internal combustion engine, external combustion engine, steam turbine, fuel cells)
- a storage system and distribution of combustive
- a storage system and distribution of fuel
- a discharge system of residual products
- the operating system of the AIP.

The AIP uses services provided by the other systems of the submarine. These must be listed on a case-by-case basis and constitute the AIP ship support.

1.1.2 Environmental conditions

The AIP system is designed to work in diving conditions only in the environmental conditions defined in Pt B, Ch 1, Sec 3.

Operation at quay and in surface situation is possible during the test and trial phases for specifically defined environmental conditions.

1.1.3 Definitions of energy production systems

The energy production system combines fuel and combustive to produce electrical energy through a combination of thermal, mechanical or chemical processes.

The system includes adaptation of the voltage to the voltage of the submarine's main network.

1.1.4 Definition of the combustive system

The combustive system includes the storage, transformation and distribution of the combustive.

The combustive commonly used is gaseous oxygen.

The storage is a cryogenic one.

1.1.5 Definition of the fuel system

The fuel used may be of marine diesel oil type or another type of diesel oil (for example low sulphur diesel oil) or another type as ethanol, methanol, liquefied or compressed gas or hydrogen stored as hybrids.

The fuel system takes into account the storage, distribution and potential transformation (reforming, desulfurization, …).

1.1.6 Definitions of the discharge system

The discharge system shall allow the conditioning and the discharge of gas and fluids produced by the AIP outside the submarine.

The system includes the potential storage, conditioning (pressurization, refrigeration, condensation, water extraction) and discharge outside the submarine.

1.1.7 Definitions of operating systems

The operating system includes the whole of the actuators and controllers allowing the system operation (configuration of the different fuel and combustive circuits, process regulation, alarm generating).

1.1.8 AIP compartments

AIP compartments are spaces in which the fuel system, the combustive system and the energy production system are fitted.

1.1.9 Safety definitions

The methodology for safety studies is defined in Pt B, Ch 1, Sec 2, [3.22].

The general safety objectives of the ship are defined in Pt B, Ch 1, Sec 2, [3.21].

The ultimate design limit is given in Pt A, Ch 1, App 2.

The risk families to be taken into account for the safety demonstration are those defined in Pt A, Ch 1, App 2.

a) Definitions of the safety functions

The safety functions of the AIP are derived from the safety objectives of the ship.

They allow for the management of accidental situations of the AIP and its return to a kept safe state.

A safe condition is a stable and controlled condition of the AIP, reached at end of the transitory phase and that can be durably maintained as concerns control of the procedure and the confinement.

b) Definitions of the hazardous areas

The hazardous areas are defined according to the potential risk of explosion or fire existing in a compartment.

The classification of these areas are defined for the risk of explosion by CEI 60079-10 standard.

The AIP compartments are considered as fire risk compartments (such as the diesel engine compartment) as defined in Pt E, Ch 1, Sec 5, [1.4].

c) Definition of the explosive lower limit

The explosive lower limit corresponds to the minimum value (expressed in % of gas in volume in the air) below which the mixture is too poor in fuel (or too poor in oxygen) for the flame to spread in a gaseous environment.

d) Definitions relating to the quality of the atmosphere

- CTC: Critical Toxic Concentration is the concentration in the air of a product that can provoke reversible pathological effects with a 15-minute exposure. Reaching the CTC calls for immediate action (using breathable air mask, ventilation or evacuation)
- CMA 1 hour: Maximum Admissible concentration is the concentration tolerable for an hour. It implies that a normal situation (i.e. a concentration lower than CMA 90 days) can be returned to in less that an hour
- CMA patrol: Maximum Admissible concentration is the concentration that shall not be exceeded if the weighted average is calculated for the duration of a patrol. It can therefore be momentarily exceeded as long as it remains under the CTC and that the average remains below the CMA patrol
- PPM: Part Per million.

1.2 Safety demonstration

1.2.1 Within the scope of integration of an AIP, a particular safety study is to be performed according to the requirements of Pt A, Ch 1, App 2.

This safety study shall take into account, for each risk family, all the life phases of the system and of the ship in the normal conditions of peace time and apart from malevolent actions.

This analysis must strive to demonstrate that all the risks issued from the AIP itself or from its ship support do not compromise the achievement of the safety objectives.

The analysis includes:

- identification and characterisation of the risks caused by the other systems of the submarine likely to impair the safety of the AIP or of the submarine in normal sailing conditions or in particular operations (tests, loading/unloading of the combustive, …)
- identification and characterisation of the risks of the other ship's installations likely to impair the AIP.

The safety objectives are fixed by levels of gravity determined by the possible consequences of accidental situations likely to derive from the integration of an AIP system. The objectives of the safety demonstration are detailed in Pt A, Ch 1, App 2.

1.3 Documents to be submitted

1.3.1 The following documents shall be submitted to the society:

- description of the process and functions of the AIP system and its material and functional integration inside the submarine
- description of the different states of the AIP system
- general arrangement of the AIP
- characteristics of the different fluids used (flash point, explosive characteristics and toxicity)
- circuits diagrams of the complete system including the list of equipment
- diagrams of the instrumentation and automation principle
- electrical diagrams
- technical documents of the components (specifications descriptions, certificates of conformity to norms and standards)
- safety file
- list of tests and trials.

2 Safety study

2.1 Safety requirements

2.1.1 Explosion

Explosions of under-pressure capacities and explosions of gaseous mixtures consequently to a leak shall be taken into account.

For the circuits and equipment conveying fluids or gas presenting a risk of explosion, the following arrangements must be taken:

- the failure modes leading to a gas or fluid leakage shall be defined
- the consequences of these leakages shall be evaluated with regards to the explosive lower limit
- the influence of cases of hyperoxia or uncontrolled pressurization of the compartment shall be taken into account
- the consequences on the atmosphere composition shall take the detection and the reaction time of the protection systems into account.

Protection arrangements among those mentioned hereunder shall be implemented to prevent and contain the leakages:

- reduction of the number of ramifications
- confinement
- shut-off valves
- inerting
- resorting to technologies with which the risk of rupture may be excluded Adaptation of the pressure vessels and the piping system scantling.

Means to detect leakages shall be implemented.

Adapted means shall be implemented to:

- isolate immediately the area in which the leakage has happened
- decontaminate the area when the ship is back on surface.

The hazardous areas shall be defined according to these potential leakages and of the confinement implemented. The use of materials in these areas shall meet the requirements defined in Pt D, Ch 4, Sec 3, [9].

It shall be demonstrated that a leakage does not lead to the loss of safety functions of the ship as defined in Pt B, Ch 1, Sec 2.

2.1.2 Safety from ingress of water

Any system in communication with the outside of the submarine shall be conceived according to the requirements of Pt D, Ch 3, Sec 5.

The particular cases connected to the type of conveyed fluid (especially oxygen and discharged gas) shall be submitted to the classification society.

2.1.3 Fire safety

It shall be demonstrated that a fire in the AIP areas will not lead to the loss of a safety function of the AIP or the ship.

It shall be demonstrated that a fire in the other rooms will not impair the safety functions of the AIP.

The AIP areas shall be provided with fire detection and an adequate fire extinguishing system as Pt E, Ch 1, Sec 6, [2.2].

The insulation class of the bulkheads and decks or the fire fighting means implemented will be according to the fires likely to be generated by the AIP system.

These fires are to be characterised according to the particular specificities relating to confinement, to the presence of a combustive source, fuel or gaseous mixture that may be isolable or not.

The ventilation systems of the AIP areas shall have shut-off valves. Shutting off the ventilation shall be remotely or locally possible.

All the sources likely to feed a fire shall be remotely isolable.

Arrangements shall be taken to avoid worsening the effects of a fire in these rooms (explosion of pressure vessels, fire resistance of the shut-off valves of the hull,…).

The system allowing the confinement of the combustive shall be fire-resistant.

The prevention towards the fire risk linked to an oxygen leakage relies on the requirements mentioned at [2.1.1].

2.1.4 Toxicity

The toxicity characteristics of the fluids used shall be evaluated (Critical Toxic Concentration, Maximum Admissible concentration).

The failure cases of the system leading to the leakage of a toxic fluid as well as the consequences of these leakages shall be studied.

The consequences in terms of atmosphere pressure, temperature and composition shall take the detection and reaction time of the protection systems into account.

Detection means adapted to potential types of pollutants shall be installed as per Pt E, Ch 2, Sec 1.

Protection means (shut-off valves, confinement, decontamination, …) shall be installed in order to minimise the consequences of a leakage.

Adequate ventilation means shall be installed in order to evacuate these pollutants when the ship is on surface.

In case an inerting system is used vis-à-vis fire or explosion risks, the consequences in terms of toxicity shall be evaluated.

2.1.5 Loss of support systems

All the support systems necessary to the proper working of the AIP shall be listed (electrical, refrigeration, fluidic, …).

The consequences of the loss of each support system on the working of the AIP shall be evaluated.

The loss of support systems shall be signalled (alarm system). This loss of support systems shall not impair the capability for the AIP to be placed and kept in a safe state.

2.1.6 Overpressure

- Under-pressure equipment

  The under-pressure equipment shall be dimensioned as per requirements of Pt D, Ch 3, Sec 3.

  In case of uncontrolled over pressure, it shall be possible to purge this capacity before reaching its integrity loss pressure. The purge shall be disposed so that it cannot constitute a hazard during the crews movements (burns, fluid projection)

- Storage capacity of the combustive

  The pressure of the storage capacity of the combustive shall be monitored at all times with alarm thresholds.

  The system of storage and supply in combustive shall have at least two means of draining, a normal one and a safety one. The normal system and the safety system shall not have a common mode.

  In case of uncontrollable over pressure, it shall be possible to purge the storage capacity towards the exterior of the submarine before reaching its breaking pressure

- Protective enclosures

  The characterisation of the overpressure in terms of temperature pressure in the protective enclosures shall take the detection and reaction time of the protection systems into account and the protective shields shall be so dimensioned as to withstand the generated overpressure.

  In case an inerting system is intended, the involved overpressure shall be taken into account in the design of the shield.

  These enclosures shall be provided with a pressure detection system with an alarm threshold.

  In case of uncontrollable over pressure, it shall be possible to purge the protective enclosures towards the exterior of the submarine before reaching its breaking pressure.

  It shall be possible to activate this system from outside the enclosures

- Lashing

  In case of breaking of a pipe or a flexible coupling, its lashing shall not lead to the loss of equipment necessary to the achievement of safety functions of the ship or the safe situation of the AIP.

  The circulation spaces of the crews shall be situated as much as possible outside the areas where there is a risk of lashing of the piping system. Otherwise arrangements shall be taken to minimise the risk (anti-lashing collar, clamping).

2.1.7 Collision

In the case of an AIP submarine, the file of resistance to collision shall take account of the case of a collision at the combustive storage area and shall demonstrate that there is no combustive leakage.

2.1.8 Other risks

This requirement concerns steam leakages, flooding and underpressure fluid projection for all that is not dealt with in the preceding requirements.

- Steam leakage

  The characterisation of the environmental conditions linked to a steam leakage in terms of temperature pressure shall take the detection and reaction time of the protection systems into account.

  The leak shall not lead to the loss of equipment necessary for the achievement of the safety functions of the ship or to place the AIP in a safe state.

  The prevention vis-à-vis the risk of steam leakages is based on the requirements mentioned at [2.1.1].

- Leak of an internal liquid capacity

  The leak shall not lead to the loss of equipment necessary to the achievement of the safety functions of the ship or to the safe situation of the AIP.

  Bilge pumping arrangements shall be implemented.

  In the case of a hydrocarbon leakage, it might be necessary to dilute the liquid in the hold before pumping.

  In the case of a liquid oxygen leak, screens and retention vats shall be provided to protect the resisting hull from a direct projection.

- High pressure fluid projection

  The leak shall not lead to the loss of equipment necessary to the achievement of the safety functions of the ship or to the safe situation of the AIP.

  The circulation areas of the crews shall be situated as far as possible outside the areas where there is a risk of under-pressure fluid projection. Otherwise devices shall be arranged to minimise the risk (shield).

- Projectiles

  The projectiles created by the blasting of an under-pressure capacity or by a breaking of the plumbing on the AIP system shall be taken into account so as to check that there is no impact on the system that might create a leakage or a capacity insulation breaking.

  Shields or specific protection measures shall be proposed if necessary.

- Burns

  The materials likely to have hot or very cold (cryogenic oxygen) surfaces shall be protected to avoid any risks of burns to the crews (see Pt D, Ch 3, Sec 1, [2.7]).

3 System requirements

3.1 Operating requirements

3.1.1 Operating systems

The operating system is constituted of:

- a nominal operating system having its own sensors and actuators which functionality is to allow the installation operation
- a safety system having its own sensors and actuators the purpose of which is to place the AIP in a safe state in case an operation limit of the system is exceeded.

Failure of a system shall not lead to the loss of the other system.

The operation system shall generate individual sound and visual alarms if the functioning limits of the AIP are exceeded.

The operation system shall be conceived in such a way that actions on the actuators in a hazardous area of type 1 or 2 can be activated without having to enter these hazardous areas.

The operation system shall be conceived in such a way that during operation a permanent human presence is not necessary in the risk areas or around the AIP (Part D, Chapter 5).

The operating system shall meet the requirements of Part D, Chapter 5.

The requirements on equipment are given at [3.4].

3.2 Requirements on energy production

3.2.1 The requirements on equipment are given in [3.4].

The energy production system shall be connected to the main network by a circuit breaker.

This circuit breaker shall ensure protection against short-circuit currents and overloads of the energy production system.

It shall be checked that the energy production system can be disconnected from the network under whichever load without damage to the AIP system or to any materials connected to the network.

Operation of the AIP without the main batteries to be connected to the main network shall be forbidden.

3.3 Installation requirements

3.3.1 The combustive storage system shall be fitted in a dedicated space. Fire protection insulation of this space shall be of type A0 or above according to the fire characterisation of the adjoining spaces with fire risks according to Pt E, Ch 1, Sec 5.

The AIP spaces shall be separated from the control stations and life zone of the ship.

There shall not be any system which operation requires a human presence in the AIP spaces during the operation phases of the AIP.

In case the system uses hydrogen, the hydrogen production and distribution system shall be fitted in a dedicated space.

3.4 Equipment and technologies requirements

3.4.1 The equipment shall be designed with regards to their applications (temperatures, pressures, nature of the fluid) and shall be in compliance with recognised standards.

The piping system, valves, pumps shall meet the requirements defined in Pt D, Ch 3, Sec 3 Pt D, Ch 3, Sec 5and Pt D, Ch 3, Sec 6.

The pipes conveying flammable liquids or gases shall be designed according to the characteristics of the conveyed fluid (temperatures, pressure).

The operating equipment shall meet the requirements defined in Pt D, Ch 5, Sec 4.

The electrical equipment shall meet the requirements defined in Pt D, Ch 4, Sec 4 to Pt D, Ch 4, Sec 10.

The equipment used for risk areas shall meet the requirements of Pt D, Ch 4, Sec 3, [9].

The use of other technologies shall be submitted to the approval of the Society.

4 Certification and testing

4.1 Equipment certification

4.1.1 The certified equipment is at least that defined in:

- Pt D, Ch 3, Sec 3 and Pt D, Ch 3, Sec 5 for class 1 equipment
- Pt D, Ch 4, Sec 14.

4.2 Quay and sea trials

4.2.1 Quay trials

The list of quay trials shall be submitted to the classification society and shall at least include the following trials:

- testing of piping system water tightness
- check of water tightness of the protective enclosure (by depression)
- testing of good operation of the actuators and sensors (temperature, pressure).

4.2.2 Tests of the normal operation means

Functional tests of normal operating system.

4.2.3 Testing of the safety systems

It shall be demonstrated that the safety functions are operational:

- safety operations testing (alarms generation, activation of the safety functions)
- fire detection testing
- gas detection testing
- testing of the loss of related services
- loss of normal operating testing
- purges testing
- automatic closing valves testing
- availability of the decontamination means
- availability of the fire fighting system.

4.2.4 Functional testing of the AIP

- starting of the AIP
- stopping of the AIP
- load variation (if applicable)
- power cut of the AIP
- testing of the AIP operation according to the electrical configurations.

4.2.5 Sea trials

Testing of the AIP system operation.

4.3 Feedback

4.3.1 Feedback on technical facts during trials and operation phases

Considering the low amount of feedback on AIP systems, the designer shall provide technical data (anomaly reports, failures) during implementation and trials phases, and during operation if those elements are available.

4.4 Maintenance of classification

4.4.1 A maintenance plan including the maintenance schedule on the AIP equipment shall be provided to the Society

This maintenance plan shall be in compliance with Pt A, Ch 2, Sec 2.

SECTION 4 COLLRES NOTATION

1 General

1.1 Application

1.1.1 The additional notation **CollRES** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.5] to submarines designed to support different types of collision without loosing the integrity of the pressure hull. This notation can be granted when the resistance to collision is part of the safety objectives of the submarine. The requirements of the **CollRES** notation are to be consistent with the requirements defined in the safety file of the submarine (see Pt A, Ch 1, App 2).

2 Scenario to be investigated

2.1 Collision with a surface vessel

2.1.1 Collision with a surface vessel are to be investigated during resurfacing phase and for Schnorchel navigation. For each case two configurations are to be investigated:

- front collision the submarine striking the surface vessel
- beam collision the submarine being hit by the surface vessel.

For each scenario the speed of both the submarine and the surface vessel are to representative of the normal operation of each one.

2.2 Collision with the bottom

2.2.1 Collision with the bottom are to be investigated for two cases:

- collision with the bottom of the sea
- collision with an underwater cliff.

2.2.2 For each scenario the collision angle and the speed of the submarine are to be representative of the most likely condition during such accident.

3 Acceptance criteria

3.1

3.1.1 The notation is granted when it has been demonstrated that the submarine is able to come back to surface without external support after any scenario of collision defined in Article [2].

SECTION 5 ANCHORING NOTATION

1 General

1.1 Application

1.1.1 The additional notation **ANCHORING** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.6] to submarine provided with one anchoring line and complying with the requirements of this Section.

1.2 Anchoring conditions

1.2.1 Requirements in this Section apply to temporary mooring of a submarine within or near an harbour, or in a sheltered area, when the submarine is awaiting a berth, the tide, etc.

Therefore, equipment complying with these requirements are not intended for holding a submarine off fully exposed coasts in rough weather or for stopping a submarine which is moving or drifting.

1.3 Definition

1.3.1 "One shot" anchor

Anchor designed to be lowered just once, and to be released from submarine after single operation.

1.3.2 Retractable anchor

Anchor designed to be lowered and hoisted several times without limitation.

2 Anchoring

2.1 General

2.1.1 Submarines are to be fitted with one anchor suitably designed according to [2.3].

2.1.2 For classification purpose, anchor fitted on the submarine may be either a "one shot" anchor or a retractable anchor.

2.2 Mooring force

2.2.1 The mooring force is the horizontal force exerted on the anchoring line (anchor + chain cable). The mooring force is to be calculated considering environmental condition not less than:

- wind: 50 knots
- current: 5 knots.

2.2.2 Designer is to submit calculation of the mooring force according to environmental conditions specified in [2.2.1].

2.3 Anchor

2.3.1 Anchor holding power is to be sufficient to support the mooring force calculated as defined in [2.2].

2.3.2 Where the anchor does not comply with a recognized standard agreed by the Society, designer is to justify the guaranteed minimum anchor holding power in all intended soil conditions.

2.3.3 As a general rule, the anchor is to be designed for mooring in good holding ground, where the conditions are such as to avoid dragging of the anchor.

Where the anchor is designed to be lowered on a poor holding ground, the anchor holding power is to be significantly reduced.

2.4 Chain cable

2.4.1 Chain cable is to comply with mass and geometry requirements defined in NR216 Materials and Welding, Ch 4, Sec 1.

Scantling of chain cable is to be such as to support the tension resulting from the mooring force calculated according to [2.2]. The safety coefficient on breaking strength to be used for the chain cable is to be not less than 6.

2.4.2 Design mooring depth is to be submitted by the designer and is not to be lower than 50 m. The ratio of the length of the mooring line to the mooring depth is not to be lower than 4.

2.4.3 Where the submarine is fitted with a "one shot" anchor, the chain cable can be replaced by a synthetic fibre rope. In this case, the strength of the synthetic fibre rope is not to be less than the equivalent chain cable.

In addition a minimum length of 12,5 m of chain cable is to be fitted between the anchor and the synthetic fibre rope.

2.5 Windlass and chain stopper

2.5.1 For a retractable anchor, a remotely operated and power driven windlass suitable for the size of the chain cable and the anchor mass is to be fitted on the submarine.

The windlass is to be fitted in a suitable position in order to ensure an easy lead of the cable trough the hawse pipe.

2.5.2 Where a chain stopper is fitted, it is to be remotely operated and able to withstand 0,8 times the breaking load of the chain cable.

Where no chain stopper is fitted, the windlass is to be able to withstand 0,8 times the breaking load of the chain.

2.5.3 Submarine structure in way of connection with windlass or chain stopper is to be suitably reinforced.

2.6 Chain locker

2.6.1 The capacity of chain locker is to be adequate to stow all the chain cable.

2.6.2 Inboard end of the chain is to be secured by an end shackle able to support 0,15 time breaking load of the chain in case of a retractable anchor and 1,1 times the breaking load of the chain in case of an "one shot" anchor.

The release of end shackle is to be remotely activated.

SECTION 6 REFUGE COMPARTMENT

1 Refuge compartment

1.1 Definition

1.1.1 A refuge compartment is a space intended for use during the survival period in the case where pressure hull is flooded.

1.2 Design and arrangement

1.2.1 Structure

In order to be considered as a refuge compartment, boundaries with adjacent spaces are to be resistant to a pressure of 20 bar or to the accidental diving depth pressure, if lower than 20 bar. Different design pressures may be considered, if explicitly required by the Naval Authority.

1.2.2 Equipment required in a refuge compartment

In order to be considered as a refuge compartment, the following facilities are to be available:

a) direct access to an escape trunk or to a landing platform able to receive an external rescue facility

b) gas control devices as mentioned in Pt E, Ch 2, Sec 1

c) oxygen supply as mentioned in Pt E, Ch 2, Sec 2

d) dangerous gases elimination devices as mentioned in Pt E, Ch 2, Sec 3

e) survival devices as mentioned in Pt E, Ch 3, Sec 4

f) an access door, able to withstand design pressure of refuge compartment and arranged such as flooding sea water pressure will press the door on refuge compartment bulkhead.

1.2.3 Piping arrangement

Piping bulkhead crossing devices are to be in accordance with requirements of Pt D, Ch 3, Sec 5, [5.3.1]. Pipes are to comply with following requirements.

a) Piping with design pressure below refuge compartment bulkhead scantling pressure:

One valve shall be fitted on the refuge compartment bulkhead., able to withstand immersion pressure reachable, on the side where crew shall be able to survive in case of flooding.This valve is to be built with same standards as pressure hull valves.

As an alternative arrangement, when two refuge compartments share a common zone, the portion of pipe crossing this zone may be scantled as a sea water pipe, taking into account refuge compartment design pressure, and fitted with a pressure resisting valve inside the common zone.

b) Piping with design pressure above refuge compartment scantling pressure:

No valve is necessary on the refuge compartment boundaries as long as piping system is able to withstand refuge compartment design pressure.