TASNEEF
هيئة الإمـــــارات للتصـــنـيـف
EMIRATES CLASSIFICATION SOCIETY

Rules for the Classification of Ships

Effective from 1 January 2026

Part C

Machinery, Systems and Fire Protection

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EMIRATES CLASSIFICATION SOCIETY

GENERAL TERMS AND CONDITIONS
OF EMIRATES CLASSIFICATION SOCIETY – L.L.C – O.P.C (TASNEEF)
EFFECTIVE AS OF 1 APRIL 2025

DEFINITIONS

Administration	means the government of the state whose flag the Ship is entitled to fly or under whose authority the Ship is authorised to operate in the specific case.
Client	means the interested party and any other party who requires the Services.
Certificate of Classification	means a certificate of classification, issued by a Society and the certificate confirms that the vessel's structure, machinery, and equipment meet the society's specific technical rules and regulations.
Interested Party	means the party, other than the society, having an interest in or responsibility for the Ship, product, plant or system subject to classification or certification (such as the owner of the Ship and his representatives, the Ship builder, the engine builder or the supplier of parts to be tested) who requests the Services or on whose behalf the Services are requested.
Owner	means the registered owner, the Ship owner, the manager or any other party with the responsibility, legally or contractually, to keep the Ship seaworthy or in service, having particular regard to the provisions relating to the maintenance of class laid down in part a, chapter 2 of the rules for the classification of Ships or in the corresponding rules indicated in the specific rules.
Register of Ships	means a register book, also known as a Register of Ships, is a comprehensive record of vessels that are classified by a society.
Rules	means the documents below issued by the Society: a. Rules for the classification of Ships or other special units. b. Complementary rules containing the requirements for certification of products, plants, systems and other or containing the requirements for the assignment of additional class notations. c. Rules for the application of statutory rules, containing the rules to perform the duties delegated by administrations. d. Guides to carry out particular activities connected with Services. e. Any other technical document, as for example rule variations or interpretations.

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Services	means the activities described in Article 1 below, rendered by the Society upon request made by or on behalf of the Interested Party.
Ship	means ships, boats, craft and other special units, as for example offshore structures, floating units and underwater craft.
Society	means Emirates Classification Society LLC OPC and/or its affiliated entities providing the Services.
Surveyor	means technical staff acting on behalf of the society in performing the Services.
UAE	means United Arab Emirates.

ARTICLE 1

1.1 The purpose of the Society is, among others, the classification and certification of Ships and the certification of their parts and components.

1.2 The Society (a) sets forth and develops Rules; (b) publishes the Register of Ships[1]; and (c) issues certificates, statements and reports based on its survey activities.

1.3 The Society also takes part in the implementation of national and international rules and standards as delegated by various Governments.

1.4 The Society carries out technical assistance activities on request and provides special services outside the scope of classification, which is regulated by these general conditions unless expressly excluded in the particular contract.

ARTICLE 2

2.1 The Rules developed by the Society reflect the level of its technical knowledge at the time they are published. Therefore, the Society, though committed, also through its research and development services, to continuous updating, does not guarantee they meet state-of-the-art science and technology at the time of publication or that they meet the Society's or others' subsequent technical developments.

2.2 The Interested Party is required to know the Rules on the basis of which the Services are provided. With particular reference to Classification Services, special attention is to be given to the Rules concerning class suspension, withdrawal and reinstatement. In case of doubt or inaccuracy, the Interested Party is to promptly contact the Society for clarification. The Rules for Classification of Ships are published on the Society's website: www.tasneefmaritime.ae

2.3 The Society exercises due care and skill:

(a) in the selection of its Surveyors; and

(b) in the performance of its Services, taking into account the level of its technical knowledge at the time the

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Services are performed.

2.4 Surveys conducted by the Society include, but are not limited to, visual inspection and non-destructive testing. Unless otherwise required, surveys are conducted through sampling techniques and do not consist of comprehensive verification or monitoring of each component of the Ship or of the items subject to certification. The surveys and checks made by the Society, either on board Ships or with remote techniques, do not necessarily require the constant and continuous presence of the Surveyor. The Society may also commission laboratory testing, underwater inspection and other checks to qualified service suppliers, who will carry out these duties under their responsibility. Survey practices and procedures are selected by the Society based on its experience and knowledge and according to generally accepted technical standards in the sector.

ARTICLE 3

3.1 The class assigned to a Ship, like the reports, statements, certificates or any other document or information issued by the Society, reflect the discretionary opinion of the Society concerning compliance, at the time the Service is provided, of the Ship or product subject to certification, with the applicable Rules (given the intended use and within the relevant time frame).

3.2 The Society is under no obligation to make statements or provide information about elements or facts which are not part of the specific scope of the Service requested by the Interested Party or on its behalf.

3.3 No report, statement, notation on a plan, review, Certificate of Classification, document or information issued or given as part of the Services provided by the Society shall have any legal effect or implication other than a representation that, on the basis of the checks made by the Society, the Ship, structure, materials, equipment, machinery or any other item covered by such document or information meet the Rules. Any such document is issued solely for the use of the Society, its committees and clients or other duly authorised bodies and for no other purpose. Therefore, the Society cannot be held liable for any act made or document issued by other parties on the basis of the statements or information given by the Society. The validity, application, meaning and interpretation of a Certificate of Classification, or any other document or information issued by the Society in connection with its Services, are governed by the Rules of the Society, whom is the sole subject entitled to make such authentic interpretation. Any disagreement on technical matters between the Interested Party and the Surveyor in the carrying out of his functions shall be raised in writing as soon as possible with the Society, which will settle any divergence of opinion or dispute.

3.4 The classification of a Ship, or the issuance of a certificate or other document connected with classification or certification and in general with the performance of Services by the Society shall have the validity conferred upon it by the Rules of the Society at the time of the assignment of class or issuance of the certificate; in no case shall it amount to a statement or warranty of seaworthiness, structural integrity, quality or fitness for a particular purpose or service of any Ship, structure, material, equipment or machinery inspected or tested by the Society.

3.5 Any document issued by the Society in relation to its activities reflects the condition of the Ship or the subject of certification or other activity at the time of the check.

3.6 The Rules, surveys and activities performed by the Society, reports, certificates and other documents issued by

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the Society are in no way intended to replace the duties and responsibilities of other parties including, without limitation, Governments, designers, ship builders, manufacturers, repairers, suppliers, contractors or sub-contractors, Owners, operators, charterers, underwriters, sellers or intended buyers of a Ship or other product or system surveyed.

3.7 These documents and activities do not relieve such parties from any fulfilment, warranty, responsibility, duty or obligation (also of a contractual nature) expressed or implied or in any case incumbent on them, nor do they confer on such parties any right, claim or cause of action against the Society. With particular regard to the duties of the Owner, the Services undertaken by the Society do not relieve the Owner of his duty to ensure proper maintenance of the Ship and ensure seaworthiness at all times. Likewise, the Rules, surveys performed, reports, certificates and other documents issued by the Society are intended neither to guarantee the buyers of the Ship, its components or any other surveyed or certified item, nor to relieve the seller of the duties arising out of the law or the contract, regarding the quality, commercial value or characteristics of the item which is the subject of transaction.

3.8 In no case, therefore, shall the Society assume the obligations incumbent upon the above-mentioned parties, even when it is consulted in connection with matters not covered by its Rules or other documents.

3.9 In consideration of the above, and within the limits of liability under Article 5 below, the Interested Party undertakes to relieve and hold harmless the Society from any third party claim, as well as from any liability in relation to the latter concerning the Services rendered, where these are attributable to the Interested Party.

3.10 Insofar as they are not expressly provided for in these General Conditions, the duties and responsibilities of the Owner and Interested Parties with respect to the Services rendered by the Society are described in the Rules applicable to the specific Service rendered.

ARTICLE 4

4.1 Any request for the Society's Services shall be submitted in writing and signed by or on behalf of the Interested Party. Such a request will be considered irrevocable as soon as received by the Society and shall entail acceptance by the applicant of all relevant requirements of the Rules, including these General Conditions. Upon acceptance of the written request by the Society, a contract between the Society and the Interested Party is entered into, which is regulated by the present General Conditions.

4.2 In consideration of the Services rendered by the Society, the Interested Party and the person requesting the service shall be jointly liable for the payment of the relevant fees and costs, even if the service is not concluded for any cause not pertaining to the Society. In the latter case, the Society shall not be held liable for non-fulfilment or partial fulfilment of the Services requested. In the event of non-payment of the invoice within the contractually agreed terms, the Society reserves the right to request, in addition to the full payment of the principal amount due and without the need for further formal notice, also:

(a) Late payment interest at a rate of 5% per annum, calculated from the due date of the invoice until full payment is received, in accordance with the applicable laws in the United Arab Emirates or the country from where the invoice is issued. Any applicable VAT, taxes, or statutory levies shall be borne by the Client as per the laws

of the respective jurisdiction;

(b) full reimbursement of any costs incurred for debt recovery, including, but not limited to, legal fees, administrative expenses, and the costs of any extrajudicial actions; and

(c) any additional amount due as compensation for damages suffered as a result of the delay or non-compliance, where documented.

4.3 The contract for the classification of a Ship or for other Services may be terminated and any certificates revoked at the request of one of the parties, subject to at least 30 days' notice to be given in writing. Failure to pay, even in part, the fees due for Services carried out by the Society will entitle the Society to immediately terminate the contract and suspend the Services.

4.4 The Society may withhold, suspend or withdraw any certificate, report or service in the event of non-payment of fees due to any member of the Society by the Client in relation to the entire business relationship between any member of the Society and the Client or by any other companies belonging to the same group as the Client. This also applies when the obligation to pay rests with a builder or with the Ship's previous Owner.

4.5 For every case of termination or suspension of the contract, the fees for the activities performed until the time of the termination or of the suspension shall be owed to the Society as well as the expenses incurred in view of activities already programmed; this is without prejudice to the right to compensation due to the Society as a consequence of the termination or of the suspension.

4.6 With particular reference to Ship classification and certification, unless decided otherwise by the Society, termination of the contract implies that the assignment of class to a Ship is withheld or, if already assigned, that it is suspended or withdrawn; any statutory certificates issued by the Society will be withdrawn in those cases where provided for by agreements between the Society and the flag State.

ARTICLE 5

5.1 In providing the Services, as well as other correlated information or advice, the Society, its Surveyors, servants or agents operate with due diligence for the proper execution of the activity. However, considering the nature of the activities performed (see Article 2), it is not possible to guarantee absolute accuracy, correctness and completeness of any information or advice supplied. Express and implied warranties are specifically disclaimed.

5.2 Therefore, subject to what provided for in Article 5.3 below, and also in the case of activities carried out by delegation of Governments, neither the Society nor any of its Surveyors will be liable for any loss, damage or expense of whatever nature sustained by any person, in tort or in contract, derived from carrying out the Services.

5.3 Notwithstanding the provisions in Article 5.1 above, should any user of the Society's Services prove that he has suffered a loss or damage due to any negligent act or omission of the Society, its Surveyors, servants or agents, then the Society will pay compensation to such person for his proved loss, up to, but not exceeding, five times the amount of the fees charged for the specific Services, information or opinions from which the loss or damage derives or, if no fee has been charged, a maximum of AED5,000 (Arab Emirates Dirhams Five Thousand only).

5.4 Where the fees charged are related to a number of Services, the amount of the fees will be apportioned for the purpose of the calculation of the maximum compensation, by reference to the estimated time involved in the

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performance of the Service from which the damage or loss derives. Any liability for indirect or consequential loss, damage or expense is specifically excluded. In any case, irrespective of the amount of the fees charged, the maximum damages payable by the Society will not be more than AED 300,000 (Three Hundred Thousand Dirhams). Payment of compensation under this Article will not entail any admission of responsibility and/or liability by the Society and will be made without prejudice to the disclaimer clause contained in Article 5.

5.5 Any claim for loss or damage of whatever nature by virtue of the provisions set forth herein shall be made to the Society in writing, within the shorter of the following periods: THREE MONTHS from the date on which the Services were performed or THREE MONTHS from the date on which the damage was discovered. Failure to comply with the above deadline will constitute an absolute bar to the pursuit of such a claim against the Society.

ARTICLE 6

6.1 Any dispute, controversy, or claim arising out of or relating to these Rules, the Services of the Society, or the interpretation, breach, or termination thereof, shall first be referred to the parties' senior management for amicable resolution within thirty (30) days of written notice by either party.

6.2 If the dispute is not resolved amicably under Article 6.1, it shall be exclusively governed by and construed in accordance with the laws of the Emirate of Abu Dhabi and the applicable federal laws of the United Arab Emirates. The courts of Abu Dhabi shall have exclusive jurisdiction to settle any such dispute.

ARTICLE 7

7.1 All plans, specifications, documents and information provided by, issued by, or made known to the Society, in connection with the performance of its Services, will be treated as confidential and will not be made available to any other party other than the Owner without authorisation of the Interested Party, except as provided for or required by any applicable legislation from a competent authority. Information about the status and validity of class and statutory certificates, including transfers, changes, suspensions, withdrawals of class, conditions of class, operating conditions or restrictions issued against classed ships and other related information, as may be required, may be published on the website or released by other means, without the prior consent of the Interested Party.

7.2 Information about the status and validity of other certificates and statements may also be published on the website or released by other means, without the prior consent of the Interested Party.

7.3 Notwithstanding the general duty of confidentiality owed by the Society to its clients in Article 7.1 above, the Society's clients hereby accept that the Society will participate in the IACS Early Warning System which requires each Classification Society to provide other involved Classification Societies with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the Ship which may be the specific property of another party), to enable such useful information to be shared and used to facilitate the proper working of the IACS Early Warning System. The Society will provide its clients with written details of such information sent to the involved Classification Societies.

7.4 In the event of transfer of class, addition of a second class or withdrawal from a double/dual class, the Interested Party undertakes to provide or to permit the Society to provide the other Classification Society with all building plans and drawings, certificates, documents and information relevant to the classed unit, including its history file,

as the other Classification Society may require for the purpose of classification in compliance with the applicable legislation and relative IACS Procedure. It is the Owner's duty to ensure that, whenever required, the consent of the builder is obtained with regard to the provision of plans and drawings to the new Society, either by way of appropriate stipulation in the building contract or by other agreement.

7.5 In the event that the ownership of the Ship, product or system subject to certification is transferred to a new subject, the latter shall have the right to access all pertinent drawings, specifications, documents or information issued by the Society or which have come to the knowledge of the Society while carrying out its Services, even if related to a period prior to transfer of ownership.

ARTICLE 8

8.1 The Society shall not be obliged to perform any obligation towards the Client (including, without limitation, obligation to (a) perform, deliver, accept, sell, purchase, pay or receive money to, from or through a person or entity, or (b) engage in any other act) if this would be in violation of, inconsistent with or expose the Society to punitive measures under any United Nations resolutions and/or under any laws, regulations, decrees, ordinances, orders, demands, requests, rules or requirements of EU, United Kingdom, and/or United States of America and which relate to foreign trade controls, export controls, embargoes or international boycotts (applying, without limitation, to the financing, payment, insurance, transportation, delivery or storage of product and/or services) hereinafter referred to as "Trade Sanctions".

8.2 Recurring the above circumstances during the performance of the contract, the Society shall be entitled at its sole and absolute discretion:

(a) to immediately suspend payment or performance of the Services which are the object of the contract until such;

(b) time as the Trading Sanctions are in force;

(c) to a full disengagement from the obligation affected by the Trading Sanctions, in the event that the inability to fulfill the said obligation persists until the term provided for the fulfilment hereunder, provided that where the relevant obligation relates to payments for activities and/or Services which have already been delivered, the affected payment obligation shall remain only suspended until such time as the Trading Sanctions no longer apply to the payment ; and/or

(d) to terminate the contract, without prejudice of the Society's rights pursuant to Article 4.

ARTICLE 9

Should any part of these General Conditions be declared invalid, this will not affect the validity of the remaining provisions.

ARTICLE 10

When the Society provides its Services to a consumer - i.e. a natural person who does not act within the scope of his business or professional activity - the following provisions do not apply Article 3 (as far as the Society is solely entitled to the authentic interpretation of the Rules); Article 4, (as far as the payment of the fees is also due for Services not

concluded due to causes not attributable to the Interested Party); Article 5 (as far as the exclusion of liability is concerned), and Article 6 (as far as the jurisdiction of a Board of Arbitrators based in Abu Dhabi is concerned).

ARTICLE 11

11.1 The Society and the Interested Party shall promote safety, protect human health and environment and create safe working conditions for their personnel.

11.2 The Interested Party shall guarantee that the working environment in which the Society's Surveyor will be required to work is adequate, safe and in all respect compliant with the applicable legislation and Rules and shall adopt all necessary measures to mitigate and/or control any relevant risk.

11.3 Furthermore, in accordance with the applicable legislation and Rules, the Interested Party shall provide the Society with complete and detailed information relevant to any actual or potential specific risk existing in the work areas where the Surveyor will be required to operate and relevant to the performance of the Services as well as with any specific safety measure that the Society's Surveyor is requested to comply with.

11.4 The Society reserves not to commence and/or to suspend the Services and/or to terminate the contract, claiming compensation for any damage occurred, if it considers that the safety requirements listed in this Article are not satisfactorily met.

EXPLANATORY NOTE TO PART C

1. Reference edition

The reference edition for Part C is the TASNEEF Rules 2000 edition, which is effective from 1 June 2000.

2. Amendments after the reference edition

2.1 TASNEEF Rules 2000 has been completely rewritten and reorganised.

2.2 Except in particular cases, the Rules are updated and published annually.

3. Effective date of the requirements

3.1 All requirements in which new or amended provisions with respect to those contained in the reference edition have been introduced are followed by a date shown in brackets.

The date shown in brackets is the effective date of entry into force of the requirements as amended by the last updating. The effective date of all those requirements not followed by any date shown in brackets is that of the reference edition.

3.2 Item 6 below provides a summary of the technical changes from the preceding edition. In general, this list does not include those items to which only editorial changes have been made not affecting the effective date of the requirements contained therein.

4. Rule Variations and Corrigenda

Until the next edition of the Rules is published, Rule Variations and/or corrigenda, as necessary, will be published on the TASNEEF web site (www.tasneef.ae). Except in particular cases, paper copies of Rule Variations or corrigenda are not issued.

5. Rule subdivision and cross-references

5.1 Rule subdivision

The Rules are subdivided into six parts, from A to F.

Part A: Classification and Surveys

Part B: Hull and Stability

Part C: Machinery, Systems and Fire Protection

Part D: Materials and Welding

Part E: Service Notations

Part F: Additional Class Notations

Each Part consists of:

- Chapters
- Sections and possible Appendices
- Articles
- Sub-articles
- Requirements

Figures (abbr. Fig) and Tables (abbr. Tab) are numbered in ascending order within each Section or Appendix.

5.2 Cross-references

Examples: Pt A, Ch 1, Sec 1, [3.2.1]or Pt A, Ch 1, App 1, [3.2.1]

- Pt A means Part A

The part is indicated when it is different from the part in which the cross-reference appears. Otherwise, it is not indicated.

- Ch 1 means Chapter 1

The Chapter is indicated when it is different from the chapter in which the cross-reference appears. Otherwise, it is not indicated.

- Sec 1 means Section 1 (or App 1 means Appendix 1)

The Section (or Appendix) is indicated when it is different from the Section (or Appendix) in which the cross-reference appears. Otherwise, it is not indicated.

- [3.2.1] refers to requirement 1, within sub-article 2 of article 3.

Cross-references to an entire Part or Chapter are not abbreviated as indicated in the following examples:

- Part A for a cross-reference to Part A
- Part A, Chapter 1 for a cross-reference to Chapter 1 of Part A.

6. Summary of amendments introduced in the edition effective from 1 January 2026

This edition of Part C contains amendments whose effective date is **1 January 2026**.

The date of entry into force of each new or amended item is shown in brackets after the number of the item concerned.

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RULES FOR THE CLASSIFICATION OF SHIPS

Part C
Machinery, Systems and Fire Protection

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Chapter 1
MACHINERY

SECTION 1 GENERAL REQUIREMENTS

1 General

1.1 Application

1.1.1 Chapter 1 applies 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 ships, as indicated in each Section of this Chapter.

1.2 Additional requirements

1.2.1 Additional requirements for machinery are given in:

- Part E, for the assignment of the service notations
- 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.

1.3.2 *(1/1/2025)*

For ships subject to the SOLAS Convention, ship builders are to identify and document the ship accelerations and motions periods to which machinery and equipment might be subjected to. The expected accelerations and ship motions periods are to be within machinery and equipment manufacturers requirements. The estimations are to consider vessel type, machinery or equipment location and expected service conditions.

1.3.3 *(1/1/2025)*

Machinery and equipment manufacturers are to submit evidence to the Society that their machinery or equipment can operate under the required static and dynamic conditions stated in Tab 1 and at least at the levels of shipboard accelerations as stated in [1.3.2] and/or specified in Pt E, Ch 9, Sec 5, [3.2]. Documentation of satisfactory performance is to take the form of:

a) Report of testing under representative conditions; or

b) Report of theoretical verification using recognised computational techniques accompanied by detailed and relevant validation data: or

c) Historical data which provides relevant demonstration of satisfactory experience in service.

1.4 Definitions

1.4.1 Machinery spaces of Category A

Machinery spaces of Category A are those spaces and trunks to such spaces which contain:

- *internal combustion machinery used for main propulsion, or*

- *internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW, or*
- *any oil fired boiler or fuel oil unit,* or
- gas generators, incinerators, waste disposal units, etc., which use oil fired equipment.

1.4.2 Machinery spaces

Machinery spaces are all machinery spaces of Category A and all other spaces containing propulsion machinery, boilers, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilising, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.

1.4.3 Fuel oil unit

Fuel oil unit is the equipment used for the preparation of fuel oil for delivery to an oil fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 0,18 N/mm^2.

For the purpose of this definition, inert gas generators are to be considered as oil fired boilers and gas turbines are to be considered as internal combustion engines.

1.4.4 Dead ship condition

Dead ship condition is the condition under which the whole propulsion system, including the main power supply, is not in operation and auxiliary means for bringing the main propulsion machinery into operation and for the restoration of the main power supply, such as compressed air and starting current from batteries, are not available, but assuming that means are available to start the emergency generator at all times.

2 Design and construction

2.1 General

2.1.1 *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.

2.1.2 Single essential propulsion components and their reliability *(1/1/2026)*

The Society shall give special consideration to the reliability of single essential propulsion components and may require a separate source of propulsion power sufficient to give the ship a navigable speed, especially in the case of unconventional arrangements.

The relevant interpretations in IACS UI SC305 apply, but the arrangement may be specially considered by the Society, upon a risk assessment being submitted and taking into account the ship service, size and navigation notation.

2.2 Materials, welding and testing

2.2.1 General

Materials, welding and testing procedures are to be in accordance with the requirements of Part D and those given in the other Sections of this Chapter. In addition, for machinery components fabricated by welding the requirements given in [2.2.2] apply.

2.2.2 Welded machinery components

Welding processes and welders are to be approved by the Society in accordance with Part D, 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
- full penetration T- or cruciform joints.

For joints between plates having a difference in thickness greater than 3 mm, a taper having a length of not less than 4 times the difference in thickness is required. Depending on the type of stress to which the joint is subjected, a taper equal to three times the difference in thickness may be accepted.

T-joints on scalloped edges are not permitted.

Lap-joints and T-joints subjected to tensile stresses are to have a throat size of fillet welds equal to 0,7 times the thickness of the thinner plate on both sides.

In the case of welded structures including cast pieces, the latter are to be cast with appropriate extensions to permit connection, through butt-welded joints, to the surrounding structures, and to allow any radiographic and ultrasonic examinations to be easily carried out.

Where required, preheating and stress relieving treatments are to be performed according to the welding procedure specification.

2.3 Vibrations

2.3.1 *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.*

2.4 Operation in inclined position

2.4.1 *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 Tab 1.*

The Society may permit deviations from angles given in Tab 1, taking into consideration the type, size and service conditions of the ship.

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.

2.5 Ambient conditions

2.5.1 Machinery and systems covered by the Rules are to be designed to operate properly under the ambient conditions specified in Tab 2, unless otherwise specified in each Section of this Chapter.

2.6 Shipboard accelerations

2.6.1 *(1/1/2025)*

Main propulsion and steering machinery and auxiliary machinery that is essential to the propulsion and steering, and the safety of the ship are to be capable of operation under the effects of acceleration and motions.

2.6.2 *(1/1/2025)*

The requirements in [1.3.2], [1.3.3] and [3.1.2] and [3.1.3] apply where documented evidence of equipment suitability is specifically required in Sec 2, Tab 2, item 28 and Pt E, Ch 9, Sec 5, [3.2] for such equipment or requested by the Society.

2.7 Power of machinery

2.7.1 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
- for auxiliary machinery, the power/rotational speed which is available in service.

2.8 Astern power

2.8.1 *(1/1/2026)*

Sufficient power for going astern is to be provided to secure proper control of the ship in all normal circumstances.

The minimum astern power required by SOLAS II-1/28-1 to secure proper control of the ship in all normal circumstances is to be determined by the ship designer and is not to exceed the maximum permissible astern power (MPAP) for which the propulsion plant is designed. Astern trials are to be conducted in accordance with the provisions of ISO 19019:2005, section 5.4: Astern trials.

Table 1 : Inclination of ship - inclinations applied to respective components *(1/1/2026)*

Installations, components	Angle of inclination (degrees) **(1)**			
	Athwartship		Fore and aft	
	static	dynamic	static	dynamic
Main and auxiliary machinery	15	22,5	5 **(4)**	7,5
Safety equipment, e.g. emergency power installations, emergency fire pumps and their devices Switch gear, electrical and electronic appliances **(3)** and remote control systems	22,5 **(2)**	22,5 **(2)**	10	10

(1) Athwartship and fore-and-aft inclinations may occur simultaneously.

(2) In ships for the carriage of liquefied gases and of chemicals the emergency power supply is to remain operable with the ship flooded to a final athwartship inclination up to a maximum of 30° (see 1983 IGC Code, clause 2.9.2.2, 2014 IGC Code, clause 2.7.2.2, IBC Code, clause 2.9.3.2).

(3) No undesired switching operations or operational changes are to occur.

(4) Where the length of the ship exceeds 100m, the fore-and-aft static angle of inclination may be taken as 500/L degrees, where L is the length of ship, in metres, as defined in Pt B, Ch 1, Sec 2,[3.1.1].

Table 2 : Ambient conditions

AIR TEMPERATURE	
Location, arrangement	Temperature range (°C)
In enclosed spaces	between 0 and +45 **(2)**
On machinery components, boilers In spaces subject to higher or lower temperatures	According to specific local conditions
On exposed decks	between -25 and +45 **(1)**

WATER TEMPERATURE	
Coolant	Temperature (°C)
Sea water or, if applicable, sea water at charge air coolant inlet	up to +32

(1) Electronic appliances are to be designed for an air temperature up to 55°C (for electronic appliances see also Chapter 2).

(2) Different temperatures may be accepted by the Society in the case of ships intended for restricted service.

Main propulsion systems with reversing gears, controllable pitch propellers or electrical propeller drive are to be designed for the maximum permissible astern power, which is not to lead to an overload of propulsion machinery.

Note 1: The designed maximum astern power, as referred to in SOLAS II-1 / 3.15, defining the maximum astern speed for the design of the main steering gear and rudder stock as per SOLAS II-1 / 29.3.4 and Pt B, Ch 10, Sec 1, [2.1.1], is not to be taken less than the MPAP.

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 (see also Sec 16).

2.9 Safety devices

2.9.1 *Where risk from overspeeding of machinery exists, means are to be provided to ensure that the safe speed is not exceeded.*

2.9.2 *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.*

2.9.3 *Main turbine propulsion machinery and, where applicable, main internal combustion propulsion machinery and auxiliary 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.

2.10 Fuels

2.10.1 *(1/1/2025)*

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. However, for engines driving emergency generators, fuel oils having a flash point of less than 60°C but not less than 43°C are acceptable.

The use of fuel oil having a flashpoint of less than 60º C but not less than 43º C may be permitted (e.g. for feeding the emergency fire pump's engines and auxiliary machines which are not located in category A machinery spaces):

a) for passenger ships not engaged in international voyages and cargo ships of less than 500 gross tonnage or of 500 gross tonnage and upwards not engaged in international voyages or

b) subject to the following:
   - fuel oil tanks except those arranged in double bottom compartments are located outside of category A machinery spaces;
   - *provisions for the measurement of oil temperature are provided on the suction pipe of the fuel oil pump;*
   - stop valves and/or cocks are provided on the inlet side and outlet side of the fuel oil strainers; and
   - pipe joints of welded construction or of circular cone type or spherical type union joint are applied as far as possible.

Fuel oil having flash points of less than 43°C may be employed on board cargo ships provided that it is stored outside machinery spaces and the arrangements adopted are specially approved by the Society.

In tankers, crude oil or slops may be used as fuel for main or auxiliary boilers at the discretion of the Society, subject to the specific requirements given in App 18.

The use of boil-off gas as fuel for boilers or propulsion engines is allowed on gas carriers subject to the requirements of Pt E, Ch 9, Sec 16.

The use of liquefied or compressed natural gas as fuel is allowed on other ship types subject to the specific requirements given in App 7 or on ships in compliance with the latest edition of the International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code), as amended, or equivalent arrangements. The use of LPG or NH3 as fuel is allowed subject to the specific requirements given in App 13. The use of hydrogen as fuel is allowed subject to the specific requirements given in App 14. The use of methyl/ethyl alcohol as fuel is allowed subject to the specific requirements given in App 15. The use of biofuel as fuel is allowed subject to the specific requirements given in App 16. The arrangement on ships of less than 500 gross tonnage is considered by the Society on a case by case basis. The use of other gases as fuel is considered by the Society on a case-by-case basis.

Note 1: The use of gas as fuel in ships requires additional acceptance by the Administration of the State whose flag the ship is entitled to fly.

2.11 Use of asbestos

2.11.1 *(1/1/2011)*

New installation of materials which contain asbestos is prohibited.

3 Arrangement and installation on board

3.1 General

3.1.1 *Provision shall be made to facilitate cleaning, inspection and maintenance of main propulsion and auxiliary machinery, including boilers and pressure vessels.*

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.

3.1.2 *(1/1/2025)*

Machinery and equipment manufacturers are to submit details of the requirements/recommendations for installation of the machinery and equipment onboard to ensure satisfactory operation in service under the required static and dynamic conditions as described in [2.4] and at least at the levels of shipboard accelerations as stated in [1.3.2] and/or specified in Pt E, Ch 9, Sec 5, [3.2].

Note 1: Consideration should be given for positioning machinery in order to minimize the dynamic load on bearings due to ship motion.

3.1.3 *(1/1/2025)*
Shipbuilders are to submit details demonstrating that the installation of the machinery and equipment onboard is in accordance with manufacturer's requirements /recommendations.

3.2 Floors

3.2.1 Floors in engine rooms are to be metallic, divided into easily removable panels.

3.3 Bolting down

3.3.1 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 Sec 7).

3.3.2 Chocking resins are to be type approved.

3.4 Safety devices on moving parts

3.4.1 Suitable protective devices are to be provided in way of moving parts (flywheels, couplings, etc.) in order to avoid injuries to personnel.

3.5 Gauges

3.5.1 All gauges are to be grouped, as far as possible, near each manoeuvring position; in any event, they are to be clearly visible.

3.6 Ventilation in machinery spaces

3.6.1 *(1/1/2012)*
Machinery spaces of category A are to be sufficiently ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions, including heavy weather, an adequate supply of air is maintained to the spaces for the safety and comfort of personnel and the operation of the machinery.

Any other machinery space shall be adequately ventilated in relation to the purpose of that machinery space.

This sufficient amount of air is to be supplied through suitably protected openings arranged in such a way that they can be used in all weather conditions, taking into account Regulation 17(3) and Regulation 19 of the 1966 Load Line Convention as amended by the Protocol of 1988.

Special attention is to be paid both to air delivery and extraction and to air distribution in the various spaces. The quantity and distribution of air are to be such as to satisfy machinery requirements for developing maximum continuous power.

The ventilation is to be so arranged as to prevent any accumulation of flammable gases or vapours.

3.7 Hot surfaces and fire protection

3.7.1 *(1/7/2004)*
Surfaces, having temperature exceeding 60°C, with which the crew are likely to come into contact during operation are to be suitably protected or insulated.

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.

The insulation of hot surfaces is to be of a type and so supported that it does not crack or deteriorate when subject to vibration.

Fire protection, detection and extinction is to comply with the requirements of Chapter 4.

3.8 Communications

3.8.1 *At least two independent means are to be provided for communicating orders from the navigating bridge to the position in the machinery space or in the control room from which the speed and the direction of the thrust of the propellers are normally controlled; one of these is to be an engine room telegraph, which provides visual indication of the orders and responses both in the machinery space and on the navigating bridge,* with audible alarm mismatch between order and response*.*

Appropriate means of communication shall be provided from the navigating bridge and the engine room to any other position from which the speed and direction of thrust of the propellers may be controlled.

The second means for communicating orders is to be fed by an independent power supply and is to be independent of other means of communication.

Where the main propulsion system of the ship is controlled from the navigating bridge by a remote control system, the second means of communication may be the same bridge control system.

The engine room telegraph is required in any case, even if the remote control of the engine is foreseen, irrespective of whether the engine room is attended.

For ships assigned with a restricted navigation notation these requirements may be relaxed at the Society's discretion.

3.9 Machinery remote control, alarms and safety systems

3.9.1 For remote control systems of main propulsion machinery and essential auxiliary machinery and relevant alarms and safety systems, the requirements of Chapter 3 apply.

3.9.2 *An engineers' alarm shall be provided to be operated from the engine control room or at the manoeuvring platform as appropriate, and shall be clearly audible in the engineers' accommodation.*

4 Tests and trials

4.1 Works tests

4.1.1 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.

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 Part D 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.

4.2 Trials on board

4.2.1 Trials on board of machinery are detailed in Sec 16.

SECTION 2 DIESEL ENGINES

1 General

1.1 Application

1.1.1 *(1/7/2024)*

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) main propulsion engines

b) engines driving electrical generators and other auxiliaries essential for safety and navigation and cargo pumps in tankers, when they develop a power of 110 kW and over.

All other engines are to be designed and constructed according to sound marine practice, with the equipment required in [4.3.4], [4.5.2], [4.7.2] [4.7.3], [4.7.5] and [4.7.8] and delivered with the relevant works' certificate (see Pt D, Ch 1, Sec 1, [4.2.3]).

Additional requirements for control and safety systems for dual fuel engines supplied with high pressure methane gas are given in App 2.

Additional requirements for internal combustion engines supplied with low pressure natural gas are given in App 12 and App 17.

In addition to the requirements of this Section, those given in Sec 1 apply.

1.2 Type approval certificate

1.2.1 *(1/7/2016)*

For each type of engine that is required to be certified, a type approval certificate is to be obtained by the engine designer.

The type approval process consists of:

- drawing and specification approval,
- conformity of production,
- approval of type testing programme,
- type testing of engines,
- review of the obtained type testing results,
- evaluation of the manufacturing arrangements,
- issue of a type approval certificate upon satisfactorily meeting the Rule requirements.

1.3 Engine certificate

1.3.1 *(1/7/2016)*

Each diesel engine manufactured for a shipboard application per [1.1.1] is to have an engine certificate:

The certification process consists of:

- the engine builder/licensee obtaining design approval of the engine application specific documents, if any, by submitting a comparison list of the production drawings to the previously approved engine design drawings referenced in [1.2.1]
- forwarding the relevant production drawings and comparison list for the use of the Surveyors at the manufacturing plant and shipyard if necessary
- engine's components testing and engine works trials
- the issuance of an engine certificate upon satisfactorily meeting the Rule requirements.

1.4 Documentation

1.4.1 Document flow for obtaining a type approval certificate *(1/7/2016)*

a) For the initial engine type, the engine designer is to submit to the Society the documentation in accordance with requirements in Tab 1 and Tab 2.

b) Upon review and approval of the submitted documentation (evidence of approval), it will be re-turned to the engine designer.

c) The engine designer arranges for a Surveyor to attend an engine type test

d) Upon satisfactory testing and examination of relevant reports, the Society issues a type approval certificate.

1.4.2 Document flow for engine certificate *(1/7/2016)*

a) The engine type must have a type approval certificate. For the first engine of a type, process and the engine certification process (ECP) may be performed simultaneously.

b) Engines to be installed in specific applications may require the engine designer/licensor to modify the design or performance requirements. The modified drawings are forwarded by the engine designer to the engine builder/licensee to develop production documentation for use in the engine manufacture in accordance with Tab 3.

c) The engine builder/licensee develops a comparison list of the production documentation to the documentation listed in Tab 1 and Tab 2. An example comparison list is provided in App 10. If there are differences in the technical content on the licensee's production drawings/documents compared to the corresponding licensor's drawings, the licensee must obtain agreement to such differences from the designer using the template in App 11.

If the designer agreement is not confirmed, the engine is to be regarded as a different engine type and is to be subjected to the complete type approval process by the licensee.

d) The engine builder/licensee is to submit the comparison list and the production documentation to the Society review/approval.

e) The reviewed/approved documentation is to be used by the engine builder/licensee and their subcontractors and attending Surveyors. The attending Surveyors may request the engine builder/licensee or their subcontractors to provide the actual documents indicated in the list, in which case these are to be made available for the Surveyors.

f) The attending Surveyors, at the engine builder/licensee/subcontractors, will issue product certificates as necessary for components manufactured upon satisfactory inspections and tests.

g) The engine builder/licensee assembles the engine, tests the engine with a Surveyor present.

h) An engine certificate is issued by the Surveyor upon satisfactory completion of assembly and tests.

1.5 Definitions

1.5.1 Engine type *(1/7/2016)*

A type of engine is defined:

- bore and stroke
- injection method (direct or indirect)
- valve and injection operation (by cams or electronically controlled)
- kind of fuel (liquid, dual-fuel, gaseous)
- working cycle (4-stroke, 2-stroke)
- turbo-charging system (pulsating or constant pressure)
- the charging air cooling system (e.g. with or without intercooler)
- cylinder arrangement (in-line or V)
- cylinder power, speed and cylinder pressures.

1.5.2 Ambient reference conditions *(1/7/2016)*

The power of engines as per [1.1.1] (a), and (b) is to be referred to the following ambient reference conditions:

- barometric pressure = 0,1 MPa
- relative humidity = 60%
- ambient air temperature = 45°
- sea water temperature (and temperature at inlet of sea water cooled charge air cooler) = 32°C.

In the case of ships assigned with a navigation notation other than unrestricted navigation, different temperatures may be accepted by the Society.

The engine Manufacturer is not expected to provide the above ambient conditions at a test bed. The rating is to be adjusted according to a recognized standard accepted by the Society.

1.5.3 **Engine power** *(1/7/2016)*

The maximum continuous power is the maximum power at ambient reference conditions [1.5.2] 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 [1.5.2] 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 [1.5.2], which the engine is capable of delivering as set after the works trials [7.4].

1.5.4 **Society Certificate (SC)** *(1/1/2020)*

This is a document issued by the Society stating:

- conformity with Rule requirements,
- that the tests and inspections have been carried out on:
  - the finished certified component itself; or
  - on samples taken from earlier stages in the production of the component, when applicable,
- that the inspection and tests were performed in the presence of the Surveyor or in accordance with special agreements, i.e. Alternative Certification Scheme (ACS).

1.5.5 **Work's Certificate (W)** *(1/1/2020)*

This is a document signed by the manufacturer stating:

- conformity with requirements
- that the tests and inspections have been carried out on:
  - the finished certified component itself; or
  - on samples taken from earlier stages in the production of the component, when applicable,
- that the tests were witnessed and signed by a qualified representative of the applicable department of the manufacturer.

A Work's Certificate may be considered equivalent to a Society Certificate and endorsed by the Society if:

- the test was witnessed by the Society Surveyor; or
- an ACS agreement is in place between the Class Society and the manufacturer or material supplier; or
- the Work's certificate is supported by tests carried out by an accredited third party that is accepted by the Society and independent from the manufacturer and/or material supplier.

1.5.6 **Test Report (R)** *(1/1/2020)*

This is a document signed by the manufacturer stating:

- conformity with requirements
- that the tests and inspections have been carried out on samples from the current production batch.

1.5.7 *(1/7/2016)*

Low-Speed Engines means diesel engines having a rated speed of less than 300 rpm.

1.5.8 *(1/7/2016)*

Medium-Speed Engines means diesel engines having a rated speed of 300 rpm and above, but less than 1400 rpm.

1.5.9 *(1/7/2016)*

High-Speed Engines means diesel engines having a rated speed of 1400 rpm or above.

2 Type approval process

2.1 Type approval step and documentation

2.1.1 *(1/7/2016)*

The type approval process consists of the steps in [2.2] to [2.5].

The documentation, as far as applicable to the type of engine, to be submitted by the engine design-er/licensor is listed in Tab 1 and Tab 2.

2.2 Documentation for information Table 1

2.2.1 *(1/7/2016)*

Tab 1 lists basic descriptive information required to be submitted to provide an overview of the engine's design, engine characteristics and performance.

2.3 Documentation for approval or recalculation Table 2

2.3.1 *(1/7/2016)*

Tab 2 lists the documents and drawings, which are to be submitted for approval.

2.4 Design approval (DA)

2.4.1 *(1/7/2016)*

DA's are valid as long as no substantial modifications have been implemented. Where substantial modifications have been made the validity of the DA's may be renewed based on evidence that the design is in conformance with all current Rules and statutory regulations (e.g. SOLAS, MARPOL). See also [4.6].

2.5 Type approval test

2.5.1 *(1/7/2016)*

A type approval test is to be carried out in accordance with [6] and is to be witnessed by the Classification Society.

The manufacturing facility of the engine presented for the type approval test is to be assessed in accordance with [7.1].

2.6 Type approval certificate

2.6.1 *(1/7/2016)*

After the requirements in [2.2] to [2.5] have been satisfactorily completed the Classification Society issues a type approval certificate (TAC).

2.7 Design modifications

2.7.1 *(1/7/2016)*

After the Classification Society has approved the engine type for the first time, only those documents as listed in the tables, which have undergone substantive changes, will have to be resubmitted for consideration by the Classification Society.

2.7.2 *(1/7/2016)*

Where changes are proposed to be carried out to a type approved engine, if the responsible party submits to the Society for consideration and/or approval those documents concerning the engine parts which have undergone changes and the proposed modifications are evaluated by the Society as non-substantial, the type approval may be considered as extended to the modified engine without a new type test.

2.8 Type approval certificate renewals

2.8.1 *(1/7/2016)*

A renewal of a Design Approval (DA) certificate will be granted upon.

Submission of information in either a) or b).

a) The submission of modified documents or new documents with substantial modifications replacing former documents compared to the previous sub-mission(s) for DA.

b) A declaration that no substantial modifications have been applied since the last DA issued.

2.9 Validity of type approval certificate

2.9.1 *(1/7/2016)*

The Society reserves the right to limit the duration of validity of the type approval certificate. The type approval certificate will be invalid if there are substantial modifications in the design, in the manufacturing or control processes or in the characteristics of the materials unless approved in advance by the Society.

2.10 Document review and approval

2.10.1 *(1/7/2016)*

The assignment of documents to Tab 1 for information does not preclude possible comments by the Society.

2.10.2 *(1/7/2016)*

Where considered necessary, the Society may request further documents to be submitted. This may include details or evidence of existing type approval or proposals for a type testing program in accordance with [6].

3 Certification process

3.1 Certification step and documentation

3.1.1 *(1/7/2016)*

The certification process consists of the steps in [3.2] to [3.7].

For those cases when a licensor - licensee agreement does NOT apply, an "engine designer" shall be understood as the entity that has the design rights for the engine type or is delegated by the entity having the design rights to modify the design.

The documents listed in Tab 3 may be submitted by:

- the engine designer (licensor),
- the manufacturer/licensee.

Table 1 : Documentation to be submitted for information, as applicable *(1/7/2022)*

No.	Item
1	Engine particulars (e.g. Data sheet with general engine information (see App 9), Project Guide, Marine Installation Manual)
2	Engine cross section
3	Engine longitudinal section
4	Bedplate and crankcase of cast design
5	Thrust bearing assembly **(1)**
6	Frame/framebox/gearbox of cast design **(2)**
7	Tie rod
8	Connecting rod
9	Connecting rod, assembly **(3)**
10	Crosshead, assembly

(1) If integral with engine and not integrated in the bedplate.
(2) Only for one cylinder or one cylinder configuration.
(3) Including identification (e.g. drawing number) of components.
(4) Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.
(5) Where engines rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves, a failure mode and effects analysis (FMEA) is to be submitted to demonstrate that failure of the control system will not result in the operation of the engine being degraded beyond acceptable performance criteria for the engine.
(6) Tests are to demonstrate the ability of the control, protection and safety equipment to function as intended under the specified testing conditions per Ch 3, Sec 8.

No.	Item
11	Piston rod, assembly **(3)**
12	Piston, assembly **(3)**
13	Cylinder jacket/ block of cast design **(2)**
14	Cylinder cover, assembly **(3)**
15	Cylinder liner
16	Counterweights (if not integral with crankshaft), including fastening
17	Camshaft drive, assembly **(3)**
18	Flywheel
19	Fuel oil injection pump
20	Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly
	For electronically controlled engines, construction and arrangement of:
21	• Control valves
22	• High-pressure pumps
23	• Drive for high pressure pumps
24	Operation and service manuals **(4)**
25	FMEA (for engine control system) **(5)**
26	Production specifications for castings and welding (sequence)
27	Evidence of quality control system for engine design and in service maintenance
28	Evidence of quality control system for engine design and in service maintenance
29	Type approval certification for environmental tests, control components **(6)**

(1) If integral with engine and not integrated in the bedplate.

(2) Only for one cylinder or one cylinder configuration.

(3) Including identification (e.g. drawing number) of components.

(4) Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.

(5) Where engines rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves, a failure mode and effects analysis (FMEA) is to be submitted to demonstrate that failure of the control system will not result in the operation of the engine being degraded beyond acceptable performance criteria for the engine.

(6) Tests are to demonstrate the ability of the control, protection and safety equipment to function as intended under the specified testing conditions per Ch 3, Sec 8.

3.2 Document development for production

3.2.1 *(1/7/2016)*

Prior to the start of the engine certification process, a design approval is to be obtained per [2.2] through [2.4] for each type of engine. Each type of engine is to be provided with a type approval certificate obtained by the engine designer/licensor prior to the engine builder/licensee beginning production manufacturing. For the first engine of a type, the type approval process and the certification process may be performed simultaneously.

The engine designer/licensor reviews the documents listed in Tab 1 and Tab 2 for the application and develops, if necessary, application specific documentation for the use of the engine builder/licensee in developing engine specific production documents.

If substantive changes have been made, the affected documents are to be resubmitted to the Classification Society as per [2.7].

3.3 Documents to be submitted for inspection and testing

3.3.1 *(1/7/2016)*

[2.7] lists the production documents, which are to be submitted by the engine builder/licensee to the Classification Society following acceptance by the engine designer/licensor. The Surveyor uses the information for inspection purposes during manufacture and testing of the engine and its components. See [3.3] through [3.6].

3.4 Alternative execution

3.4.1 *(1/7/2016)*

If there are differences in the technical content on the licensee's production drawings/documents compared to the corresponding licensor's drawings, the licensee must provide to the Society a "Confirmation of the licensor's acceptance of licensee's modifications" approved by the licensor and signed by licensee and licensor. Modifications applied by the licensee are to be provided with appropriate quality requirements.

3.5 Manufacturer approval

3.5.1 *(1/7/2016)*

The Classification Society assesses conformity of production with the Classification Society's requirements for production facilities comprising manufacturing facilities and processes, machining tools, quality assurance, testing facilities, etc. See [7.1] Satisfactory conformance results in the issue of a class approval document.

3.6 Document availability

3.6.1 *(1/7/2016)*

In addition to the documents listed in Tab 3, the engine builder/licensee is to be able to provide to the Surveyor performing the inspection upon request the relevant detail drawings, production quality control specifications and acceptance criteria. These documents are for supplemental purposes to the survey only.

3.7 Engine assembly and testing

3.7.1 *(1/7/2016)*

Engine assembly and testing procedure are to be carried out under survey of a Society surveyor unless an Alternative Certification Scheme is agreed between manufacturer and the Society.

Table 2 : Documentation to be submitted for approval, as applicable *(1/7/2016)*

No.	Item
1	Bedplate and crankcase of welded design, with welding details and welding instructions **(1)**, **(2)**
2	Thrust bearing bedplate of welded design, with welding details and welding instructions **(1)**
3	Bedplate/oil sump welding drawings
4	Frame/framebox/gearbox of welded design, with welding details and instructions **(1)**, **(2)**
5	Engine frames, welding drawings **(1)**, **(2)**
6	Crankshaft, details, each cylinder No.
7	Crankshaft, assembly, each cylinder No.
8	Crankshaft calculations (for each cylinder configuration) according to App 9
9	Thrust shaft or intermediate shaft (if integral with engine)

(1) For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.
(2) For each cylinder for which dimensions and details differ.
(3) For comparison with Society requirements for material, NDT and pressure testing as applicable.
(4) All engines.
(5) Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m^3 or more.
(6) The documentation to contain specifications for pressures, pipe dimensions and materials.
(7) The type test report may be submitted shortly after the conclusion of the type test.

No.	Item
10	Shaft coupling bolts
11	Material specifications of main parts with information on non-destructive material tests and pressure tests
	Schematic layout or other equivalent documents on the engine of:
12	• Starting air system
13	• Fuel oil system
14	• Lubricating oil system
15	• Cooling water system
16	• Hydraulic system
17	• Hydraulic system (for valve lift)
18	• Engine control and safety system
19	Shielding of high pressure fuel pipes, assembly **(4)**
20	Construction of accumulators (for electronically controlled engine)
21	Construction of common accumulators (for electronically controlled engine)
22	Arrangement and details of the crankcase explosion relief valve **(5)**
23	Calculation results for crankcase explosion relief valves
24	Details of the type test program and the type test report) **(7)**
25	High pressure parts for fuel oil injection system **(6)**
26	Oil mist detection and/or alternative alarm arrangements
27	Details of mechanical joints of piping systems (see Sec 10)
28	Documentation verifying compliance with inclination limits (see Sec 1)
29	Documents as required in Ch 3, Sec 3 as applicable

(1) For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.

(2) For each cylinder for which dimensions and details differ.

(3) For comparison with Society requirements for material, NDT and pressure testing as applicable.

(4) All engines.

(5) Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m^3 or more.

(6) The documentation to contain specifications for pressures, pipe dimensions and materials.

(7) The type test report may be submitted shortly after the conclusion of the type test.

Table 3 : Documentation for the inspection of components and systems *(1/7/2016)*

No.	Item
1	Engine particulars as per data sheet in App 9
2	Material specifications of main parts with information on non-destructive material tests and pressure tests **(1)**
3	Bedplate and crankcase of welded design, with welding details and welding instructions **(2)**
4	Thrust bearing bedplate of welded design, with welding details and welding instructions **(2)**
5	Frame/framebox/gearbox of welded design, with welding details and instructions **(2)**
6	Crankshaft, assembly and details
7	Thrust shaft or intermediate shaft (if integral with engine)
8	Shaft coupling bolts
9	Bolts and studs for main bearings
10	Bolts and studs for cylinder heads and exhaust valve (two stroke design)
11	Bolts and studs for connecting rods
12	Tie rods
	Schematic layout or other equivalent documents on the engine of:
13	• Starting air system
14	• Fuel oil system
15	• Lubricating oil system
16	• Cooling water system
17	• Hydraulic system
18	• Hydraulic system (for valve lift)
19	• Engine control and safety system
20	Shielding of high pressure fuel pipes, assembly **(4)**
21	Construction of accumulators for hydraulic oil and fuel oil
22	High pressure parts for fuel oil injection system **(5)**
23	Arrangement and details of the crankcase explosion relief valve (see [2.3]) **(6)**
24	Oil mist detection and/or alternative alarm arrangements (see [2.3])
25	Cylinder head
26	Cylinder block, engine block
27	Cylinder liner
28	Counterweights (if not integral with crankshaft), including fastening

(1) For comparison with Society requirements for material, NDT and pressure testing as applicable.

(2) For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.

(3) Details of the system so far as supplied by the engine manufacturer such as: main dimensions, operating media and maximum working pressures.

(4) All engines.

(5) The documentation to contain specifications for pressures, pipe dimensions and materials.

(6) Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m^3 or more.

(7) Including identification (e.g. drawing number) of components.

(8) Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.

(9) Required for engines that rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves.

(10) Documents modified for a specific application are to be submitted to the Classification Society for information or approval, as applicable. See [3.2], App 9 and App 10.

No.	Item
29	Connecting rod with cap
30	Crosshead
31	Piston rod
32	Piston, assembly **(7)**
33	Piston head
34	Camshaft drive, assembly **(7)**
35	Flywheel
36	Arrangement of foundation (for main engines only)
37	Fuel oil injection pump
38	Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly
39	Construction and arrangement of dampers
	For electronically controlled engines, assembly drawings or arrangements of:
40	• Control valves
41	• High-pressure pumps
42	• Drive for high pressure pumps
43	• Valve bodies, if applicable
44	Operation and service manuals **(8)**
45	Test program resulting from FMEA (for engine control system) **(9)**
46	Production specifications for castings and welding (sequence)
47	Type approval certification for environmental tests, control components **(10)**
48	Quality requirements for engine production

(1) For comparison with Society requirements for material, NDT and pressure testing as applicable.

(2) For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.

(3) Details of the system so far as supplied by the engine manufacturer such as: main dimensions, operating media and maximum working pressures.

(4) All engines.

(5) The documentation to contain specifications for pressures, pipe dimensions and materials.

(6) Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m^3 or more.

(7) Including identification (e.g. drawing number) of components.

(8) Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.

(9) Required for engines that rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves.

(10) Documents modified for a specific application are to be submitted to the Classification Society for information or approval, as applicable. See [3.2], App 9 and App 10.

4 Design and construction

4.1 Materials and welding

4.1.1 Crankshaft materials *(1/7/2016)*

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 or spheroidal or nodular graphite cast iron of appropriate quality and manufactured by a suitable procedure having a tensile strength as follows:

a) between 400 N/mm^2 and 560 N/mm^2 for cast carbon steel

b) between 400 N/mm^2 and 700 N/mm^2 for cast alloyed steel.

The acceptable values of tensile strength for spheroidal or nodular graphite cast iron will be considered by the Society on a case by case basis.

4.1.2 Welded frames and foundations *(1/7/2016)*

Steels used in the fabrication of welded frames and bedplates are to comply with the requirements of Part D.

Welding is to be in accordance with the requirements of Sec 1, [2.2].

4.2 Crankshaft

4.2.1 Check of the scantling *(1/7/2016)*

The check of crankshaft strength is to be carried out in accordance with App 1.

4.3 Crankcase

4.3.1 Strength *(1/7/2016)*

Crankcase construction and crankcase doors are to be of sufficient strength to withstand anticipated crankcase pressures that may arise during a crankcase explosion taking into account the installation of explosion relief valves required in [4.3.4]. Crankcase doors are to be fastened sufficiently securely for them not be readily displaced by a crankcase explosion.

4.3.2 Ventilation and drainage *(1/1/2026)*

Ventilation of the crankcase, or any arrangement which could produce a flow of external air into the crankcase, is in principle not permitted except for engines fuelled with gas or low-flashpoint fuel, where this might be necessary to maintain the gas concentration in the crankcase below LEL provided that:

a) it is demonstrated that the risk connected with a crankcase explosion is not increased by the ventilation system

b) the operation of the ventilation system is monitored

c) the automatic safety actions to be activated and/or the risk mitigation measures to be implemented in case of detection of a ventilation failure are specified by the engine manufacturer and justified in the safety concept of the engine.

Note 1: LEL means the Lower Explosive Limit, as defined in IEC 60079-10-1 (February 2021) standard, paragraph 3.6.12. The lowest applicable LEL of all possible gas or low flashpoint fuels, fuel vapours or mixture is to be considered.

Where provided, crankcase ventilation pipes are to be as small as practicable to minimise the inrush of air after a crankcase explosion.

When forced extraction of crankcase atmosphere is provided, the crankcase pressure level is not to influence the reliable function of measurement and safety devices (such as oil mist detection) in the crankcase.

To avoid interconnection between crankcases and the possible spread of fire following an explosion, crankcase ventilation pipes and oil drain pipes for each engine are to be independent of any other engine.

For engines fuelled with gas or low flashpoint fuel a detailed evaluation regarding the safety of crankcase is to be carried out justifying that:

a) either the gas concentration in the crankcase remains below the LEL without specific measures, or

b) the risk of a crankcase explosion is reduced through specific measures (see, for example, [4.3.2] or [4.3.5]).

Lubricating oil drain pipes from the engine sump to the drain tank are to be continuously submerged at their outlet ends.

4.3.3 Warning notice *(1/7/2016)*

A warning notice is to be fitted either on the control stand or, preferably, on a crankcase door on each side of the engine.

This warning notice is to specify that, whenever overheating is suspected within the crankcase, the crankcase doors or sight holes are not to be opened before a reasonable time has elapsed, sufficient to permit adequate cooling after stopping the engine.

4.3.4 Relief valves *(1/7/2016)*

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 according to the requirements of this item [4.3.4].

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).

b) 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 the inrush of air thereafter.

The valve discs in relief valves are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

Relief valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,02 N/mm^2.

The free area of each crankcase explosion relief valve is not to be less than 45 cm^2. The aggregate 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.

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.

Relief valves are to be type approved. Type testing is to be carried out in a configuration that represents the installation arrangements that will be used on an engine in accordance with App 5.

Where 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.

c) 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:

1) Description of valve with details of function and design limits
2) Copy of type test certification
3) Installation instructions
4) Maintenance in service instructions to include testing and renewal of any sealing arrangements
5) Actions required after a crankcase explosion.

A copy of the installation and maintenance manual required above is to be provided on board ship.

Plans showing details and arrangements of crankcase explosion relief valves are to be submitted for approval in accordance with Tab 1.

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.

d) Engines of a cylinder diameter of 200 mm and above, but not exceeding 250 mm, are to have at least one valve near each end; however, for engines with more than 8 crankthrows, an additional valve is to be fitted near the middle of the engine.

Engines of a cylinder diameter of 250 mm and above, 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 of a cylinder diameter exceeding 300 mm are to have at least one valve in way of each main crankthrow.

e) 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.

4.3.5 Oil mist detection/monitoring arrangements *(1/1/2026)*

Oil mist detection arrangements (or engine bearing temperature monitors or equivalent devices) are required:

- for alarm and slowdown purposes for low-speed I.C engines of 2250 kW and above or having cylinders of more than 300 mm bore (see Note 1)
- for alarm and automatic shut-off purposes for medium- and high-speed I.C engines of 2250 kW and above or having cylinders of more than 300 mm bore (see Note 1).

Note 1:

- Low-Speed Engines means diesel I.C engines having a rated speed of less than 300 rpm.
- Medium-Speed Engines means diesel I.C engines having a rated speed of 300 rpm and above, but less than 1400 rpm.
- High-Speed Engines means diesel I.C engines having a rated speed of 1400 rpm and above.

Oil mist detection arrangements are to be of a type approved by the Society and tested in accordance with App 6 and are to comply with the requirements indicated hereinafter.

Engine bearing temperature monitors or equivalent devices (see Note 2) used as safety devices are to be of a type approved by classification societies for such purposes.

Note 2: Engine bearing temperature monitors or equivalent devices are defined as follows:

a) For crosshead engines:

The wording “engine bearing” of the term “engine bearing temperature monitors or equivalent devices” includes at least journal and connecting rod bearings and the crosshead bearings.

b) For trunk piston engines:

“Engine bearing temperatures monitors” may be accepted as an alternative to the oil mist detector only when the temperature of all bearings, including the piston pin bearings, are monitored.

c) The expression “equivalent devices” includes measures applied to engines where specific design features to preclude the risk of crankcase explosion are incorporated, subject to satisfactory justifications.

d) The examples of acceptable “temperature monitors or equivalent devices” are as follows:

1) a temperature monitoring system of the bearing concerned
2) a bearing oil outlet temperature monitoring system
3) a splash oil temperature monitoring system
4) measures applied to engines where specific design features to preclude the risk of crankcase explosions are incorporated, subject to satisfactory justifications.

The oil mist detection system and arrangements are to be installed in accordance with the engine Designer's and oil mist detection system Manufacturer's instructions/recommendations. The following particulars are to be included in the instructions:

- Schematic layout of engine oil mist detection and alarm system showing location of engine crankcase sample points and piping or cable arrangements together with pipe dimensions to detector
- The Manufacturer's maintenance and test manual
- Information relating to type or in-service testing of the engine carried out with engine protection system test arrangements having approved types of oil mist detection equipment.

A copy of the oil mist detection equipment maintenance and test manual required above is to be provided on board ship.

Oil mist detection and alarm information is to be capable of being read from a safe location away from the engine.

Each engine is to be provided with its own independent oil mist detection arrangement and a dedicated alarm.

Oil mist detection and alarm systems are to be capable of being tested on the test bed and on board under engine at standstill and engine running at normal operating conditions in accordance with test procedures that are acceptable to the Society.

Alarms and shutdowns for the oil mist detection/monitoring system are to be in accordance with Pt F, Ch 3, Sec 1, Tab 2, Pt F, Ch 3, Sec 1, Tab 3 and Pt F, Ch 3, Sec 1, Tab 27 and the system arrangements are to comply with Ch 3, Sec 2, [6] and Ch 3, Sec 2, [7].

The oil mist detection arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements.

The oil mist detection system is to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

Where oil mist detection equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with Chapter 3.

Plans showing details and arrangements of oil mist detection and alarm arrangements are to be submitted for approval in accordance with Tab 2, item 26.

Documentation containing evidence of studies justifying the selected location of sample points and the sample extraction rate (if applicable), supported by a confirmation from the oil mist detection system manufacturer, from the crankcase and the spaces mentioned in [4.3.4] e), is to be provided to the Society for reference purposes only.

As an alternative to the evidence of studies, an oil mist inlet test may be performed on a running engine. Test conditions such as setup, records or engine loads are to be agreed upon between engine designer, oil mist detector (OMD) manufacturer and respective class society. The test engine is to be chosen to demonstrate OMD arrangement suitability to cover a specified range of engine types and configurations. To allow a repeatable and comparable test, an oil mist generator as described under App 6 is to be used.

The equipment together with detectors is to be tested when installed on the test bed and on board ship to demonstrate that the detection and alarm system functionally operates. The testing arrangements are to be to the satisfaction of the Society.

Where sequential oil mist detection arrangements are provided, the sampling frequency and time are to be as short as reasonably practicable.

Where alternative methods are provided for the prevention of the build-up of potentially explosive oil mist conditions within the crankcase, details are to be submitted for consideration. The following information is to be included in the details to be submitted for consideration:

- Engine particulars - type, power, speed, stroke, bore and crankcase volume
- Details of arrangements to prevent the build-up of potentially explosive conditions within the crankcase, e.g. bearing temperature monitoring, oil splash temperature, crankcase pressure monitoring, recirculation arrangements
- Evidence to demonstrate that the arrangements are effective in preventing the build-up of potentially explosive conditions together with details of in-service experience
- Operating instructions and the maintenance and test instructions.

Where it is proposed to use the introduction of inert gas into the crankcase to minimise a potential crankcase explosion, details of the arrangements are to be submitted to the Society for consideration.

4.4 Scavenge manifolds

4.4.1 Fire extinguishing *(1/7/2016)*

For two-stroke crosshead type engines, scavenge spaces in open connection (without valves) to the cylinders are to be connected to a fixed fire-extinguishing system, which is to be entirely independent of the fire-extinguishing system of the machinery space.

4.4.2 Blowers *(1/7/2016)*

Where a single two-stroke propulsion engine is equipped with an independently driven blower, alternative means to drive the blower or an auxiliary blower are to be provided ready for use.

4.4.3 Relief valves *(1/7/2016)*

Scavenge spaces in open connection to the cylinders are to be fitted with explosion relief valves in accordance with [4.3.4].

4.5 Systems

4.5.1 General *(1/7/2016)*

In addition to the requirements of the present sub-article, those given in Sec 10 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.

Unless otherwise stated in Sec 10, propulsion engines are to be equipped with external connections for standby pumps for:

- fuel oil supply
- lubricating oil and cooling water circulation.

4.5.2 Fuel oil system *(1/7/2016)*

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 Sec 10.

a) 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.

b) For ships classed for restricted navigation, the requirements under a) may be relaxed at the Society's discretion.

4.5.3 Lubricating oil system *(1/7/2016)*

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 Sec 10.

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.

4.5.4 Charge air system *(1/7/2016)*

a) Requirements relevant to design, construction, arrangement, installation, tests and certification of exhaust gas turbochargers are given in Sec 14.

b) When two-stroke propulsion engines are supercharged by exhaust gas turbochargers which operate on the impulse system, provision is to be made to prevent broken piston rings entering turbocharger casings and causing damage to blades and nozzle rings.

4.6 Starting air system

4.6.1 *(1/7/2016)*

The requirements given in [5.1] apply.

4.7 Control and monitoring

4.7.1 General *(1/7/2016)*

In addition to those of this item [4.7], the general requirements given in Chapter 3 apply.

In the case of ships with automation notations, the requirements in Part F, Chapter 3 also apply.

4.7.2 Alarm *(1/7/2016)*

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.

4.7.3 Governors of main and auxiliary engines *(1/7/2016)*

Each engine, except the auxiliary engines for driving electric generators for which [4.7.5] applies, is to be fitted with a speed governor so adjusted that the engine does not exceed the rated speed by more than 15%.

4.7.4 Overspeed protective devices of main and auxiliary engines *(1/7/2016)*

In addition to the speed governor, each

- main propulsion engine having a rated power of 220kW and above, which can be declutched or which drives a controllable pitch propeller, and
- auxiliary engine having a rated power of 220kW and above, except those for driving electric generators, for which [4.7.6] applies

is to be fitted with a separate overspeed protective device so adjusted that the engine cannot exceed the rated speed n by more than 20%; arrangements are to be made to test the overspeed protective device.

Equivalent arrangements may be accepted subject to special consideration by the Society in each case.

The overspeed protective device, including its driving mechanism or speed sensor, is to be independent of the governor.

4.7.5 Governors for auxiliary engines driving electric generators *(1/1/2020)*

a) Auxiliary engines intended for driving electric generators are to be fitted with a speed governor which prevents transient frequency variations in the electrical network in excess of ±10% of the rated frequency with a recovery time to steady state conditions not exceeding 5 seconds, when the maximum electrical step load is switched on or off.

When a step load equivalent to the rated output of a generator is switched off, a transient speed variation in excess of 10% of the rated speed may be acceptable, provided this does not cause the intervention of the overspeed device as required by [4.7.4].

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) Prime movers are to be selected in such a way that they meet the load demand within the ship's mains and, when running at no load, can satisfy the requirement in item a) above if suddenly loaded to 50% of the rated power of the generator, followed by the remaining 50% after an interval sufficient to restore speed to steady state. Steady state conditions (see Note 1) are to be achieved in not more than 5 s.

Note 1: Steady state conditions are those at which the envelope of speed variation does not exceed ±1% of the declared speed at the new power.

d) 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 on 4-stroke diesel engines expected maximum possible sudden power increase) 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.

e) Emergency generator sets must satisfy the governor conditions as per items a) and b), even when:

1) their total consumer load is applied suddenly, or

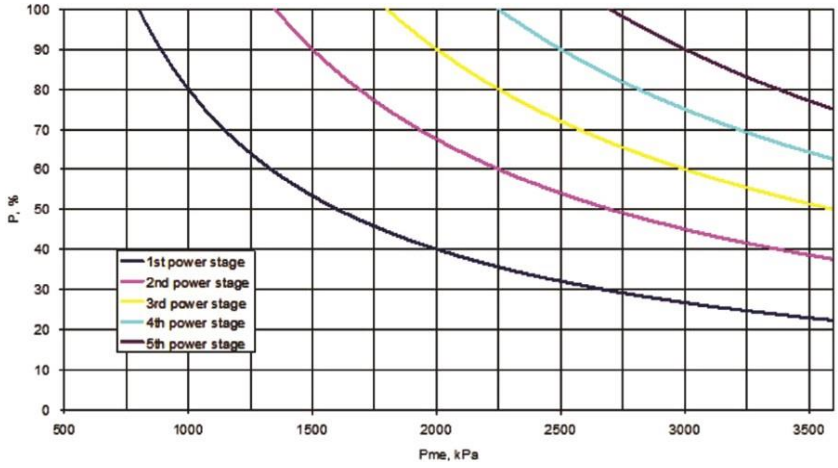
2) their total consumer load is applied in steps, provided that:

- the total load is supplied within 45 seconds of power failure on the main switchboard, and
- the maximum step load is declared and demonstrated, and
- the power distribution system is designed such that the declared maximum step loading is not exceeded, and
- compliance of time delays and loading sequence with the above is demonstrated at ship's trials.

f) For alternating current generating sets operating in parallel, the governing characteristics of the prime movers are to be such that, within the limits of 20% and 100% total load, the load on any generating set will not normally differ from its proportionate share of the total load by more than 15% of the rated power in kW of the largest machine or 25% of the rated power in kW of the individual machine in question, whichever is the lesser.

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 : Reference values for maximum possible sudden power increases as a function of brake mean effective pressure, Pme, at declared power (four-stroke diesel engines) *(1/1/2020)*



Pme: declared power mean effective pressure

P : power increase referred to declared power at site conditions

1 : first power stage - 2 : second power stage - 3 : third power stage - 4 : fourth power stage - 5 : fifth power stage

4.7.6 Overspeed protective devices of auxiliary engines driving electric generators *(1/7/2016)*

In addition to the speed governor, auxiliary engines of rated power equal to or greater than 220 kW driving electric generators are to be fitted with a separate overspeed protective device, with a means for manual tripping, adjusted so as to prevent the rated speed from being exceeded by more than 15%.

This device is to automatically shut down the engine.

4.7.7 Use of electronic governors *(1/1/2017)*

a) Type approval

Electronic governors and their actuators are to be type approved by the Society, according to Ch 3, Sec 8.

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.

d) The acceptance of electronic governors fitted on engines driving emergency generators will be considered by the Society on a case by case basis, anyway, a back-up pre-programmed governor is to be provided for immediate replacement in case of failure of the governor in use; if practicable, the backup governor is to be in place, fixed to the engine in a position near to the governor in use, and arranged so that the exchange is quick, easy and error-free; special consideration is to be given to the governor power supply.

4.7.8 Alarms and safeguards for emergency reciprocating I.C. engines *(1/7/2025)*

a) These requirements apply to reciprocating I.C. engines, which use distillate marine fuels covered by ISO 8217:2024, required to be immediately available in an emergency (i.e. emergency generating set engine, emergency fire pump engine, etc.) and capable of being controlled remotely or automatically operated.

b) Information demonstrating compliance with these requirements is to be submitted to the Society. The information is to include instructions to test the alarm and safety systems.

c) The alarms and safeguards are to be fitted in accordance with Tab 6. It is the responsibility of the Manufacturer to set the alarms and safeguards so that they activate when the controlled parameter deviates from normal values but before reaching hazardous conditions.

d) The safety and alarm systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the system and its associated machinery, but also the complete installation, as well as the ship.

e) Regardless of the engine output, if shutdowns additional to those specified in Tab 6, except for the overspeed shutdown, are provided, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.

f) The alarm system is to function in accordance with Part F, Chapter 3 with the additional requirement that grouped alarms are to be arranged on the bridge.

g) In addition to the fuel oil control from outside the space, a local means of engine shutdown is to be provided.

h) Local indications of at least those parameters listed in are Tab 6 to be provided within the same space as the reciprocating I.C engines and are to remain operational in the event of failure of the alarm and safety systems.

4.7.9 Summary tables *(1/7/2021)*

Diesel engines are to be equipped with monitoring equipment as detailed in Tab 4 and Tab 5, for main propulsion and auxiliary services, respectively.

For ships classed for restricted navigation, the acceptance of a reduction in the monitoring equipment required in Tab 4 and Tab 5 may be considered.

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).

It is the responsibility of the Manufacturer to set the alarms and safeguards so that they activate when the controlled parameter deviates from normal values but before reaching hazardous conditions.

In the case of diesel engines required to be immediately available in an emergency and capable of being controlled remotely or automatically operated, Tab 6 applies.

Table 4 : Monitoring of main propulsion diesel engines *(1/7/2021)*

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
Fuel oil pressure after filter (engine inlet)		local					
Fuel oil viscosity before injection pumps or fuel oil temperature before injection pumps (For engine running on heavy fuel)		local					
Leakage from high pressure pipes where required	H						
Lubricating oil to main bearing and thrust bearing pressure **(5)**	L	local					
	LL			X			
Lubricating oil to cross-head bearing pressure when separate **(5)**	L	local					
	LL			X			
Lubricating oil to camshaft pressure when separate **(5)**	L	local					
	LL			X			
Turbocharger lubricating oil inlet pressure		local					
Lubricating oil inlet temperature		local					
Thrust bearing pads or bearing outlet temperature	H	local					
Cylinder fresh cooling water system inlet pressure	L	local **(3)**					
Cylinder fresh cooling water outlet temperature or, when common cooling space without individual stop valves, the common cylinder water outlet temperature		local					
Piston coolant inlet pressure on each cylinder **(1)**	L	local					
Piston coolant outlet temperature on each cylinder **(1)**		local					
Piston coolant outlet flow on each cylinder **(1) (2)**	L						
Scavenging air receiver pressure		local					
Scavenging air box temperature (Detection of fire in receiver)		local					
Exhaust gas temperature		local **(4)**					

(1) Not required, if the coolant is oil taken from the main cooling system of the engine

(2) Where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted

(3) For engines of 220 kW and above

(4) Indication is required after each cylinder, for engines of 500 kW/cylinder and above

(5) To ensure independency of safety functions from control and monitoring functions, a separate sensor is to be installed for each row of the table.

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
Engine speed / direction of speed (when reversible) **(5)**		local					
	H			X			
Fault in the electronic governor system	X						

(1) Not required, if the coolant is oil taken from the main cooling system of the engine
(2) Where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted
(3) For engines of 220 kW and above
(4) Indication is required after each cylinder, for engines of 500 kW/cylinder and above
(5) To ensure independency of safety functions from control and monitoring functions, a separate sensor is to be installed for each row of the table.

Table 5 : Monitoring of diesel engines used for auxiliary services *(1/7/2021)*

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 **(2)**		local					
Fuel oil pressure **(2)**		local					
Fuel oil leakage from pressure pipes	H						
Lubricating oil pressure	L	local		X **(1)**			
Pressure or flow of cooling water, if not connected to main system	L	local					
Temperature of cooling water or cooling air		local					
Engine speed **(4)**		local					
	H			X **(3)**			
Fault in the electronic governor system	X						

(1) Not acceptable to emergency generator set
(2) Where heavy fuel is used
(3) Only requested for diesel engines having rating of 220 kW and above
(4) To ensure independency of safety functions from control and monitoring functions, a separate sensor is to be installed for each row of the table.

Table 6 : Monitoring of reciprocating I.C. engines required to be immediately available in an emergency and capable of being controlled remotely or automatically operated *(1/1/2024)*

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 activation	Indication	Slow-down	Shut-down with alarm	Control	Stand by Start	Stop
Fuel oil leakage from high pressure pipes (fuel injection pipes and common rails)	X						
Lubricating oil pressure	L	local					
Lubricating oil temperature **(1)**	H	local					
Pressure or flow of cooling water **(1)**	L	local					
Activation of oil mist detection arrangements (or activation of the temperature monitoring systems or equivalent devices of: • the engine main and crank bearing oil outlet; or • the engine main and crank bearing) **(2)**	X	local					
Temperature of cooling water or cooling air	H	local					
Engine Overspeed activated **(1)**, **(3)**		local					
				X			
Fault in the electronic governor system	X						

(1) Requested only for engines having a power of or more than 220 kW .

(2) Requested only for engines having a power of or more than 2250 kW or cylinder bore of 300 mm and above

(3) To ensure independency of safety functions from control and monitoring functions, a separate sensor is to be installed for each row of the table.

5 Arrangement and installation

5.1 Starting arrangements

5.1.1 Mechanical air starting *(1/7/2025)*

a) Air starting the main and auxiliary engines is to be arranged such that the necessary air for the first charge can be produced on board the ship without external aid.

b) The total capacity of air receivers is to be sufficient to provide, without replenishment, not less than 12 consecutive starts alternating between ahead and astern of each main engine of the reversible type, and not less than 6 consecutive starts of each main non-reversible type engine connected to a controllable pitch propeller or other device enabling the start without opposite torque.

When other users such as auxiliary engine starting systems, low-pressure compressed air systems (see Sec 10, [17.3.2.2]), control systems, whistle etc. are connected to the starting air receivers of main propulsion engines, their air consumption is also to be taken into account.

Regardless of the above, for multi-engine installations the total number of starts required to be provided from the starting air receivers is indicated in Tab 7, valid when all the air receivers may be used to start all propulsion engines; if each engine or group of engines connected to a shaft is fitted with dedicated air receivers, the minimum number of starts for each group of engines connected to the same shaft is 12 for reversible engines and 6 for non-reversible engines.

In case of Diesel-electric or turbine-electric propulsion, the minimum number of total consecutive starts required to be provided from the starting air receivers is to be determined from the following equation:

$S = 6 + N (N - 1)$

where

S : total number of consecutive starts

N : number of engines. (need not to be greater than 3).

c) If other compressed air systems, such as control air, are supplied from the same starting air receivers, the total capacity of the receivers is to be sufficient for continued operation of these systems after the air necessary for the required number of starts has been used.

d) 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 d) do not apply to engines started by pneumatic motors.

e) Compressed air receivers are to comply with the requirements of Sec 3. Compressed air piping and associated air compressors are to comply with the requirements of Sec 10.

Table 7 : Required number of starts *(1/7/2016)*

	Single propeller vessels		Multiple propeller vessels	
Engine type	One engine per shaft	Two or more engines per shaft	One engine per shaft	Two or more engines per shaft
Reversible	12	16	24	24
Non-reversible	6	8	8	8

5.1.2 Electrical starting *(1/7/2016)*

a) Where main internal combustion engines are arranged for electrical starting, at least two separate batteries are to be fitted.

The arrangement is to be such that the batteries cannot be connected in parallel.

Each battery is to be capable of starting the main engine when in cold and ready to start condition.

The combined capacity of batteries is to be sufficient to provide within 30 min, without recharging, the number of starts required in [5.1.1] (b) in the event of air starting.

b) Electrical starting arrangements for auxiliary engines are to have two separate storage batteries or may be supplied by two separate circuits from main engine storage batteries when these are provided. In the case of a single auxiliary engine, one battery is acceptable. The combined capacity of the batteries is to be sufficient for at least three starts for each engine.

c) The starting batteries are only to be used for starting and for the engine's alarm and monitoring. Provision is to be made to maintain the stored energy at all times.

d) Each charging device is to have at least sufficient rating for recharging the required capacity of batteries within 6 hours.

5.1.3 Special requirements for starting arrangements for emergency generating sets *(1/7/2016)*

a) Emergency generating sets are to be capable of being readily started in their cold condition at a temperature of 0°C. If this is impracticable, or if lower temperatures are likely to be encountered, provision acceptable to the Society shall be made for the maintenance of heating arrangements, to ensure ready starting of the generating sets.

b) Each emergency generating set arranged to be automatically started shall be equipped with starting devices approved by the Society with a stored energy capability of at least three consecutive starts.

The source of stored energy shall be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. In addition, a second source of energy shall be provided for an additional three starts within 30 minutes, unless manual starting can be demonstrated to be effective.

c) The stored energy is to be maintained at all times, as follows:

- *electrical and hydraulic starting systems shall be maintained from the emergency switchboard*
- *compressed air starting systems may be maintained by the main or auxiliary compressed air receivers through a suitable non-return valve or by an emergency air compressor which, if electrically driven, is supplied from the emergency switchboard*

- *all of these starting, charging and energy storing devices are to be located in the emergency generator space; these devices are not to be used for any purpose other than the operation of the emergency generating set. This does not preclude the supply to the air receiver of the emergency generating set from the main or auxiliary compressed air system through the non-return valve fitted in the emergency generator space.*

d) Where automatic starting is not required, manual starting, such as manual cranking, inertia starters, manually charged hydraulic accumulators, or powder charge cartridges, is permissible where this can be demonstrated as being effective.

e) When manual starting is not practicable, the requirements of (b) and (c) are to be complied with, except that starting may be manually initiated.

5.2 Turning gear

5.2.1 *(1/7/2016)*

Each engine is to be provided with hand-operated 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.

5.3 Trays

5.3.1 *(1/7/2016)*

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.

5.4 Exhaust gas system

5.4.1 *(1/7/2016)*

In addition to the requirements given in Sec 10, the exhaust system is to be efficiently cooled or insulated in such a way that the surface temperature does not exceed 220°C (see also Sec 1, [3.7]).

6 Type tests

6.1 Type tests - General

6.1.1 *(1/7/2016)*

Type testing is required for every new engine type intended for installation onboard ships subject to classification.

6.2 Objectives

6.2.1 *(1/7/2016)*

The type testing, is to be arranged to represent typical foreseen service load profiles, as specified by the engine builder, as well as to cover for required margins due to fatigue scatter and reasonably foreseen in-service deterioration.

This applies to:

- Parts subjected to high cycle fatigue (HCF) such as connecting rods, cams, rollers and spring tuned dampers where higher stresses may be provided by means of elevated injection pressure, cylinder maximum pressure, etc.
- Parts subjected to low cycle fatigue (LCF) such as "hot" parts when load profiles such as idle-full load -idle (with steep ramps) are frequently used.
- Operation of the engine at limits as defined by its specified alarm system, such as running at maximum permissible power with the lowest permissible oil pressure and/or highest permissible oil inlet temperature.

6.3 Validity

6.3.1 *(1/7/2016)*

A type test carried out for a particular type of engine at any place of manufacture will be accepted for all engines of the same type built by licensees or the licensor, subject to each place of manufacture being found to be acceptable to the Society.

6.3.2 *(1/7/2016)*

One type test will be considered adequate to cover a range of different numbers of cylinders. However, a type test of an in-line engine may not always cover the V-version. Subject to the individual Societies' discretion, separate type tests may be required for the V-version. On the other hand, a type test of a V-engine covers the in-line engines, unless the bmep is higher.

Items such as axial crankshaft vibration, torsional vibration in camshaft drives, and crankshafts, etc. may vary considerably with the number of cylinders and may influence the choice of engine to be selected for type testing.

6.3.3 *(1/7/2016)*

The engine is type approved up to the tested ratings and pressures (100% corresponding to MCR).

Provided documentary evidence of successful service experience with the classified rating of 100% is submitted, an increase (if design approved*) may be permitted without a new type test if the increase from the type tested engine is within:

- 5% of the maximum combustion pressure, or
- 5% of the mean effective pressure, or
- 5% of the rpm

*Only crankshaft calculation and crankshaft drawings, if modified.

Providing maximum power is not increased by more than 10%, an increase of maximum approved power may be permitted without a new type test provided engineering analysis and evidence of successful service experience in similar field applications (even if the application is not classified) or documentation of internal testing are submitted if the increase from the type tested engine is within:

- 10% of the maximum combustion pressure, or
- 10% of the mean effective pressure, or
- 10% of the rpm.

6.4 De-rated engine

6.4.1 *(1/7/2016)*

If an engine has been design approved, and internal testing per Stage A is documented to a rating higher than the one type tested, the Type Approval may be extended to the increased power/mep/rpm upon submission of an Extended Delivery Test Report at:

- Test at over speed (only if nominal speed has increased)
- Rated power, i.e. 100% output at 100% torque and 100% speed corresponding to load point No.1. (2 measurements with one running hour in between)
- Maximum permissible torque (normally 110%) at 100% speed corresponding to load point No.3 or maximum permissible power (normally 110%) and speed according to nominal propeller curve corresponding to load point 3a., for 30 minutes
- 100% power at maximum permissible speed corresponding to load point 2, for 30 minutes.

6.5 Integration Test

6.5.1 *(1/7/2016)*

An integration test demonstrating that the response of the complete mechanical, hydraulic and electronic system is as predicted maybe carried out for acceptance of sub-systems (Turbo Charger, Engine Control System, Dual Fuel, Exhaust Gas treatment…) separately approved. The scope of these tests shall be proposed by the designer/licensor taking into account of impact on engine.

6.6 Safety precautions

6.6.1 *(1/7/2016)*

Before any test run is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer/shipyard and is to be operational, and its correct functioning is to be verified.

6.6.2 *(1/7/2016)*

This applies especially to crankcase explosive conditions protection, but also over-speed protection and any other shut down function.

6.6.3 *(1/7/2016)*
The inspection for jacketing of high-pressure fuel oil lines and proper screening of pipe connections (as required in [6.10.9] fire measures) is also to be carried out before the test runs.

6.6.4 *(1/7/2016)*
Interlock test of turning gear is to be performed when installed.

6.7 Test programme

6.7.1 **The type testing is divided into 3 stages:** *(1/7/2016)*
- STAGE A - internal tests
  This includes some of the testing made during the engine development, function testing, and collection of measured parameters and records of testing hours. The results of testing required by the Society or stipulated by the designer are to be presented to the Society before starting stage B.
- STAGE B - witnessed tests
  This is the testing made in the presence of Classification Society personnel.
- STAGE C - component inspection
  This is the inspection of engine parts to the extent as required by the Society.

6.7.2 *(1/7/2016)*
The complete type testing program is subject to approval by the Society. The extent of the Surveyor's attendance is to be agreed in each case, but at least during stage B and C.

6.7.3 *(1/7/2016)*
Testing prior to the witnessed type testing (stage B and C), is also considered as a part of the complete type testing program.

6.7.4 *(1/7/2016)*
Upon completion of complete type testing (stage A through C), a type test report is to be submitted to the Society for review. The type test report is to contain:
- overall description of tests performed during stage A. Records are to be kept by the builders QA management for presentation to the Classification Society.
- detailed description of the load and functional tests conducted during stage B.
- inspection results from stage C.

6.7.5 *(1/7/2016)*
As required in [6.2] the type testing is to substantiate the capability of the design and its suitability for the intended operation. Special testing such as LCF and endurance testing will normally be conducted during stage A.

6.7.6 *(1/7/2016)*
High speed engines for marine use are normally to be subjected to an endurance test of 100 hours at full load. Omission or simplification of the type test may be considered for the type approval of engines with long service experience from non-marine fields or for the extension of type approval of engines of a well-known type, in excess of the limits given in [6.3].

Propulsion engines for high speed vessels that may be used for frequent load changes from idle to full are normally to be tested with at least 500 cycles (idle - full load - idle) using the steepest load ramp that the control system (or operation manual if not automatically controlled) permits. The duration at each end is to be sufficient for reaching stable temperatures of the hot parts.

6.8 Measurements and recordings *(1/7/2016)*

6.8.1 *(1/7/2016)*
During all testing the ambient conditions (air temperature, air pressure and humidity) are to be recorded.

6.8.2 *(1/7/2016)*
As a minimum, the following engine data are to be measured and recorded.
- Engine r.p.m.
- Torque
- Maximum combustion pressure for each cylinder 1)

- Mean indicated pressure for each cylinder
- Charging air pressure and temperature
- Exhaust gas temperature
- Fuel rack position or similar parameter related to engine load
- Turbocharger speed
- All engine parameters that are required for control and monitoring for the intended use (propulsion, auxiliary, emergency).

Note 1: For engines where the standard production cylinder heads are not designed for such measurments, a special cylinder head made for this purpose may be used. In such a case, the measurements may be carried out as part of Stage A and are to be properly documented. Where deemed necessary e.g. for dual fuel engines, the measurement of maximum combustion pressure and mean indicated pressure may be carried out by indirect means, provided the re-liability of the method is documented.

Calibration records for the instrumentation used to collect data as listed above are to be presented to - and reviewed by the attending Surveyor.

Additional measurements may be required in connection with the design assessment.

6.9 Stage A - Internal tests

6.9.1 *(1/7/2016)*

During the internal tests, the engine is to be operated at the load points important for the engine designer and the pertaining operating values are to be recorded. The load conditions to be tested are also to include the testing specified in the applicable type approval programme.

6.9.2 *(1/7/2016)*

At least the following conditions are to be tested:

- Normal case:

  The load points 25%, 50%, 75%, 100% and 110% of the maximum rated power for continuous operation, to be made along the normal (theoretical) propeller curve and at constant speed for propulsion engines (if applicable mode of operation i.e. driving controllable pitch propellers), and at constant speed for engines intended for generator sets including a test at no load and rated speed.
- The limit points of the permissible operating range. These limit points are to be defined by the engine manufacturer.
- For high speed engines, the 100 hr full load test and the low cycle fatigue test apply as required in connection with the design assessment.
- Specific tests of parts of the engine, required by the Society or stipulated by the designer.

6.10 Stage B - Witnessed tests

6.10.1 *(1/7/2016)*

The tests listed below are to be carried out in the presence of a Surveyor. The achieved results are to be recorded and signed by the attending Surveyor after the type test is completed.

6.10.2 *(1/7/2016)*

The over-speed test is to be carried out and is to demonstrate that the engine is not damaged by an actual engine overspeed within the overspeed shutdown system set-point. This test may be carried out at the manufacturer's choice either with or with-out load during the speed overshoot.

6.10.3 Load points *(1/7/2016)*

The engine is to be operated according to the power and speed diagram in Fig 2. The data to be measured and recorded when testing the engine at the various load points have to include all engine parameters listed in [6.8]. The operating time per load point depends on the engine size (achievement of steady state condition) and on the time for collection of the operating values. Normally, an operating time of 0.5 hour can be assumed per load point, however sufficient time should be allowed for visual inspection by the Surveyor.

6.10.4 *(1/7/2016)*

The load points are:

- Rated power (MCR), i.e. 100% output at 100% torque and 100% speed corresponding to load point 1, normally for 2 hours with data collection with an interval of 1 hour. If operation of the engine at limits as defined by its specified alarm system (e.g. at alarm levels of lub oil pressure and inlet temperature) is required, the test should be made here.

- 100% power at maximum permissible speed corresponding to load point 2.
- Maximum permissible torque (at least and normally 110%) at 100% speed corresponding to load at point 3, or maximum permissible power (at least and normally 110%) and 103.2% speed according to the nominal propeller curve corresponding to load point 3a. Load point 3a applies to engines only driving fixed pitch propellers or water jets. Load point 3 applies to all other purposes.

Load point 3 (or 3a as applicable) is to be replaced with a load that corresponds to the specified overload and duration approved for intermittent use. This applies where such overload rating exceeds 110% of MCR. Where the approved intermittent overload rating is less than 110% of MCR, subject overload rating has to replace the load point at 100% of MCR. In such case the load point at 110% of MCR remains.

- Minimum permissible speed at 100% torque, corresponding to load point 4.
- Minimum permissible speed at 90% torque corresponding to load point 5. (Applicable to propulsion engines only).
- Part loads e.g. 75%, 50% and 25% of rated power and speed according to nominal propeller curve (i.e. 90.8%, 79.3% and 62.9% speed) corresponding to points 6, 7 and 8 or at constant rated speed setting corresponding to points 9, 10 and 11, depending on the intended application of the engine.
- Crosshead engines not restricted for use with C.P. propellers are to be tested with no load at the associated maximum permissible engine speed.

6.10.5 *(1/7/2016)*

During all these load points, engine parameters are to be within the specified and approved values.

6.10.6 **Operation with damaged turbocharger** *(1/7/2016)*

For 2-stroke propulsion engines, the achievable continuous output is to be determined in the case of turbocharger damage.

Engines intended for single propulsion with a fixed pitch propeller are to be able to run continuously at a speed (r.p.m.) of 40% of full speed along the theoretical propeller curve when one turbocharger is out of operation. (The test can be performed by either by-passing the turbocharger, fixing the turbocharger rotor shaft or removing the rotor.).

6.10.7 **Functional tests** *(1/7/2016)*

- Verification of the lowest specified propulsion engine speed according to the nominal propeller curve as specified by the engine designer (even though it works on a water- brake). During this operation, no alarm shall occur.
- Starting tests, for non-reversible engines and/or starting and reversing tests, for reversible engines, for the purpose of determining the minimum air pressure and the consumption for a start.
- Governor tests: tests for compliance with [4.7.3] and [4.7.5] are to be carried out.

6.10.8 **Integration test** *(1/7/2016)*

For electronically controlled diesel engines, integration tests are to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes. The scope of these tests is to be agreed with the Society for selected cases based on the FMEA required in Tab 1.

6.10.9 **Fire protection measures** *(1/7/2016)*

Verification of compliance with requirements for jacketing of high-pressure fuel oil lines, screening of pipe connections in piping containing flammable liquids and insulation of hot surfaces:

- The engine is to be inspected for jacketing of high-pressure fuel oil lines, including the system for the detection of leakage, and proper screening of pipe connections in piping containing flammable liquids.
- Proper insulation of hot surfaces is to be verified while running the engine at 100% load, alternatively at the overload approved for intermittent use. Readings of surface temperatures are to be done by use of Infrared Thermoscanning Equipment. Equivalent measurement equipment may be used when so approved by the Society. Readings obtained are to be randomly verified by use of contact thermometers.

6.11 Stage C - Opening up for inspections

6.11.1 *(1/7/2016)*

The crankshaft deflections are to be measured in the specified (by designer) condition (except for engines where no specification exists).

6.11.2 *(1/7/2016)*

High speed engines for marine use are normally to be stripped down for a complete inspection after the type test.

6.11.3 *(1/7/2016)*

For all the other engines, after the test run the components of one cylinder for in-line engines and two cylinders for V-engines are to be presented for inspection as follows (engines with long service experience from non-marine fields can have a reduced ex-tent of opening):

- piston removed and dismantled
- crosshead bearing dismantled
- guide planes
- connecting rod bearings (big and small end) dismantled (special attention to serrations and fretting on contact surfaces with the bearing backsides)
- main bearing dismantled
- cylinder liner in the installed condition
- cylinder head, valves disassembled
- cam drive gear or chain, camshaft and crankcase with opened covers. (The engine must be turnable by turning gear for this inspection.).

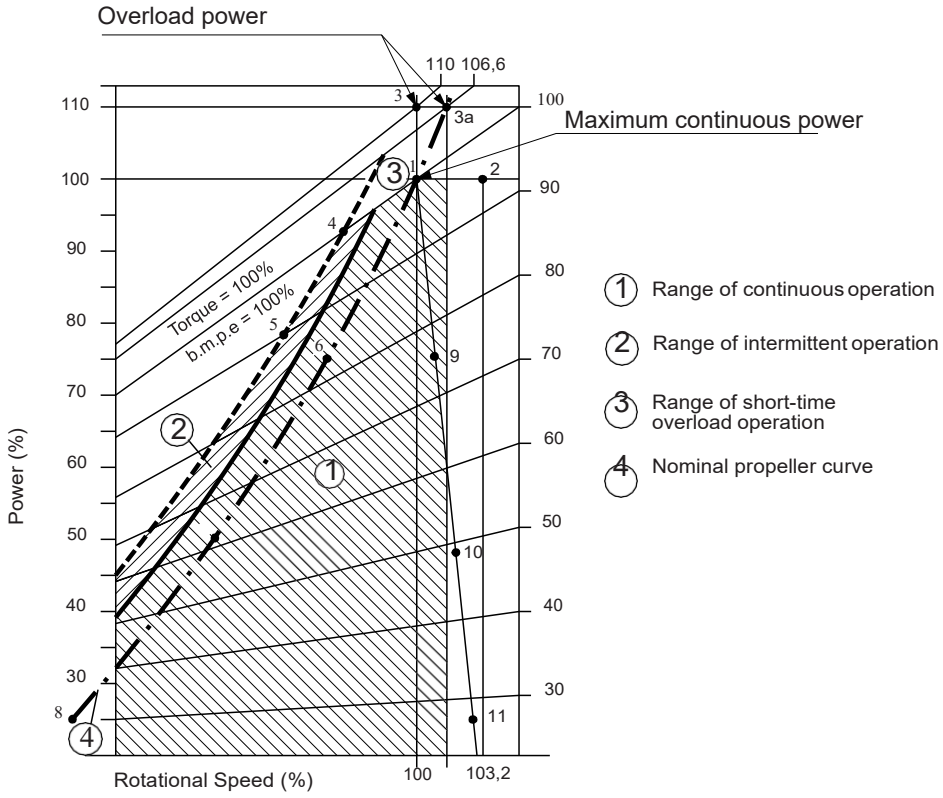
6.11.4 *(1/7/2016)*

For V-engines, the cylinder units are to be selected from both cylinder banks and different crank throws.

6.11.5 *(1/7/2016)*

If deemed necessary by the surveyor, further dismantling of the engine may be required.

Figure 2 : Power/speed diagram *(1/7/2016)*



7 Certification of engine components, Workshop inspections and trials

7.1 General

7.1.1 *(1/1/2020)*

The engine manufacturer is to have a quality control system that is suitable for the actual engine types to be certified by the Society. The quality control system is also to apply to any sub-suppliers. The Society re-serves the right to review the system or parts thereof. Materials and components are to be produced in compliance with all the applicable

production and quality instructions specified by the engine manufacturer. The Society requires that certain parts are verified and documented by means of Society Certificate (SC), Work Certificate (W) or Test Report (TR).

a) The documents above are used for product documentation as well as for documentation of single inspections such as crack detection, dimensional check, etc. If agreed to by the Society, the documentation of single tests and inspections may also be arranged by filling in results on a control sheet following the component through the production.

b) The Surveyor is to review the TR and W for compliance with the agreed or approved specifications. SC means that the Surveyor also witnesses the testing, batch or individual, unless an ACS provides other arrangements.

c) The manufacturer is not exempted from responsibility for any relevant tests and inspections of those parts for which documentation is not explicitly requested by the Society. The manufacturing process and equipment is to be set up and maintained in such a way that all materials and components can be consistently produced to the required standard. This includes production and assembly lines, machining units, special tools and devices, assembly and testing rigs as well as all lifting and transportation devices.

7.2 Parts to be documented

7.2.1 *(1/7/2016)*

The extent of parts to be documented depends on the type of engine, engine size and criticality of the part.

A summary of the required documentation for the engine components is listed in Tab 8.

Symbols used are listed in Tab 9.

Table 8 : Summary of required documentation for engine components *(1/7/2024)*

Item	Part **(5) (6) (7) (8)**	Material properties **(1)**	Non-destructive examination **(2)**	Hydrostatic test **(3)**	Dimensional inspection, including surface condition	Visual inspection (surveyor)	Applicable to engines:	Component certificate
1	Welded bedplate	W(C+M)	W(UT+CD)			fit-up + post-welding	All	SC
2	Bearing transverse girders GS	W(C+M)	W(UT+CD)			X	All	SC
3	Welded frame box	W(C+M)	W(UT+CD)			fit-up + post-welding	All	SC
4	Cylinder block GJL			W **(10)**			400 kW/cyl	

(1) Material properties include chemical composition and mechanical properties, and also surface treatment such as surface hardening (hardness, depth and extent), peening and rolling (extent and applied force).

(2) Non-destructive examination means e.g. ultrasonic testing, crack detection by MPI or DP. When certain NDE method on the finished component is impractical (for example UT for items 12/13), the NDE method can be performed at earlier appropriate stages in the production of the component, see [1.5.4].

(3) Hydrostatic test is applied on the water/oil side of the component. Items are to be tested by hydraulic pressure at the pressure equal to 1.5 times the maximum working pressure. High pressure parts of the fuel injection system are to be tested by hydraulic pressure at the pressure equal to 1.5 maximum working pressure or maximum working pressure plus 300 bar, whichever is the less. Where design or testing features may require modification of these test requirements, special consideration may be given.

(4) Material certification requirements for pumps and piping components are dependent on the operating pressure and temperature. Requirements given in this Table apply except where alternative requirements are explicitly given elsewhere in the Rule requirements.

(5) For turbochargers, see Sec 14.

(6) Crankcase explosion relief valves are to be type tested in accordance with App 5 and documented according to [4.3.4].

(7) Oil mist detection systems are to be type tested in accordance with Appendix 6 and documented according to [4.3.5].

(8) For Speed governor and overspeed protective devices, see [4.7.3] to [4.7.6].

(9) Charge air coolers need only be tested on the water side.

(10) Hydrostatic test is also required for those parts filled with cooling water and having the function of containing the water which is in contact with the cylinder or cylinder liner.

Item	Part **(5) (6) (7) (8)**	Material properties **(1)**	Non-destructive examination **(2)**	Hydrostatic test **(3)**	Dimensional inspection, including surface condition	Visual inspection (surveyor)	Applicable to engines:	Component certificate
5	Cylinder block GJS			W **(10)**			400 kW/cyl	
6	Welded cylinder frames	W(C+M)	W(UT+CD)				CH	SC
7	Engine block GJL			W **(10)**			>400 kW/cyl	
8	Engine block GJS	W(M)		W **(10)**			>400 kW/cyl	
9	Cylinder liner	W(C+M)		W **(10)**			D>300mm	
10	Cylinder head GJL			W			D>300mm	
11	Cylinder head GJS			W			D>300mm	
12	Cylinder head GS	W(C+M)	W(UT+CD)	W		X	D>300mm	SC
13	Forged cylinder head	W(C+M)	W(UT+CD)	W		X	D>300mm	SC
14	Piston crown GS	W(C+M)	W(UT+CD)			X	D>400mm	SC
15	Forged piston crown	W(C+M)	W(UT+CD)			X	D>400mm	SC
16	Crankshaft: made in one piece	SC(C+M)	W(UT+CD)		W	Random, of fillets and oil bores	All	SC
17	Semi-built crankshaft (Crankthrow, forged main journal and journals with flange)	SC(C+M)	W(UT+CD)		W	Random, of fillets and shrinkfittings	All	SC
18	Exhaust gas valve cage			W			CH	

(1) Material properties include chemical composition and mechanical properties, and also surface treatment such as surface hardening (hardness, depth and extent), peening and rolling (extent and applied force).

(2) Non-destructive examination means e.g. ultrasonic testing, crack detection by MPI or DP. When certain NDE method on the finished component is impractical (for example UT for items 12/13), the NDE method can be performed at earlier appropriate stages in the production of the component, see [1.5.4].

(3) Hydrostatic test is applied on the water/oil side of the component. Items are to be tested by hydraulic pressure at the pressure equal to 1.5 times the maximum working pressure. High pressure parts of the fuel injection system are to be tested by hydraulic pressure at the pressure equal to 1.5 maximum working pressure or maximum working pressure plus 300 bar, whichever is the less. Where design or testing features may require modification of these test requirements, special consideration may be given.

(4) Material certification requirements for pumps and piping components are dependent on the operating pressure and temperature. Requirements given in this Table apply except where alternative requirements are explicitly given elsewhere in the Rule requirements.

(5) For turbochargers, see Sec 14.

(6) Crankcase explosion relief valves are to be type tested in accordance with App 5 and documented according to [4.3.4].

(7) Oil mist detection systems are to be type tested in accordance with Appendix 6 and documented according to [4.3.5].

(8) For Speed governor and overspeed protective devices, see [4.7.3] to [4.7.6].

(9) Charge air coolers need only be tested on the water side.

(10) Hydrostatic test is also required for those parts filled with cooling water and having the function of containing the water which is in contact with the cylinder or cylinder liner.

Item	Part **(5) (6) (7) (8)**	Material properties **(1)**	Non-destructive examination **(2)**	Hydrostatic test **(3)**	Dimensional inspection, including surface condition	Visual inspection (surveyor)	Applicable to engines:	Component certificate
19	Piston rod	SC(C+M)	W(UT+CD)			Random	D>400mm CH	SC
20	Cross head	SC(C+M)	W(UT+CD)			Random	CH	SC
21	Connecting rod with cap	SC(C+M)	W(UT+CD)		W	Random, of all surfaces, in particular those shot peened	All	SC
22	Coupling bolts for crankshaft	SC(C+M)	W(UT+CD)		W	Random, of interference fit	All	SC
23	Bolts and studs for main bearings	W(C+M)	W(UT+CD)				D>300mm	
24	Bolts and studs for cylinder heads	W(C+M)	W(UT+CD)			TR of thread making	D>300mm	
25	Bolts and studs for connecting rods	W(C+M)	W(UT+CD)			TR of thread making	D>300mm	
26	Tie rod	W(C+M)	W(UT+CD)			Random	CH	SC
27	High pressure fuel injection pump body	W(C+M)		W			D>300mm	
		W(C+M)		TR			D≤300mm	
28	High pressure fuel injection valves (only for those not autofretted)			W			D>300mm	
				TR			D≤300mm	

(1) Material properties include chemical composition and mechanical properties, and also surface treatment such as surface hardening (hardness, depth and extent), peening and rolling (extent and applied force).

(2) Non-destructive examination means e.g. ultrasonic testing, crack detection by MPI or DP. When certain NDE method on the finished component is impractical (for example UT for items 12/13), the NDE method can be performed at earlier appropriate stages in the production of the component, see [1.5.4].

(3) Hydrostatic test is applied on the water/oil side of the component. Items are to be tested by hydraulic pressure at the pressure equal to 1.5 times the maximum working pressure. High pressure parts of the fuel injection system are to be tested by hydraulic pressure at the pressure equal to 1.5 maximum working pressure or maximum working pressure plus 300 bar, whichever is the less. Where design or testing features may require modification of these test requirements, special consideration may be given.

(4) Material certification requirements for pumps and piping components are dependent on the operating pressure and temperature. Requirements given in this Table apply except where alternative requirements are explicitly given elsewhere in the Rule requirements.

(5) For turbochargers, see Sec 14.

(6) Crankcase explosion relief valves are to be type tested in accordance with App 5 and documented according to [4.3.4].

(7) Oil mist detection systems are to be type tested in accordance with Appendix 6 and documented according to [4.3.5].

(8) For Speed governor and overspeed protective devices, see [4.7.3] to [4.7.6].

(9) Charge air coolers need only be tested on the water side.

(10) Hydrostatic test is also required for those parts filled with cooling water and having the function of containing the water which is in contact with the cylinder or cylinder liner.

Item	Part **(5) (6) (7) (8)**	Material properties **(1)**	Non-destructive examination **(2)**	Hydrostatic test **(3)**	Dimensional inspection, including surface condition	Visual inspection (surveyor)	Applicable to engines:	Component certificate
29	High pressure fuel injection pipes including common fuel rail	W(C+M)		W for those that are not autofrettaged			D>300mm	
		W(C+M)		TR for those that are not autofrettaged			D≤300mm	
30	High pressure common servo oil system	W(C+M)		W			D>300mm	
		W(C+M)		TR			D≤300mm	
31	Cooler, both sides **(9)**	W(C+M)		W			D>300mm	
32	Accumulator	W(C+M)		W			All engines with accumulators with a capacity of > 0,5 l	
33	Piping, pumps, actuators, etc. for hydraulic drive of valves, if applicable	W(C+M)		W			>800 kW/cyl	

(1) Material properties include chemical composition and mechanical properties, and also surface treatment such as surface hardening (hardness, depth and extent), peening and rolling (extent and applied force).

(2) Non-destructive examination means e.g. ultrasonic testing, crack detection by MPI or DP. When certain NDE method on the finished component is impractical (for example UT for items 12/13), the NDE method can be performed at earlier appropriate stages in the production of the component, see [1.5.4].

(3) Hydrostatic test is applied on the water/oil side of the component. Items are to be tested by hydraulic pressure at the pressure equal to 1.5 times the maximum working pressure. High pressure parts of the fuel injection system are to be tested by hydraulic pressure at the pressure equal to 1.5 maximum working pressure or maximum working pressure plus 300 bar, whichever is the less. Where design or testing features may require modification of these test requirements, special consideration may be given.

(4) Material certification requirements for pumps and piping components are dependent on the operating pressure and temperature. Requirements given in this Table apply except where alternative requirements are explicitly given elsewhere in the Rule requirements.

(5) For turbochargers, see Sec 14.

(6) Crankcase explosion relief valves are to be type tested in accordance with App 5 and documented according to [4.3.4].

(7) Oil mist detection systems are to be type tested in accordance with Appendix 6 and documented according to [4.3.5].

(8) For Speed governor and overspeed protective devices, see [4.7.3] to [4.7.6].

(9) Charge air coolers need only be tested on the water side.

(10) Hydrostatic test is also required for those parts filled with cooling water and having the function of containing the water which is in contact with the cylinder or cylinder liner.

Item	Part **(5) (6) (7) (8)**	Material properties **(1)**	Non-destructive examination **(2)**	Hydrostatic test **(3)**	Dimensional inspection, including surface condition	Visual inspection (surveyor)	Applicable to engines:	Component certificate
34	Engine driven pumps (oil, water, fuel, bilge) other than pumps referred to in item 27 and 33			W			>800 kW/cyl	
35	Bearings for main, crosshead, and crankpin	TR(C)	TR (UT for full contact between base material and bearing metal)		W		>800 kW/cyl	

(1) Material properties include chemical composition and mechanical properties, and also surface treatment such as surface hardening (hardness, depth and extent), peening and rolling (extent and applied force).

(2) Non-destructive examination means e.g. ultrasonic testing, crack detection by MPI or DP. When certain NDE method on the finished component is impractical (for example UT for items 12/13), the NDE method can be performed at earlier appropriate stages in the production of the component, see [1.5.4].

(3) Hydrostatic test is applied on the water/oil side of the component. Items are to be tested by hydraulic pressure at the pressure equal to 1.5 times the maximum working pressure. High pressure parts of the fuel injection system are to be tested by hydraulic pressure at the pressure equal to 1.5 maximum working pressure or maximum working pressure plus 300 bar, whichever is the less. Where design or testing features may require modification of these test requirements, special consideration may be given.

(4) Material certification requirements for pumps and piping components are dependent on the operating pressure and temperature. Requirements given in this Table apply except where alternative requirements are explicitly given elsewhere in the Rule requirements.

(5) For turbochargers, see Sec 14.

(6) Crankcase explosion relief valves are to be type tested in accordance with App 5 and documented according to [4.3.4].

(7) Oil mist detection systems are to be type tested in accordance with Appendix 6 and documented according to [4.3.5].

(8) For Speed governor and overspeed protective devices, see [4.7.3] to [4.7.6].

(9) Charge air coolers need only be tested on the water side.

(10) Hydrostatic test is also required for those parts filled with cooling water and having the function of containing the water which is in contact with the cylinder or cylinder liner.

Table 9 : Symbols used in Table 8 *(1/7/2016)*

Symbol	Description
C	chemical composition
CD	crack detection by MPI or DP
CH	crosshead engines
D	cylinder bre diameter (mm)
GJL	gray cast iron
GJS	spheroidal graphite cast iron
GS	cast steel
M	mechanical properties
SC	society certificate
TR	test report
UT	ultrasonic testing
W	work certificate
X	visual examination of accessible surfaces by the Surveyor

7.3 Hydrostatic tests

7.3.1 *(1/7/2016)*

In addition to what indicated in Tab 8, pressure pipes, valves and other fittings (used for water, lubricating oil, fuel oil, compressed air and other fluid), are to be subjected to hydrostatic tests at 1,5 times the maximum working pressure, but not less than 0,4 MPa.

7.4 Workshop inspections and testing

7.4.1 *(1/7/2021)*

In addition to the type test, diesel engines are to be subjected to works trials, which are to be witnessed by the Surveyor except where an Alternative Certification Scheme has been granted or where otherwise decided by the Society on a case by case basis.

Engines which are to be subjected to trials on the test bed at the Manufacturer's works and under the Society's supervision are to be tested in accordance with the scope as specified below.

Exceptions to this require the agreement of the Society.

Before any official testing, the engines shall be run-in as prescribed by the engine manufacturer.

Adequate test bed facilities for loads as required in [7.4.4] shall be provided. All fluids used for testing purposes such as fuel, lubrication oil and cooling water are to be suitable for the purpose intended, e.g. they are to be clean, preheated if necessary and cause no harm to engine parts. This applies to all fluids used temporarily or repeatedly for testing purposes only.

On occasion of the workshop testing, engines are to be inspected for:

- Jacketing of high-pressure fuel oil lines including the system used for the detection of leakage.
- Screening of pipe connections in piping containing flammable liquids.
- Insulation of hot surfaces by taking random temperature readings that are to be compared with corresponding readings obtained during the type test. This shall be done while running at the rated power of engine. Use of contact thermometers may be accepted at the discretion of the attending Surveyor. If the insulation is modified subsequently to the Type Approval Test, the Society may request temperature measurements as required in [6.10.9].
- Presence of sensors for the alarms and safeguards required in Tab 4, Tab 5 and Tab 6 as applicable; and relevant functionality as far as possible.

These inspections are normally to be made during the works trials by the manufacturer and the attending surveyor, but at the discretion of the Society parts of these inspections may be postponed to the shipboard testing.

Engines for which an Alternative Certification Scheme has been agreed with the Manufacturer are to be subjected to trials at the Manufacturer's works in accordance with a procedure previously accepted on a case-by-case basis by the Society and recorded in the documentation relevant to the admission to the Alternative Certification Scheme.

7.4.2 Objectives *(1/7/2016)*

The purpose of the works trials is to verify design premises such as power, safety against fire, adherence to approved limits (e.g. maximum pressure), and functionality and to establish reference values or base lines for later reference in the operational phase.

7.4.3 Records *(1/7/2016)*

a) The following environmental test conditions are to be recorded:
   1) Ambient air temperature
   2) Ambient air pressure
   3) Atmospheric humidity

b) For each required load point, the following parameters are normally to be recorded:
   - Power and speed
   - Fuel index (or equivalent reading)
   - Maximum combustion pressures (only when the cylinder heads installed are designed for such measurement).
   - Exhaust gas temperature before turbine and from each cylinder (to the extent that monitoring is required in Sec 14 and [4.7.9].
   - Charge air temperature
   - Charge air pressure
   - Turbocharger speed (to the extent that monitoring is required in Sec 14.

c) Calibration records for the instrumentation are, upon request, to be presented to the attending Surveyor.

d) For all stages at which the engine is to be tested, the pertaining operational values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer. This also includes crankshaft deflections if considered necessary by the engine designer.

e) In each case, all measurements conducted at the various load points are to be carried out at steady state operating conditions. However, for all load points provision should be made for time needed by the Surveyor to carry out visual inspections. The readings for MCR, i.e. 100% power (rated maximum continuous power at corresponding rpm) are to be taken at least twice at an interval of normally 30 minutes.

7.4.4 Test loads *(1/7/2016)*

Test loads for various engine applications are given below. In addition, the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

Note 1: Alternatives to the detailed tests may be agred between the manufacturer and the Society when the overall scope of tests is found to be equivalent.

a) Propulsion engines driving propeller or impeller only

1) 100% power (MCR) at corresponding speed n_0: at least 60 min.

2) 110% power at engine speed $1.032n_0$: Records to be taken after 15 minutes or after steady conditions have been reached, whichever is shorter.

Note 2: Only required once for each different engine/turbocharger configuration.

3) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.

4) 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve, the sequence to be selected by the engine manufacturer.

5) Reversing manoeuvres (if applicable).

Note 3: After running on the test bed, the fuel delivery system is to be so adjusted that overload power cannot be given in service, unless intermittent overload power is approved by the Society. In that case, the fuel delivery system is to be blocked to that power.

b) Engine driving generators for electric propulsion

1) 100% power (MCR) at corresponding speed no.: at least 60 min.

2) 110% power at engine speed n_0: 15 min. - after having reached steady conditions.

3) Governor tests for compliance with [4.7.3] and [4.7.5] are to be carried out.

4) 75%, 50% and 25% power and idle, the sequence to be selected by the engine manufacturer.

Note 4: After running on the test bed, the fuel delivery system is to be adjusted so that full power plus a 10% margin for transient regulation can be given in service after installation onboard.

The transient overload capability is required so that the required transient governing characteristics are achieved also at 100% loading of the engine, and also so that the protection system of the electric distribution system can be activated before the engine stalls.

c) Engines driving generators for auxiliary purposes

Tests to be performed as per b)

d) Propulsion engines also driving power take off (PTO) generator

1) 100% power (MCR) at corresponding speed no.: at least 60 min.

2) 110% power at engine speed n°: 15 min. - after having reached steady conditions.

3) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.

4) 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve or at constant speed no., the sequence to be selected by the engine manufacturer.

Note 5: After running on the test bed, the fuel delivery system is to be adjusted so that full power plus a margin for transient regulation can be given in service after installation onboard. The transient overload capability is required so that the electrical protection of downstream system components is activated before the engine stalls. This margin may be 10% of the engine power but at least 10% of the PTO power.

e) Engines driving auxiliaries

1) 100% power (MCR) at corresponding speed no.: at least 30 min.

2) 110% power at engine speed n°: 15 min. - after having reached steady conditions.

3) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.

4) For variable speed engines, 75%, 50% and 25% power in accordance with the nominal power consumption curve, the sequence to be selected by the engine manufacturer.

Note 6: After running on the test bed, the fuel delivery system is to be so adjusted that overload power cannot be given in service, unless intermittent overload power is approved by the Society. In that case, the fuel delivery system is to be blocked to that power.

7.4.5 Turbocharger matching with engine *(1/7/2016)*

a) Compressor chart

Turbochargers shall have a compressor characteristic that allows the engine, for which it is intended, to operate without surging during all operating conditions and also after extended periods in operation.

For abnormal, but permissible, operation conditions, such as misfiring and sudden load reduction, no continuous surging shall occur.

In this section, surging and continuous surging are defined as follows:

- Surging means the phenomenon, which results in a high pitch vibration of an audible level or explosion-like noise from the scavenger area of the engine.
- Continuous surging means that surging happens repeatedly and not only once.

b) Surge margin verification

Category C turbochargers used on propulsion engines are to be checked for surge margins during the engine workshop testing as specified below. These tests may be waived if successfully tested earlier on an identical configuration of engine and turbocharger (including same nozzle rings).

- For 4-stroke engines:

  The following shall be performed without indication of surging:

  - With maximum continuous power and speed (=100%), the speed shall be reduced with constant torque (fuel index) down to 90% power.
  - With 50% power at 80% speed (= propeller characteristic for fixed pitch), the speed shall be reduced to 72% while keeping constant torque (fuel index).

- For 2 stroke engines:

  The surge margin shall be demonstrated by at least one of the following methods:

  - The engine working characteristic established at workshop testing of the engine shall be plotted into the compressor chart of the turbocharger (established in a test rig). There shall be at least 10% surge margin in the full load range, i.e. working flow shall be 10% above the theoretical (mass) flow at surge limit (at no pressure fluctuations).
  - Sudden fuel cut-off to at least one cylinder shall not result in continuous surging and the turbocharger shall be stabilized at the new load within 20 seconds. For applications with more than one turbocharger the fuel shall be cut-off to the cylinders closest upstream to each turbocharger.

    This test shall be performed at two different engine loads:

    - The maximum power permitted for one cylinder misfiring.
    - The engine load corresponding to a charge air pressure of about 0.6 bar (but without auxiliary blowers running).

  - No continuous surging is to occur and the turbocharger shall be stabilized at the new load within 20 seconds when the power is abruptly reduced from 100% to 50% of the maximum continuous power.

7.4.6 Integration tests *(1/7/2016)*

For electronically controlled engines, integration tests are to be made to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes and the tests considered as a system are to be carried out at the works. If such tests are technically unfeasible at the works, however, these tests may be conducted during sea trial. The scope of these tests is to be agreed with the Society for selected cases based on the FMEA required in Tab 1.

7.4.7 Component inspections *(1/7/2016)*

Random checks of components to be presented for inspection after works trials are to be selected by the Manufacturer or by the Surveyor if the works trials are witnessed.

8 Certification

8.1 Testing certification

8.1.1 *(1/7/2023)*

a) Engines admitted to an Alternative Certification Scheme

Work's Certificate (W) (see [1.5.5] and Pt D, Ch 1, Sec 1, [4.2.3]) is required for components and tests indicated in Tab 8 and for works trials as per [7.4]. In this case, a Work's Certificate (W) may be considered equivalent to a Society Certificate (SC) and endorsed by the Society.

b) Engines not admitted to an Alternative Certification Scheme

Society Certificate (SC) (see [1.5.4] and Pt D, Ch 1, Sec 1, [4.2.1]) is required for components and tests indicated in Tab 8 and for works trials as per [7.4], in addition to other Work's Certificates (W) indicated in Tab 8.

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 Certificate are also to be indicated in the statement.

SECTION 3 BOILERS AND PRESSURE VESSELS

1 General

1.1 Principles

1.1.1 Scope of the Rules

The boilers and other pressure vessels, associated piping systems and fittings shall 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.

1.1.2 Continuity of service *(1/1/2026)*

For single essential propulsion components and their reliability, refer to Sec 1, [2.1.2].

1.1.3 Propulsion capability

Means shall be provided whereby normal operation of main boilers can be sustained or restored even though one of the essential auxiliaries becomes inoperative. Special consideration is to be given to the malfunctioning of:

- *the sources of steam supply*
- *the boiler feed water systems*
- *the fuel oil supply systems for boilers;*
- *the mechanical air supply for boilers.*

However, the Society, having regard to overall safety considerations, may accept a partial reduction in propulsion capability from normal operation.

1.1.4 Tests

All boilers and other pressure vessels including 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 (see also [7]).

1.1.5 Protection against overpressure

Where main or auxiliary boilers and other pressure vessels or any parts thereof may be subject to dangerous overpressure, means shall be provided where practicable to protect against such excessive pressure.

1.2 Application

1.2.1 Boilers and pressure vessels covered by the Rules

The requirements of this Section apply to:

- all boilers and other steam generators, including the associated fittings and mountings with the exception of those indicated in [1.2.2]
- pressure vessels of metallic construction and heat exchangers, including the associated fittings and mountings with the exception of those indicated in [1.2.2].

1.2.2 Boilers and pressure vessels not covered by the Rules

The following boilers and pressure vessels are not covered by the Rules and will be considered on a case by case basis:

a) boilers with design pressure p > 10 MPa

b) pressure vessels intended for radioactive material

c) small pressure vessels included in self-contained domestic equipment.

1.2.3 Pressure vessels not requiring design approval *(1/7/2003)*

Plan approval is not required for pressure vessels of class 3 (as specified in [1.4]), having design pressure $p \leq 1$ MPa and product $p\,V \leq 150$ (V being the internal volume, in dm^3, calculated deducting the volume of tube bundles, if any).

However, the Society reserves the right to apply all or part of the requirements of this Section to class 3 heat exchangers and pressure vessels, depending on the criticality of the equipment and/or of the system of which they are part.

1.2.4 Pressure vessels covered in other parts of the Rules

Specific requirements relative to pressure vessels for liquefied gases and pressure vessels for refrigerating plants are stipulated in Part E, Chapter 9 and Part F, Chapter 8 respectively.

1.3 Definitions

1.3.1 Pressure vessel

Pressure vessel is a welded or seamless container used for the containment of fluids at a pressure above or below the ambient pressure and at any temperature. Fluid power cylinders in hydraulic or pneumatic plants are also considered pressure vessels.

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.

1.3.3 Unfired pressure vessel

Any pressure vessel which is not a fired pressure vessel is an unfired pressure vessel.

1.3.4 Boiler

a) 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 by means of heat resulting from combustion of fuel or from combustion gases.

b) 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 part of the boiler upstream of the isolating valve and part of the associated piping system downstream of the isolating valve.

1.3.5 Steam generator

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.

1.3.6 Heat exchanger

Heat exchanger is a pressure vessel used to heat or cool a fluid with 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.

1.3.7 Superheaters, economisers, reheaters, de-superheaters

Superheaters, economisers, reheaters and de-superheaters are heat exchangers associated with a boiler.

1.3.8 Incinerator

Incinerator is a shipboard facility for incinerating solid garbage approximating in composition to household garbage and liquid garbage deriving from the operation of the ship (e.g. domestic garbage, cargo-associated garbage, maintenance garbage, operational garbage, cargo residue, and fishing gear), as well as for burning sludge with a flash point above 60°C.

These facilities may be designed to use the heat energy produced.

1.3.9 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.

1.3.10 Design temperature *(1/1/2001)*

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 account of the effect of any temperature fluctuations which may occur during the service.

b) The design temperature is to be not less than the temperatures stated in Tab 1, unless specially agreed between the manufacturer and the Society on a case by case basis.

For boilers the design temperature is to be not less than 250 °C.

1.3.11 Boiler heating surface

Heating surface is the area of that part of the boiler through which the heat is supplied to the medium, measured on the side exposed to fire or hot gas.

1.3.12 Maximum steam output

Maximum steam output is the maximum quantity of steam that can be produced continuously by the boiler or steam generator operating under the design steam conditions.

1.3.13 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.

1.3.14 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

Table 2 : Pressure vessels classification

Equipment	class 1	class 2	class 3
Boilers	$p > 0,35$ MPa	$p \leq 0,35$ MPa	-
Steam heated generators or steam generators heated by another fluid	$p > 1,15$ MPa, or $p \cdot D > 1500$	All steam generators which are not class 1	-
Pressure vessels and heat exchangers	$p > 4$ MPa, or $t_A > 40$ mm, or $T > 350$°C	$1,75 < p \leq 4$ MPa, or $15 < t_A \leq 40$ mm, or $150 < T \leq 350$°C, or $p \cdot t_A > 15$	All pressure vessels and heat exchangers which are not class 1 or 2
Pressure vessels for toxic substances	All	-	-
Pressure vessels for corrosive substances	$p > 4$ MPa, or $t_A > 40$ mm, or $T > 350$°C	All pressure vessels which are not class 1	-
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

No.	A/I	Item
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 draft 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		

1.4 Classes

1.4.1 Boilers and pressure vessels are classed as indicated in Tab 2 in consideration of their service, characteristics and scantlings. The symbols used in the table have the following meanings:

p : Design pressure, in MPa

T : Design temperature, in °C

D : Inside diameter of the vessel, in mm

t_A : Actual thickness of the vessel, in mm

1.5 Alternative standards

1.5.1

a) All 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.

1.6 Documentation to be submitted

1.6.1 Boilers

The plans listed in Tab 3 are to be submitted.

The drawings listed in Tab 3 are to contain at least: the constructional details of all pressure parts, such as shells, headers, tubes, tube plates, nozzles; all 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.

1.6.2 Other pressure vessels and heat exchangers

The plans listed in Tab 5 are to be submitted.

The drawings listed in Tab 5 are to contain at least the constructional details of all pressure parts, such as shells, headers, tubes, tube plates, nozzles, opening reinforcements and covers, and of all strengthening members, such as stays, brackets and reinforcements.

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 water-walls
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 *(1/7/2002)*

No.	A/I	Item
1	I	General arrangement plan including nozzles and fittings
2	A	Sectional assembly
3	A	Material specifications
4	A	Welding details, including at least: • Typical weld joint design • Welding procedure specifications • Post-weld heat treatments
5	I	Design data, including at least design pressure and design temperatures (as applicable)
6	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
7	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		

1.6.3 Incinerators

Incinerators will be considered on a case by case basis, based on their actual arrangement, using the applicable requirements for boilers and pressure vessels.

2 Design and Construction - Principles

2.1 Materials

2.1.1 Materials for high temperatures

a) Materials for pressure parts having a design temperature exceeding the ambient temperature are 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 [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.

2.1.2 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.

2.1.3 Cast iron

Grey 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 > 0,7MPa or product pV > 15, where V is the internal volume of the pressure vessel in m^3

c) Bolted covers and closures of pressure vessels having a design pressure p > 1MPa, except for covers intended for boiler shells, for which [2.2.3] applies.

Spheroidal cast iron may be used subect to the agreement of the Society following special consideration. However, it is not to be used for parts having a design temperature exceeding 350°C.

2.1.4 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 thermal 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 for fittings with design temperature T exceeding 300°C.

2.1.5 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 [1.5], the material specifications are to be in compliance with the requirements of the standard used.

2.2 Boilers and other steam generators

2.2.1 Insulation of 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.

2.2.2 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.

2.2.3 Access arrangement *(1/7/2009)*

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 300 mm x 400 mm. 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 [3.3.10] and [3.4.8], as applicable.

c) In pressure vessels which are part of a boiler and are not covered by the requirement in 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.

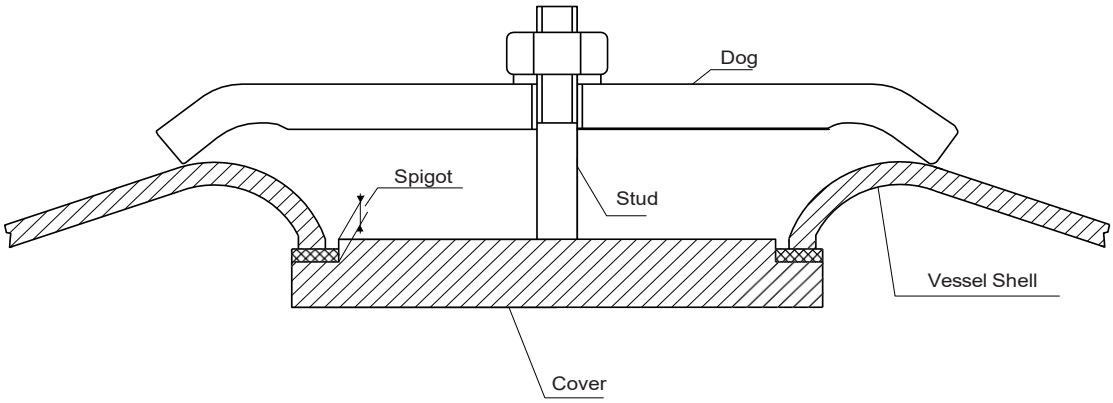
f) Covers are to be of self-closing internal type. Opening covers of other type, having a diameter not exceeding 150 mm, may be accepted by the Society.

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. Fig 1 shows a typical arrangement.

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. For fastening bolt or stud arrangement see Fig 1.

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.

Figure 1 : Opening cover



2.2.4 Fittings

a) In general, cocks and valves are to be designed in accordance with the requirements in Sec 10, [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.

2.2.5 Boiler burners

Burners are to be arranged so that they cannot be withdrawn unless the fuel supply to the burners is cut off.

2.2.6 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.

2.2.7 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 whistles, steam operated steering gears, 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.

2.2.8 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.

2.2.9 Blow-down devices

a) Each boiler is to be fitted with at least one bottom blow-down valve or cock and, where necessary, with a similar valve or cock for scumming from the surface. These valves or cocks are to be secured directly to the boiler shell and are to be connected to overboard discharge pipes.

b) The diameter of valves or cocks and of the connected piping is not to be less than 20 mm and need not be more than 40 mm.

c) Where the bottom blow-down valve may not be directly connected to the boiler shell in water tube boilers, the valve may be placed immediately outside the boiler casing with a pipe of substantial thickness suitably supported and protected from the heat of the combustion chamber.

d) Where two or more boilers have the bottom blow-down and surface scumming-off valves connected to the same discharge, the relevant valves and cocks are to be of the non-return type to prevent the possibility of the contents of one boiler passing to another.

2.2.10 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.

2.2.11 Water sample

a) Every boiler shall be provided with means to supervise and control the quality of the feed water. Suitable arrangements shall 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.

2.2.12 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 Boiler and steam generator safety valves

2.3.1 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 a) provided that their capacity does not account for more than 25% of the total capacity required in [2.3.2], 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 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.

2.3.2 Orifice minimum aggregate area *(1/1/2025)*

a) The minimum aggregate area of the orifices of the safety valves in way of the seat is to be determined by the appropriate formula below.
- Saturated steam:

$$A = c \cdot \frac{d}{h} \cdot \frac{W}{10{,}2 \cdot p + 1}$$

- Superheated steam:

$$A_s = c \cdot \frac{d}{h} \cdot \frac{W_s}{10{,}2 \cdot p + 1} \cdot \left(1 + \frac{T_s}{556}\right)$$

where:

A : Aggregate area, in mm^2, of the orifices in way of the seat, for saturated steam safety valves

A_S : Aggregate area, in mm^2, as defined above, for superheated steam safety valves

p : Maximum working pressure of the boiler or other steam generator, in MPa

p_S : Maximum working pressure of the superheated steam, in MPa

W : Maximum steam production, in kg/h.

Under no circumstances, the value of W is to be based on evaporating capacities (referring to evaporating surfaces of the boiler concerned) not less than the following:
- 14 kg/(m^2 × h) for exhaust gas heated boilers
- 29 kg/(m^2 × h) for coal fired or oil fired boilers

- 60 kg/(m² × h) for water walls of oil fired boilers

W_S : Steam relieving capacity, in kg/h, of the valves fitted at the superheater outlet. This 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

d/h : Ratio of the actual orifice diameter in way of the seat to the actual lift of the safety valve plug. The values of d/h are to be taken not less than 4 and not greater than 24.

For valves of common type, or where the lift of the plug is not known, the value d/h = 24 is to be used

c : 0,875 for safety valves whose relieving capacity has not been ascertained experimentally as specified hereunder

0,485/Z where Z is the flow coefficient, for valves of large relieving capacity ascertained experimentally as directed by the Society, in the presence of the Surveyor. The flow coefficient Z is to be taken as the ratio of 90% of the experimentally checked relieving capacity to the theoretical relieving capacity calculated with a flow coefficient equal to 1. Values of Z higher than 0,88 are not to be used

T_S : Temperature of superheated steam, in °C

b) The orifice diameter in way of the safety valves seat is not to be less than 40 mm for main boilers and 25 mm for auxiliary boilers. 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.

c) 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.

2.3.3 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.

2.3.4 Steam heated steam generator protection

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 [2.3.2] 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.

2.3.5 Safety valve setting

a) 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.

b) 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.

c) 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.

2.3.6 Safety valve fitting on boiler

a) The safety valves of a boiler are to be directly connected to the boiler and separated from other valve bodies.

b) 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 [2.3.2], when $d/h \geq 8$, and not less than the aggregate area of the valves, when $4 \leq d/h < 8$.

c) 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.

2.3.7 Exhaust pipes

a) The minimum cross-sectional area of the exhaust pipes of safety valves which have not been experimentally tested is not to be less than 11,5 h/d times the aggregate area as calculated by the formulae in [2.3.2]. However, this area is not to be less than 1,1 times the safety valve aggregate area.

b) The minimum cross-sectional area of the exhaust pipes of large relieving capacity safety valves whose capacity has been experimentally tested is to be not less than 18 Z × h/d times the aggregate area calculated by the formulae in [2.3.2].

c) 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.

d) Silencers fitted on exhaust manifolds are to have a free passage area not less than that of the manifolds.

e) 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.

f) 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.

g) Exhaust manifolds are to be led to the open and 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.

2.4 Pressure vessels

2.4.1 Access arrangement *(1/7/2009)*

The access requirements for boilers stated in [2.2.3], except item (f), are also applicable for other pressure vessels.

2.4.2 Safety valves

a) 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. See also [6.3] for grouped pressure vessels.

b) In particular, air pressure vessels which can be isolated from the safety valves ensuring their protection in normal service are to be fitted with another safety device, such as a rupture disc or a fusible plug, in order to ensure their discharge in case of fire. This device is to discharge to the open.

c) 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%.

2.4.3 Protection of 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.

2.4.4 Corrosion protection

Vessels and equipment containing media that might lead to accelerated corrosion are to be suitably protected.

2.4.5 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.

b) Drainage devices are also to be fitted on other vessels, in particular steam vessels, in which condensation water is likely to accumulate.

2.4.6 Marking

a) 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

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 smaller pressure vessels the indication of the design pressure only may be sufficient.

2.5 Thermal oil heaters and other pressure vessels associated with thermal oil installations

2.5.1 General

a) The following requirements apply to thermal oil heaters in which organic liquids (thermal oils) are heated by oil fired burners, exhaust gases or electricity to temperatures below their initial boiling point at atmospheric pressure.

b) Thermal oils are only to be used within the limits set by the manufacturer.

c) Means are to be provided for manual operation. However, at least the temperature control device on the oil side and flow monitoring are to remain operative even in manual operation.

d) Means are to be provided to take samples of thermal oil.

2.5.2 Thermal oil heaters

a) Heaters are to be so constructed that neither the surfaces nor the thermal oil becomes excessively heated at any point. The flow of the thermal oil is to be ensured by forced circulation.

b) The surfaces which come into contact with the thermal oil are to be designed for the design pressure, subject to the minimum pressure of 1 MPa.

c) Copper and copper alloys are not permitted.

d) Heaters heated by exhaust gas are to be provided with inspection openings at the exhaust gas intake and outlet.

e) Oil fired heaters are to be provided with inspection openings for examination of the combustion chamber. The opening for the burner may be considered as an inspection opening, provided its size is sufficient for this purpose.

f) Heaters are to be fitted with means enabling them to be completely drained.

g) Thermal oil heaters heated by exhaust gas are to be fitted with a permanent system for extinguishing and cooling in the event of fire, for instance a pressure water spraying system.

2.5.3 Safety valves

Each heater is to be equipped with at least one safety valve having a discharge capacity at least equal to the increase in volume of the thermal oil at the maximum heating power. During discharge the pressure may not increase above 10% over the design pressure.

2.5.4 Pressure vessels

The design pressure of all vessels which are part of a thermal oil system, including those open to the atmosphere, is to be taken not less than 0,2 MPa.

2.5.5 Equipment of the expansion, storage and drain tanks

For the equipment to be installed on expansion, storage and drain tanks, see Sec 10, [13].

2.5.6 Marking

Each thermal oil heater and other pressure vessels which are part of a thermal oil installation are 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):

a) Heaters
   - Maximum allowable heating power
   - Design pressure
   - Maximum allowable discharge temperature
   - Minimum flow rate
   - Liquid capacity

b) Vessels
   - Design pressure
   - Design temperature
   - Capacity.

2.6 Special types of pressure vessels

2.6.1 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.

2.6.2 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.

2.7 Additional requirements for shell type exhaust gas economisers

2.7.1 Application *(1/7/2008)*

These requirements apply to shell type exhaust gas economisers that are intended to be operated in a flooded condition and that can be isolated from the steam piping system.

2.7.2 Design and Construction *(1/7/2008)*

Design and construction of shell type exhaust gas economisers are to pay particular attention to the welding, heat treatment and inspection arrangements at the tube plate connection to the shell.

2.7.3 Pressure Relief *(1/7/2016)*

The requirements given in [2.3.1] apply.

To avoid the accumulation of condensate on the outlet side of safety valves, the discharge pipes and/or safety valve housings are to be fitted with drainage arrangements from the lowest part, directed with continuous fall to a position clear of the shell type exhaust gas economisers where it will not pose threats to either personnel or machinery. No valves or cocks are to be fitted in the drainage arrangements.

Full details of the proposed arrangements to satisfy the requirements in this paragraph are to be submitted for approval.

2.7.4 Pressure Indication *(1/7/2008)*

Every shell type exhaust gas economiser is to be provided with a means of indicating the internal pressure located so that the pressure can be easily read from any position from which it may be controlled.

2.7.5 Lagging *(1/7/2008)*

Every shell type exhaust gas economiser is to be provided with removable lagging at the circumference of the tube end plates to enable ultrasonic examination of the tube plate to shell connection.

2.7.6 Feed Water *(1/7/2008)*

Every shell type exhaust gas economiser is to be provided with arrangements for preheating and de-aeration, addition of water treatment or combination thereof to control the quality of feed water to within the Manufacturer's recommendations.

2.7.7 Operating Instructions *(1/7/2008)*

The Manufacturer is to provide operating instructions for each shell type exhaust gas economiser which are to include reference to:

a) Feed water treatment and sampling arrangements

b) Operating temperatures - exhaust gas and feed water temperatures

c) Operating pressure

d) Inspection and cleaning procedures

e) Records of maintenance and inspection

f) The need to maintain adequate water flow through the economiser under all operating conditions

g) Periodical operational checks of the safety devices to be carried out by the operating personnel and to be documented accordingly

h) Procedures for using the exhaust gas economiser in the dry condition

i) Procedures for maintenance and overhaul of safety valves.

3 Design and construction - Scantlings

3.1 General

3.1.1 Application

a) In general, the formulae in this Section 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 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 Section.

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.

3.1.2 Additional 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 Section, 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.

3.2 Permissible stresses

3.2.1 Permissible stress tables

The permissible stresses K, in N/mm^2, for steels, to be used in the formulae of this Section, may be determined from Tab 6, Tab 7, Tab 8 and Tab 9, where R_m is the ultimate strength of the material in N/mm^2. For intermediate values of the temperature, the value of K is to be obtained by linear interpolation.

Table 6 : Permissible stresses K for carbon steels intended for boilers and thermal oil heaters

Carbon steel	T (°C)	≤ 50	100	150	200	250	300	350	400
R_m = 360 N/mm^2 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/mm^2 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/mm^2 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/mm^2 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/mm^2 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/mm^2 Grades HB, HD	t ≤ 60 mm	170	170	169	159	147	134	125	112

Table 7 : Permissible stresses K for carbon steels intended for other pressure vessels

Carbon steel	T (°C)	≤ 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 8 : Permissible stresses K for alloy steels intended for boilers and thermal oil heaters

Alloy steel	T(°C)	≤ 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 9 : Permissible stresses K for alloy steels intended for other pressure vessels

Alloy steel	T(°C)	≤ 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

3.2.2 Direct determination of permissible stresses

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/mm^2

$R_{S,MIN,T}$: Minimum between R_{eH} and $R_{p\ 0,2}$ at the design temperature T, in N/mm^2

S_A : Average stress to produce creep rupture in 100000 hours, in N/mm^2, 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/mm^2

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/mm^2

f) Additional conditions:

- In special cases the Society reserves the right to apply values of permissible stress K lower than those specified above.
- 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.

3.3 Cylindrical, spherical and conical shells with circular cross-sections subject to internal pressure

3.3.1 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 formula in [3.3.2], [3.3.3], [3.3.4] and [3.7.2].

b) The thicknesses obtained by the formulae in [3.3.2], [3.3.3], [3.3.4], are “net” thicknesses, as they do not include any corrosion allowance. Unless a greater value is agreed in the vessel contract specification, the thickness obtained by the above formulae is to be increased by 0.75 mm. See also [3.3.7].

3.3.2 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:

$$t = \frac{pD}{2Ke - p}$$

where:

p : Design pressure, in MPa

D : Inside diameter of vessel, in mm

K : Permissible stress, in N/mm^2, obtained as specified in [3.2]

e : Efficiency of welded joint. For the value of the efficiency e, see [3.3.5].

b) The minimum thickness of shells having ratio external diameter/inside diameter exceeding 1,5 is subject of special consideration.

3.3.3 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:

$$t = \frac{pD}{4Ke - p}$$

For the meaning of the symbols, see [3.3.2].

b) The minimum thickness of shells having ratio external diameter/inside diameter exceeding 1,5 is subject of special consideration.

3.3.4 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.

$$t = \frac{pD}{(2Ke - p) \cdot \cos\varphi}$$

For the meaning of the symbols, see [3.3.2].

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 2). When φ exceeds 75°, the shell thickness is to be taken as required for flat heads, see [3.5].

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.

3.3.5 Efficiency

The values of efficiency e to be used in the formulae in [3.3.2], [3.3.3] and [3.3.4] are indicated in Tab 10.

Table 10 : Efficiency of unpierced shells *(1/7/2004)*

Case	e
Seamless shells	1
Shells of class 1 vessels **(1)**	1
Shells of class 2 vessels (with partial radiographic examination of butt-joints)	0,85
Shells of class 2 vessels (without radiographic examination of butt-joints)	0,75
Shells of class 3 vessels	0,6
(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.	

3.3.6 Minimum thickness *(1/7/2009)*

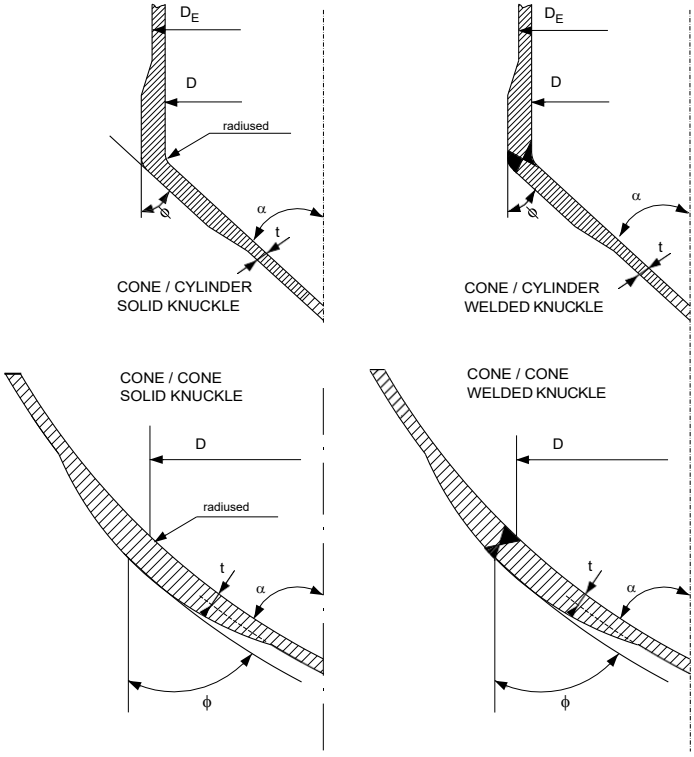
Irrespective of the value calculated by the formulae in [3.3.2], [3.3.3] [3.3.4], the thickness t of shells is to be not less than one of the following values, as applicable:

- for pressure vessels:
  - in carbon and low alloy steel: t = 3 + D/1500 mm
  - in stainless steel and non-ferrous materials: t = 3 mm
- for unpierced plates of boilers: t = 6 mm
- for boiler cylindrical tube plates: t = 9,5 mm.

No corrosion allowance needs to be added to the above values.

For pressure vessels where the cylindrical part is made of a pipe or where corrosion-resistant materials are used, a smaller minimum thickness may be accepted.

Figure 2 : Conic shells



3.3.7 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.

3.3.8 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.

c) Openings are considered isolated when the distance between the centres of two adjacent holes in the longitudinal axis is not less than:

   $d + 1{,}1(D \cdot t_A)^{0,5}$ or

   5 d

   whichever is the lesser,

   where:

   d : Diameter of the openings, in mm, (if the two openings have different diameter, d is the average diameter).

3.3.9 Openings requiring compensation *(1/7/2008)*

The following openings are to be compensated in accordance with the requirements of [3.3.10]:

a) Isolated openings in shell plates having a diameter, in mm, greater than the smaller of the following values:

   2,5 t + 70 or

   $\frac{D}{6}$ or

   200 mm

   whichever is the lesser, where t is the thickness calculated by the formulae in [3.3.2], [3.3.3] or [3.3.4] as applicable, using an efficiency value e equal to 1 and not adding the corrosion constant.

b) Non-isolated openings.

3.3.10 Compensation of openings in shells

a) The compensation area is to be provided in each diametrical direction of the opening and is to be at least equal to the area of the missing material in that direction, corrected as indicated in b).

   The area of the missing material in one direction is the width of the opening in that direction multiplied by the required minimum shell thickness calculated by the formulae in [3.3.2], [3.3.3], or [3.3.4], as applicable, using an efficiency value e equal to 1 without corrosion constant.

b) The area corresponding to the maximum opening diameter for which compensation is not required may be deducted from the computation of the compensating area to be provided.

c) Material around the opening outside the width exceeding the opening radius in any direction is not to be included in the calculation of the compensation.

d) Excess thickness in the shell with respect to the Rule thickness t, calculated as indicated in a), may be considered as contributing to the compensation of the opening for a width not exceeding the opening radius.

e) Where nozzles are welded to the shell, their excess thickness with respect to the Rule thickness, calculated in accordance with the requirements in [3.6.1], may be considered as contributing to the compensation of the hole for a height h, in mm, equal to:

   $h = [(d_B - 2t) \cdot t_B]^{0,5}$

   where d_B and t_B are the values, in mm, of the outer diameter and thickness of the nozzle, respectively. See also Fig 3.

f) The sectional area of welds connecting compensating parts may be included in the compensation calculation if they fall inside the area mentioned in a).

g) If the material of rings, nozzles and reinforcement collars has a lower permissible stress than the shell material, the compensating area is to be proportionally increased.

h) Fig 3 summarises the compensation criteria described in the above items.

i) Different arrangements will be specially considered by the Society on a case by case basis.

3.3.11 Cylindrical shells pierced by tube holes

For the minimum thickness of cylindrical shells pierced by tube holes, see [3.7.1].

3.3.12 Covers *(1/1/2023)*

a) Circular, oval and elliptical inspection openings are to be provided with steel covers. Inspection openings on boilers with a diameter not exceeding 150 mm and on pressure vessels 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 11 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.

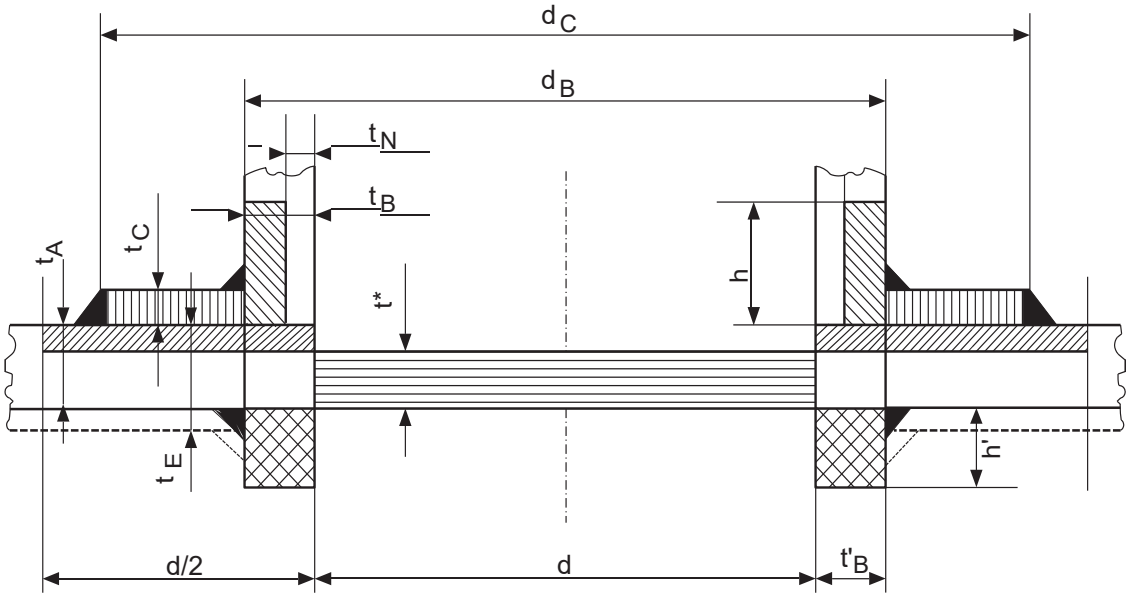
c) The thickness obtained by the formula in a) is “net” thickness, as it does not include any corrosion allowance. Unless a greater value is agreed in the vessel contract specification, the thickness obtained by the above formula is to be increased by 1 mm. See also [3.3.7]

d) The formula in b) above is calibrated for flat covers.

e) For concave covers, also scantlings based on the formula for concave heads in [3.4.3] may be accepted to the satisfaction of the Society.

f) The provisions of this paragraph also apply to covers located on the dished heads.

Figure 3 : Opening compensation



AREA TO BE COMPENSATED = (d minus largest acceptable non-compensated hole diameter). t^*

EXCESS OF SHELL THICKNESS = $d\ (t_A - t^*)$

EXCESS OF NOZZLE THICKNESS = $2h\ (t_B - t_N)$

NOZZLE EXTENSION INSIDE SHELL = $2h'.t'_B$

WELDINGS TOTAL AREA

COMPENSATION = $(d_C - d_B)\ t_C$ with $(d_C - d_B) \leq d$

t^* = thickness calculated with e = 1 and without corrosion constant

t_E = actual thickness "as built" including corrosion allowance

Table 11 : Coefficient C

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

3.4 Dished heads subject to pressure on the concave (internal) side

3.4.1 Dished heads for boiler headers

Dished heads for boiler headers are to be seamless.

3.4.2 Dished head profile

The following requirements are to be complied with for the determination of the profile of dished heads (see Fig 4 (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.

D : Outside diameter of the head base, in mm

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

D : Outside diameter of the head base, in mm

H : External depth of head calculated by the following formula (see Fig 4 (b)):

$$H = R_E - [(R_E - 0,5\ D).(R_E + 0,5\ D - 2\ r_E)]^{0,5}$$

where:

R_E : External radius of the spherical part, in mm

r_E : External knuckle radius, in mm.

3.4.3 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 5, as a function of H/D and t/D

for other symbols, see [3.3.2].

b) The thickness obtained by the formula in a) is “net” thickness, as it does not include any corrosion allowance. Unless a greater value is agreed in the vessel contract specification, the thickness obtained by the above formula is to be increased by 0.75 mm. See also [3.3.7].

3.4.4 Composed torispherical heads

a) Torispherical heads may be constructed with welded elements of different thickness (see Fig 6).

b) Where a torispherical head is built in two sections, the thickness of the torispherical part is to be obtained by the formula in [3.4.3], while the thickness of the spherical part may be obtained by the formula in [3.3.3].

c) The spherical part may commence at a distance from the knuckle not less than:

$0,5.(R_{IN}.t)^{0,5}$

where:

R_{IN} : Internal radius of the spherical part, in mm

t : Knuckle thickness, in mm

3.4.5 Minimum thickness *(1/1/2001)*

Irrespective of the value calculated in [3.4.3] and [3.4.4] the thickness t of dished heads is not to be less than:

- 3 + D/1500 mm for normal pressure vessels in carbon and low alloy steel
- 3 mm for normal pressure vessels in stainless steel and non-ferrous materials
- 6 mm for boiler pressure vessels

No corrosion allowance needs to be added to the above values.

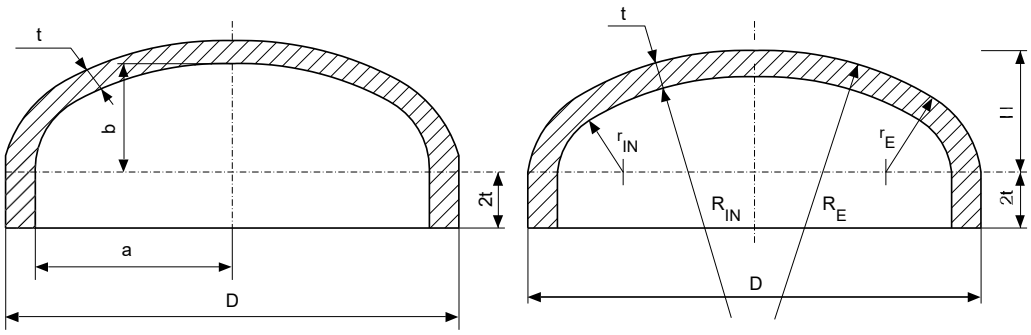
3.4.6 Connection of heads to cylindrical shells

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 [3.3.2] using the same efficiency factor e adopted for calculation of the head thickness. Fig 7 and Fig 8 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 8.

Other types of connections are subject of special consideration by the Society.

Figure 4 : Dished head profiles



(a) ELLIPSOIDAL HEAD

(b) TORISPHERICAL HEAD

Figure 5 : Shape factor for dished heads

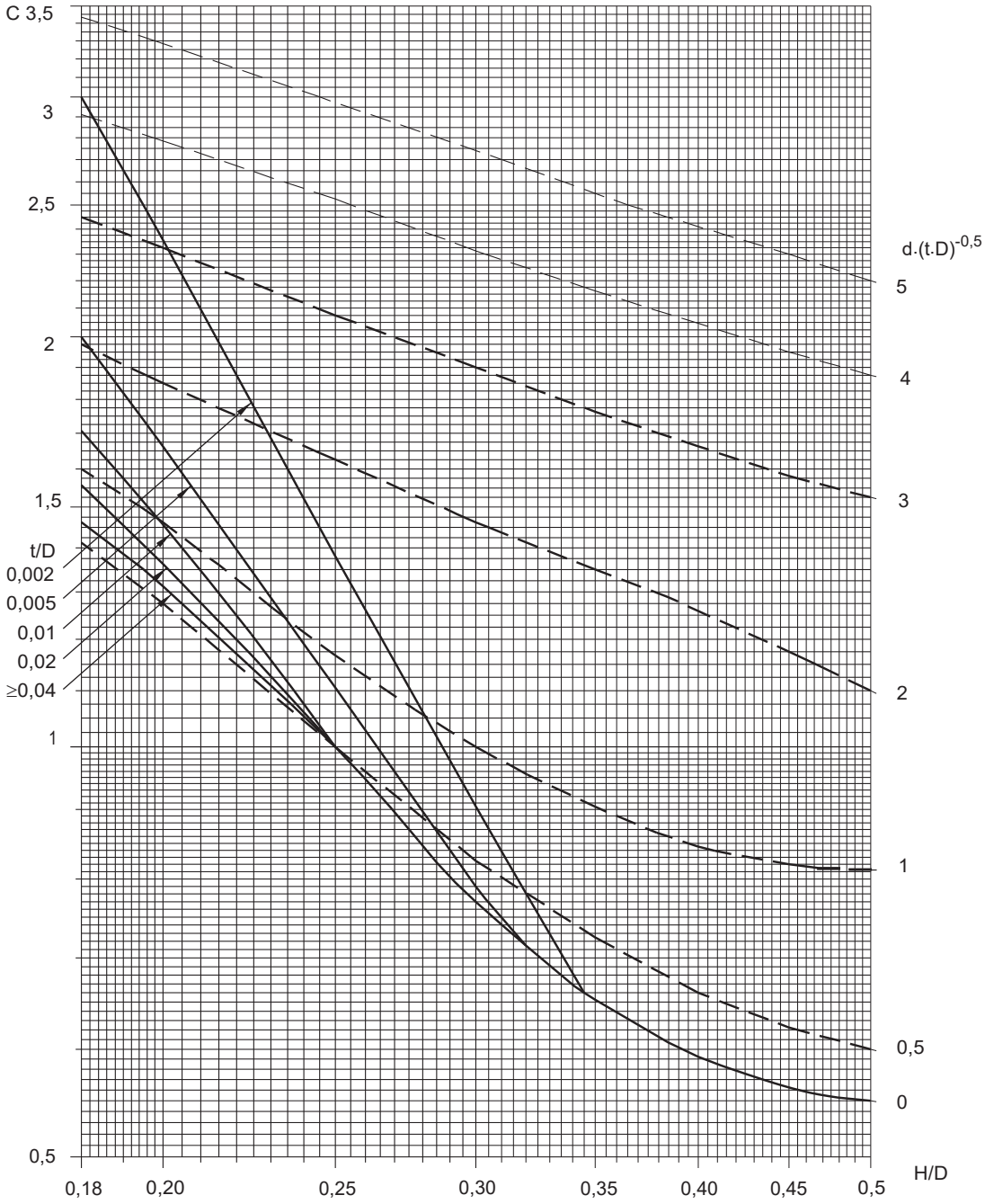
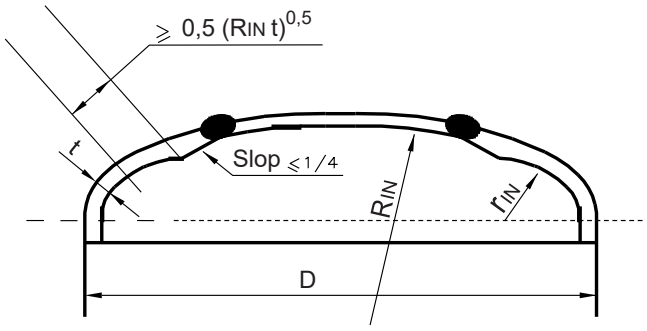


Figure 6 : Composed torispherical head *(1/7/2001)*



3.4.7 Dished heads with openings

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.

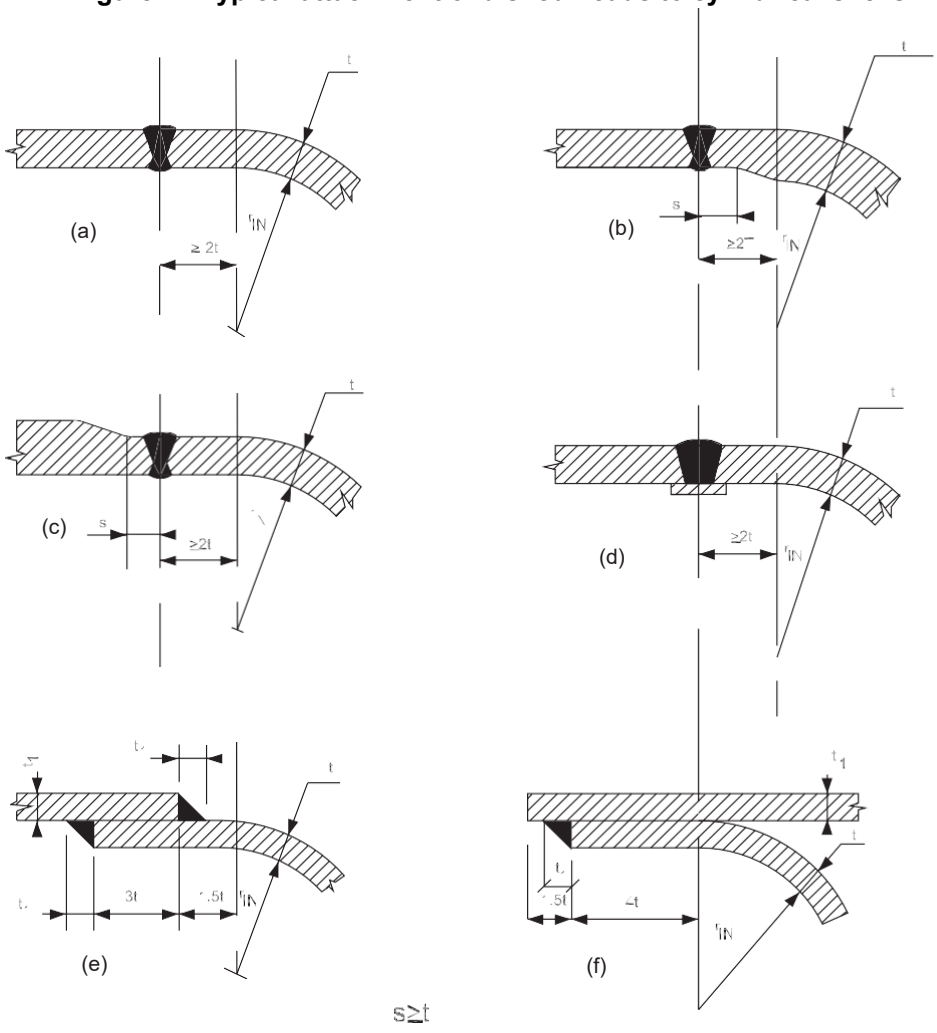
c) The opening is to be so situated that its projection, or its reinforcement projection in the case of compensated openings, is completely contained inside a circle having its centre at the centre of the head and a diameter of 0,8D, D being the external diameter of the head (see Fig 9). However, a small reinforced opening for drainage may be accepted outside the indicated area.

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 [3.4.3] using the smallest of the shape factors C obtained from the graph in Fig 5 as a function of:

H/D and t/D or H/D and $d.(t.D)^{-0,5}$,

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.

Figure 7 : 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.

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 9
- For flanged openings, the radius r of the flanging (see Fig 9) is not to be less than 25 mm
- The thickness of the flanged part may be less than the Rule thickness.

3.4.8 Compensated openings 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 [3.4.3], the openings are to be compensated.

b) Fig 22, Fig 23, Fig 24 and Fig 25 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 [3.4.3] and using the shape-factor C obtained from the graph in Fig 5 using the value:

$$\left(d - \frac{A}{t}\right) \cdot (tD)^{-0,5}$$

in lieu of:

$d.(tD)^{-0,5}$

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:

$d.(tD)^{-0,5} = 0$

e) If necessary, calculations are to be repeated.

3.4.9 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:

$l = 0,5\ d$

$l = (2\ R_{IN}\ t)^{0,5}$

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 (see Fig 4 a):

$$R_{IN} = \frac{[a^4 - x^4(a^2 - b^2)]^{3/2}}{a^4 b}$$

where;

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:

$(d_B \,.\, t_B)^{0,5}$

where d_B and t_B are the diameter of the opening and the thickness of the pad or nozzle, in mm, respectively. See also Fig 3.

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.

3.5 Flat heads

3.5.1 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 [3.2]

D : Diameter of the head, in mm. For circular section heads, the diameter D is to be measured as shown in Fig 10 and Fig 11 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 10 and Fig 11:

Fig 10(a): C = 400 for circular heads

Fig 10(b): C = 330 for circular heads

Fig 10(c): C = 350 for circular heads

Fig 10(d): C = 400 for circular heads and C = 250 for rectangular heads

Fig 10(e): C = 350 for circular heads and C = 200 for rectangular heads

Fig 10(f): C = 350 for circular heads

Fig 10(g): C = 300 for circular heads

Fig 10(h): C = 350 for circular heads and C = 200 for rectangular heads

Fig 11(i): C = 350 for circular heads and C = 200 for rectangular heads

Fig 11(j): C = 200 for circular heads

Fig 11(k): C = 330 for circular heads

Fig 11(l): C = 300 for circular heads

Fig 11(m):C = 300 for circular heads

Fig 11(n): C = 400 for circular heads

Fig 11(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 11(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 < 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 11(o)

m, y : Adimensional coefficients, whose values are given in Tab 12, 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 10 and Fig 11 will be the subject of special consideration by the Society.

b) The thickness obtained by the formula in a) is "net" thickness, as it does not include any corrosion allowance. Unless a greater value is agreed in the vessel contract specification, the thickness obtained by the above formula is to be increased by 1 mm. See also [3.3.7].

Figure 8 : Connection of hemispherical head to the cylindrical shell

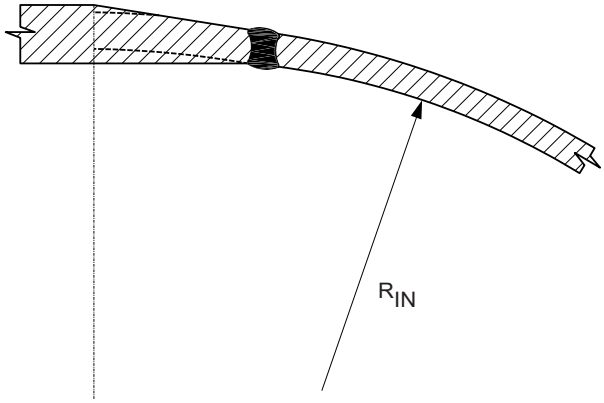
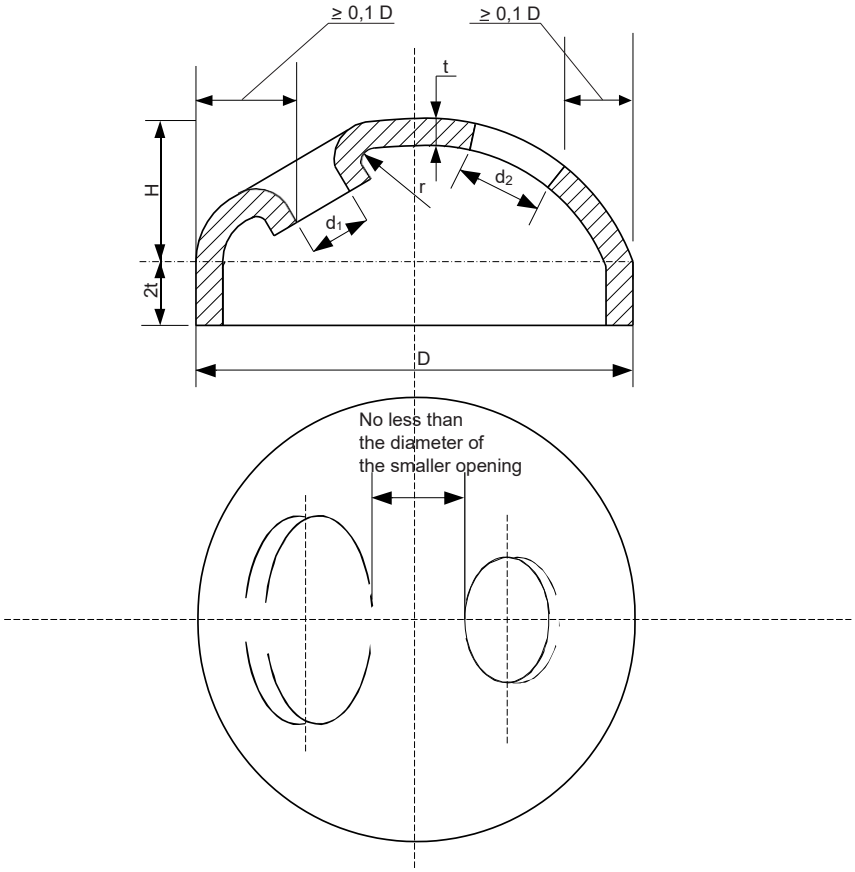


Figure 9 : Openings on dished heads



3.5.2 Stayed flat head minimum thickness

For the minimum thickness of stayed flat heads, see [3.8.4].

3.5.3 Compensation of openings in flat plates

Openings in flat plates for inspection purposes or for connection of fittings are to be compensated by reinforcement collars or by flanges.

In the latter case, the depth h of the flange, in mm, measured from the outer surface, is not to be less than the value obtained from the following formula:

$h = (t \cdot d_M)^{0,5}$

where t and d_M are the values, in mm, of the plate thickness and of the minimum width of the opening.

Table 12 : 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 layers	22	8,2
Synthetic fibre with suitable binders:		
- 3 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

3.6 Nozzles

3.6.1 Thickness

a) The thickness t, in mm, of nozzles attached to shells and headers of boilers is not to be less than:

$$t = \frac{d_E}{25} + 2,5$$

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.

3.6.2 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 22, Fig 23, Fig 24 and Fig 25 show some typical acceptable connections of nozzles to shells. Other types of connections will be considered by the Society on a case by case basis.

3.7 Water tube boilers

3.7.1 Drums and headers

The scantlings of cylindrical drums and headers pierced by pipe holes are to be obtained by the applicable formulae in [3.3], [3.4], [3.5], [3.7.2] and [3.7.3].

Figure 10 : Types of unstayed flat heads (1)

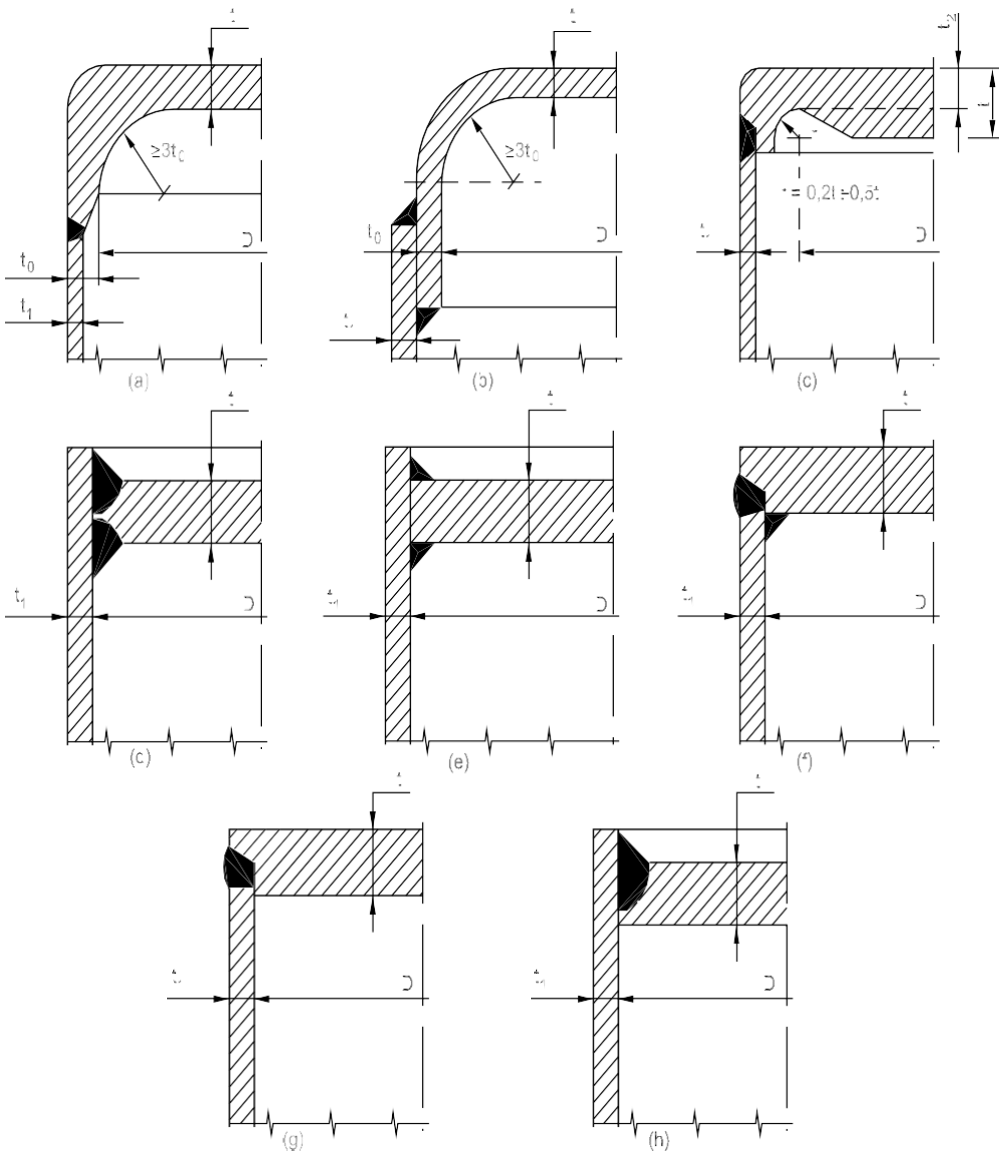
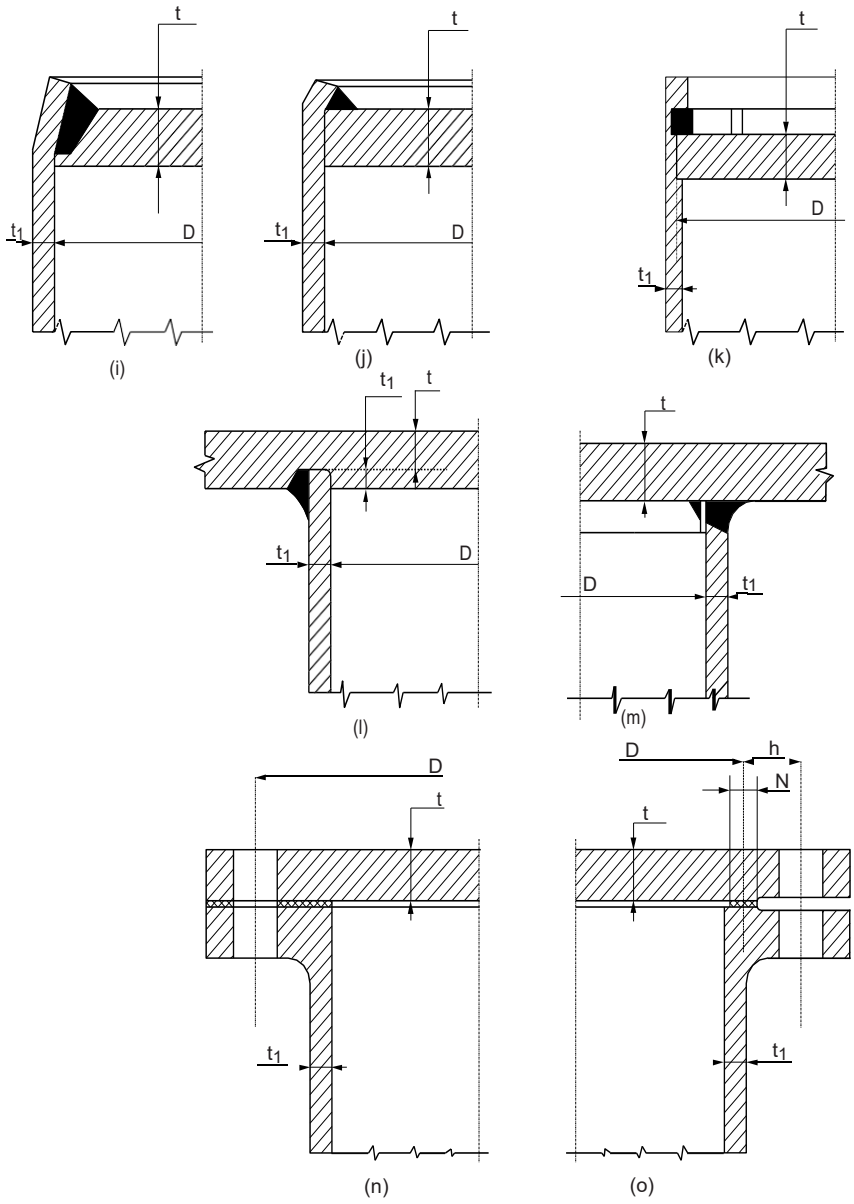


Figure 11 : Types of unstayed flat heads (2)



3.7.2 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 12):

$$e = \frac{1}{\frac{s}{s-d} \cdot (1 - (0{,}5 \cdot \sin^2\alpha)) + m \cdot \sin 2\alpha}$$

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 A/t_A, where A is the compensating area, in mm^2, of nozzle and welds (see [3.3.9] and Fig 3).

α : Angle between the axis of hole row considered and the axis of the cylinder (α=0° if the hole row is parallel to the cylinder generating line; α=90° for circumferential hole row).

m : Coefficient depending upon the ratio d/s, as obtained from Tab 13. For intermediate values of d/s, the value of m is to be obtained by linear interpolation.

The value of e actually used is to be the smallest calculated value for either longitudinal, diagonal or circumferential rows of holes.

Figure 12 : Hole pattern in cylindrical shells

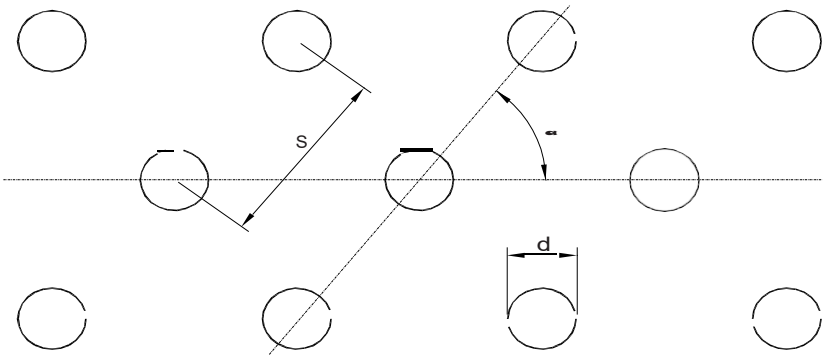


Table 13 : Coefficient m

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

3.7.3 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 [3.3.5]) and for each configuration of holes (as per [3.7.2]).

3.7.4 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 13):

$$t = \left(\frac{100pM_1}{K}\right)^{0,5}$$

$$t_1 = \left(\frac{100pM_2}{eK}\right)^{0,5}$$

where (see also Fig 13):

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/mm², obtained as specified in [3.2]

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:

$$e = \frac{s - d}{s} \quad \text{for } d < a$$

$$e = \frac{s - 0,67d}{s} \quad \text{for } a \le d < 1,3a$$

$$e = \frac{s - 0,33d}{s} \quad \text{for } d \ge 1,3a$$

where:

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

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:

$$M_2 = \frac{b^2 - \frac{1}{2}a^2 - ab + \frac{3}{2}c^2}{50}$$

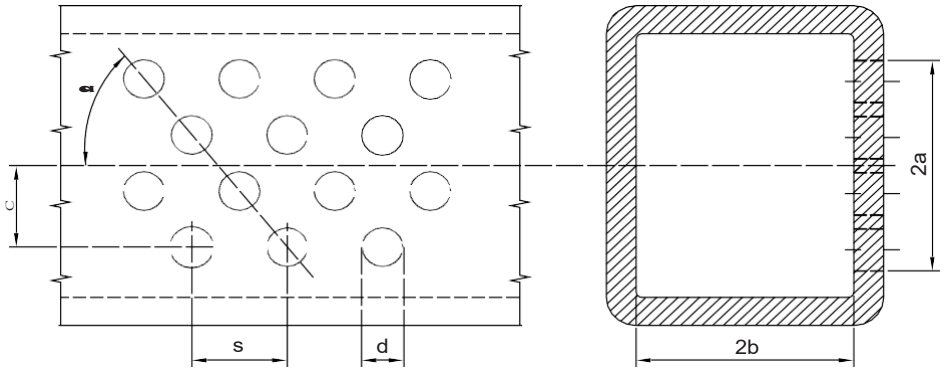
For a staggered pattern of holes:

$$M_2 = \frac{b^2 - \frac{1}{2}a^2 - ab}{50}\cos\alpha$$

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. Unless a greater value is agreed in the vessel contract specification, the thickness obtained by the above formula is to be increased by 1,5 mm. See also [3.3.7].

Figure 13 : Rectangular section headers



3.7.5 Water tubes, superheaters and economiser tubes

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, in mm, given by the following formula:

$$t = \frac{pd}{2K + p} + 0,3$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm^2, obtained as specified in [3.2]

d : Outside diameter of tube, in mm

However, irrespective of the value calculated by the formulae in a), the thickness t of tubes is not to be less than the values given in Tab 14.

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 precise pipes, the thickness calculated by the formula in 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 in a) may be increased to the satisfaction of the Society.

d) The thickness of tubes which form an integral part of the boiler and which are not exposed to combustion gases is to comply with the requirements for steam pipes (see Sec 10, [15]).

3.8 Additional requirements for vertical boilers and cylindrical boilers (fire tube boilers)

3.8.1 Shells of vertical boilers and cylindrical boilers

The scantlings of the shells of vertical boilers and cylindrical boilers are to be determined in accordance with [3.3].

Table 14 : 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 or open 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	-

3.8.2 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 [3.4].

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 [3.2]

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 b) is “net” thickness, as it does not include any corrosion allowance. Unless a greater value is agreed in the vessel contract specification, the thickness obtained by the above formula is to be increased by 0,7 mm. See also [3.3.7].

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.

3.8.3 Ends of cylindrical boilers

The minimum thickness of the dished and/or unstayed flat ends of the cylindrical boilers is to be determined in accordance with [3.4] and/or [3.5], as applicable.

3.8.4 Stayed flat head minimum thickness

a) 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 : t_1/t = Ratio of the thickness of the large washer or doubler, where fitted, to the thickness of the plate. The value of B is to be taken between 0,67 and 1

K : Permissible stress, in N/mm^2, obtained as specified in [3.2]

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:

- 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 14); or

  $(a^2+b^2)^{0,5}$ 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.

- 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 14).

b) 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.

c) 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.

d) The thickness obtained by the formulae in a), is “net” thickness, as it does not include any corrosion allowance. Unless a greater value is agreed in the vessel contract specification, the thickness obtained by the above formula is to be increased by 1 mm. See also [3.3.7].

3.8.5 Furnaces

a) In general, the minimum thickness of furnaces is to be calculated in accordance with the requirements of a recognised Standard for pressure vessels subject to external pressure accepted by the Society.

b) 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 formula in [3.8.6], [3.8.7] and [3.8.8].

c) The thickness of furnaces is not to be less than 8 mm and the stays are to be spaced such that the thickness does not exceed 22 mm.

d) All the thicknesses obtained for furnaces by the formulae in [3.8.6], [3.8.7], [3.8.8], [3.8.9] and [3.8.10] are “net” thicknesses, as they do not include any corrosion allowance. Unless a greater value is agreed in the vessel contract specification, the thicknesses obtained by the above formulae are to be increased by 1 mm. See also [3.3.7].

3.8.6 Plain furnaces with reinforcing rings and similar, and bottoms of combustion chambers

The minimum thickness t, in mm, of plain furnaces with reinforcing rings and bottoms of combustion chambers is not to be less than the value given by the following equation:

$$t = \frac{pD_E}{0,28R_m} + \frac{L}{286}$$

where:

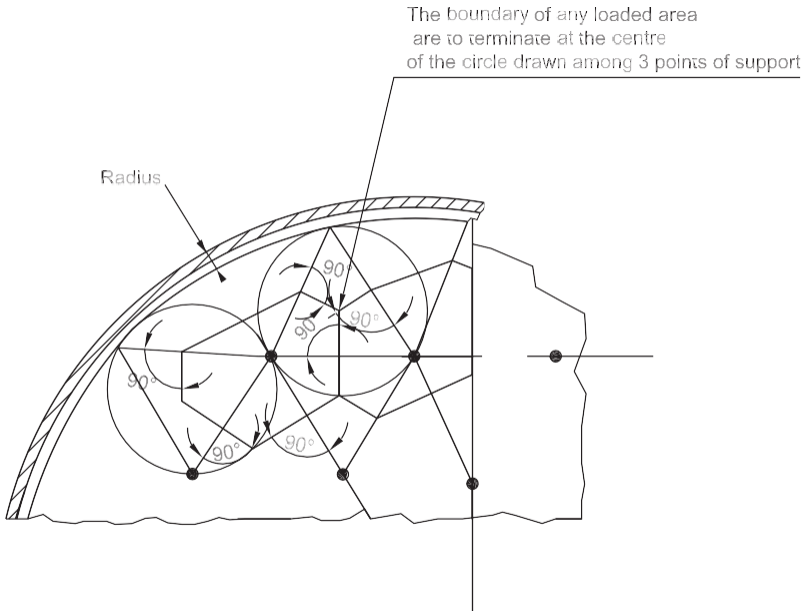
p : Design pressure, in MPa

R_m : Ultimate tensile strength, in N/mm^2

D_E : External diameter of the furnace, in mm

L : Length of furnace or spacing of reinforcing rings, in mm.

Figure 14



3.8.7 Corrugated or rib-reinforced furnaces

The minimum thickness t, in mm, of corrugated or rib-reinforced furnaces is to be not less than the value given by the following equation:

$$t = \frac{pD_E}{CR_m}$$

where:

D_E : Diameter of the furnace at the bottom of the corrugation or at the outside of the plain portion, in mm.

C : 0,26 for corrugated furnaces

0,28 for furnaces with rib reinforcements.

For the meaning of other symbols, see [3.8.6].

3.8.8 Hemispherical furnaces

The minimum thickness t, in mm, of hemispherical furnaces is to be not less than the value given by the following equation:

$$t = \frac{pD_E}{120}$$

For the meaning of the symbols, see [3.8.6].

3.8.9 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 [3.2]

s : Pitch of stay tubes, taken as the greatest mean pitch of the stay tubes supporting a quadrilateral portion of the plate, in mm.

3.8.10 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 [3.8.9] 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 [3.8.9]

3.8.11 Tube plates outside tube bundles

For those parts of tube plates which are outside the tube bundle, the formula in [3.8.4] 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.

3.8.12 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 [3.10.1].

3.8.13 Stay and stay tube scantlings

a) 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 : $R_m / 7$

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.

b) 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.

c) 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.

d) For welded connections of stays to tube plates, see Fig 29.

3.8.14 Stay and stay tube construction

a) In general, doublers are not to be fitted in plates exposed to flame.

b) As far as possible, stays are to be fitted perpendicularly to the supported surface.

c) Long stays in double front boilers and, in general, stays exceeding 5 m in length, are to be supported at mid-length.

d) 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.

e) After forging, the ends of stay tubes are to be stress relieved.

3.8.15 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 the case of an odd number of stays:

$$t = \frac{pL(L-s)l}{0{,}25R_m a^2} \cdot \frac{n+1}{n}$$

- In the 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

l : Distance between centres of girders, in mm

n : Number of stays on the girder

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:

a) The stays are regularly distributed over the length L.

b) The distance from the supports of the outer stays does not exceed the uniform pitch s.

c) 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.

d) When the curvature radius mentioned under c) 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.

3.8.16 Ogee rings

The thickness of ogee rings connecting the furnaces to the shell in vertical auxiliary boilers (see Fig 15), 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:

$$t = [1{,}02 \cdot 10^{-3} \cdot pD_A \cdot (D_A - d_A)]^{0{,}5} + 1$$

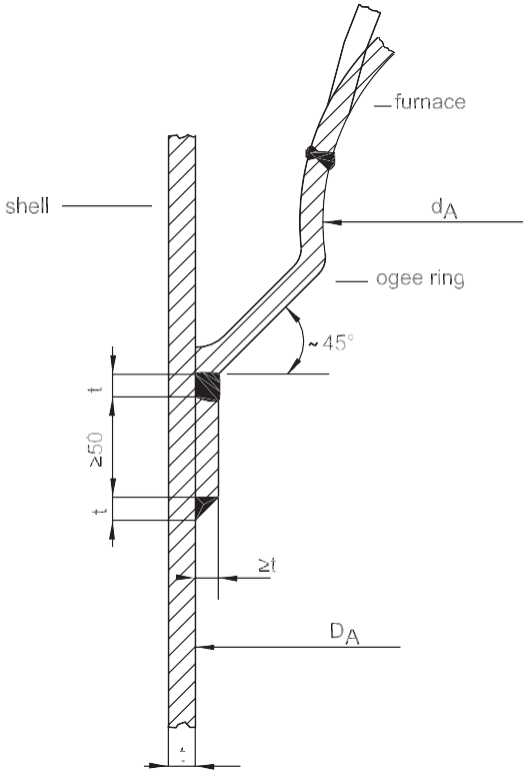
where:

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

Figure 15 : Ogee Ring



3.8.17 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 thickness of the tubes is not to be less than 3 mm.

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 precise pipes, the thickness calculated by the formula in 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.

3.9 Bottles containing pressurised gases

3.9.1 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, length not exceeding 2000 mm and capacity not exceeding 150 litres (see also [2.6.1]).

c) For bottles exceeding the above capacity and dimensions, the following requirements may be applied at the discretion of the Society.

3.9.2 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:

- 25 MPa for CO_2 bottles
- For refrigerants, the value of hydrostatic test pressure is given in Part F, Chapter 8.

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

3.9.3 Dished ends

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 [3.3.3].

b) Convex ends: see Fig 16.

c) Concave base ends: see Fig 17.

d) Ends with openings: see Fig 18.

e) Other types of ends will be specially considered by the Society.

3.10 Heat exchangers

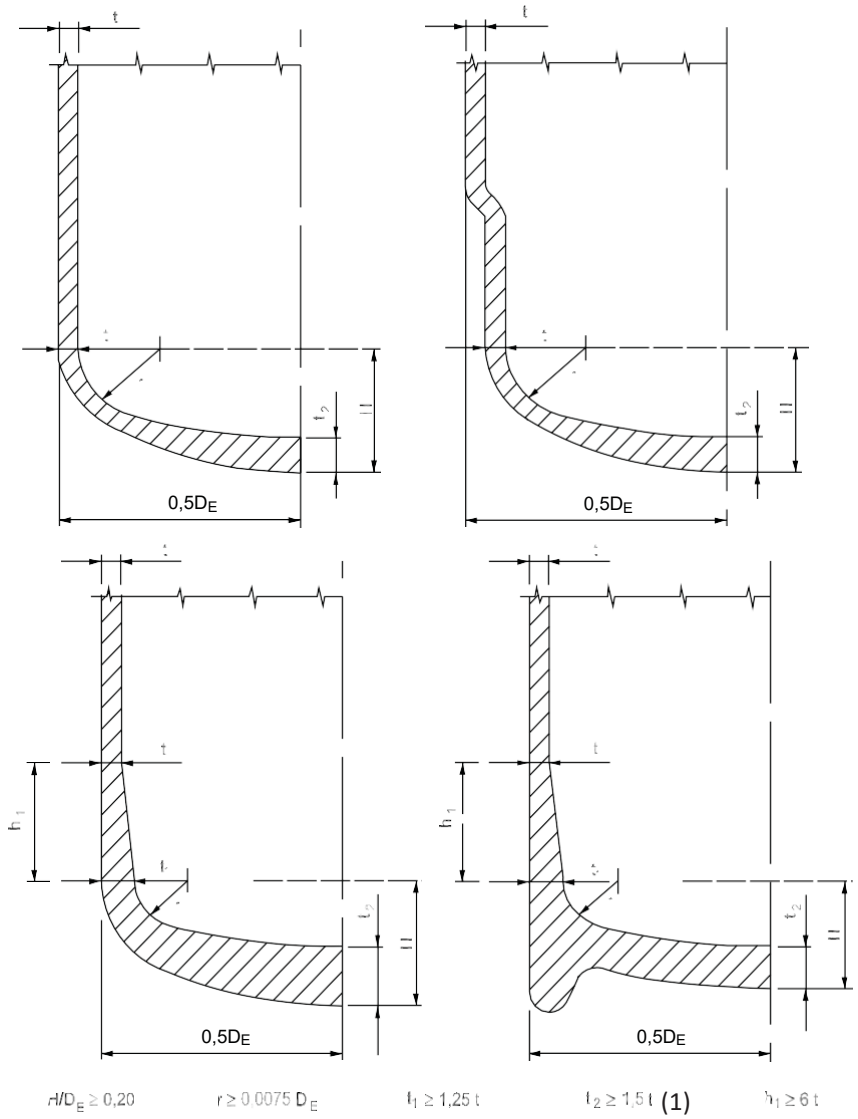
3.10.1 Scantlings

a) Vessels are to be designed in accordance with the applicable requirements stated in [3.3] and [3.4].

b) Tubes are to be designed in accordance with [3.7.5].

c) Tube plates are to be designed in accordance with a recognised Standard accepted by the Society.

Figure 16 : Dished convex ends *(1/7/2010)*



(1) : $t_2 > t$ in the case of dished ends manufactured from plates by deep drawing procedure, provided that $H/D_e > 0,4$ and thickness according to [3.4.3].

Figure 17 : Dished concave ends

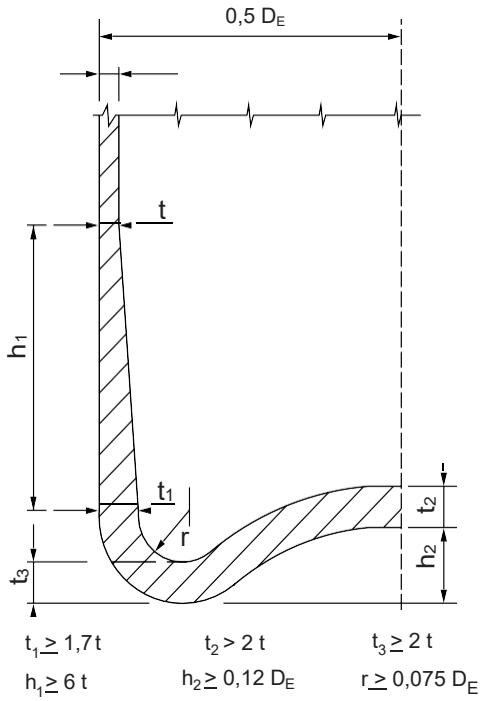
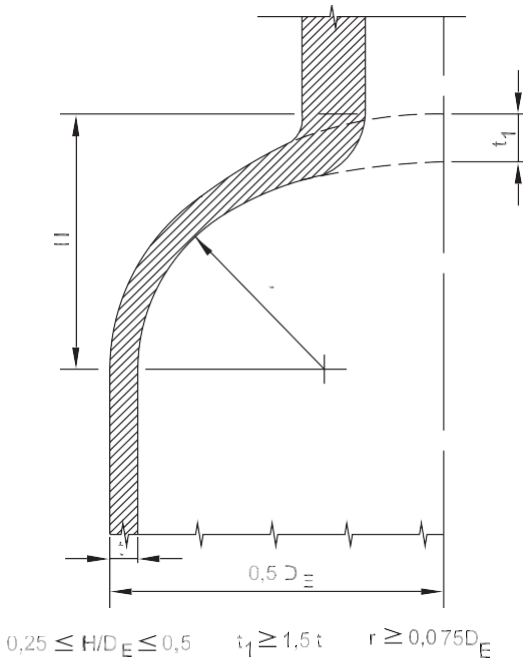


Figure 18 : Heads with openings



3.10.2 Thermal oil heat exchangers

The provisions of [3.10.1] apply also to thermal oil heat exchangers. However, irrespective of the thickness obtained by the formula in [3.7.5], the tube thickness of oil fired and exhaust gas thermal oil heaters is to be not less than the values indicated in Tab 15.

Table 15 : Minimum thickness of thermal oil heat exchanger tubes

Outside diameter in mm	Minimum thickness in mm of tubes subject to internal pressure of oil fired and exhaust gas thermal oil heaters
< 63,5	2,4
70 - 89	2,9
> 89	3,6

4 Design and construction - Fabrication and welding

4.1 General

4.1.1 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 will be the subject of special consideration.

4.1.2 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.

4.1.3 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.

4.1.4 Forming of the 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 radiographic 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 460N/mm^2 and 510N/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, 1Mn 0,5Mo, 1Mn 0,5MoV and 0,5Cr 0,5Mo.
- After forming, the joints are to be subjected to radiographic examination or equivalent and to a magnetic particle or liquid penetrant test.

4.2 Welding design

4.2.1 Main welded joints

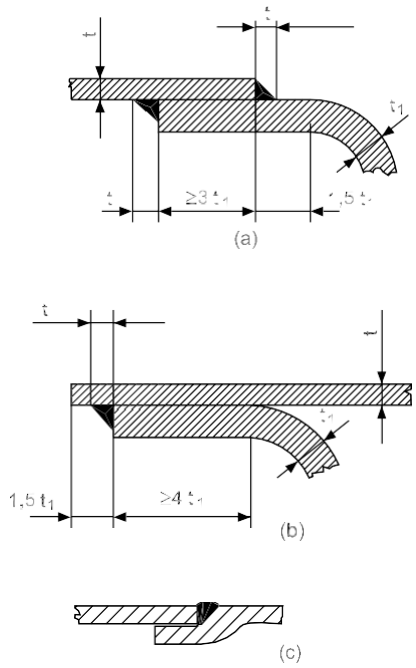
a) All joints of class 1 and 2 pressure parts of boilers and pressure vessels are to be butt-welded, with the exception of welding connecting flat heads or tube sheets to shells, for which partial penetration welds or fillet welds may be accepted.

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 19 shows some acceptable details of circumferential lap welds for class 3 pressure vessels.

4.2.2 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 19 : Example of acceptable lap-joints



Details (b) and (c) may be used only for pressure vessels having internal diameter less than 600mm.

4.2.3 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.

4.2.4 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 [4.2.3] 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.

4.2.5 Welding location

The location of main welded joints is to be chosen so that these joints are not submitted to appreciable bending stresses.

4.2.6 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.

4.2.7 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.

4.2.8 Type of weldings

Fig 20, Fig 21, Fig 22, Fig 23, Fig 24, Fig 25, Fig 26, Fig 27, Fig 28 and Fig 29 indicate the type and size of weldings of typical pressure vessel connections. Any alternative type of welding or size will be the subject of special consideration by the Society.

4.3 Miscellaneous requirements for fabrication and welding

4.3.1 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.

4.3.2 Cleaning of parts to be welded

a) Parts to be welded are, for a distance of at least 25mm 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.

4.3.3 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.

4.3.4 Interruption in welding

If, for any reason, welding is stopped, care is to be taken on restarting to obtain a complete fusion.

4.3.5 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.

4.3.6 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:
- 2,5mm for plates having a thickness not exceeding 12mm
- 3mm for plates having a thickness greater than 12mm but less than 25mm
- 5mm for plates having a thickness at least equal to 25mm.

4.4 Preparation of parts to be welded

4.4.1 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.

Figure 20 : Types of joints for unstayed flat heads (1)

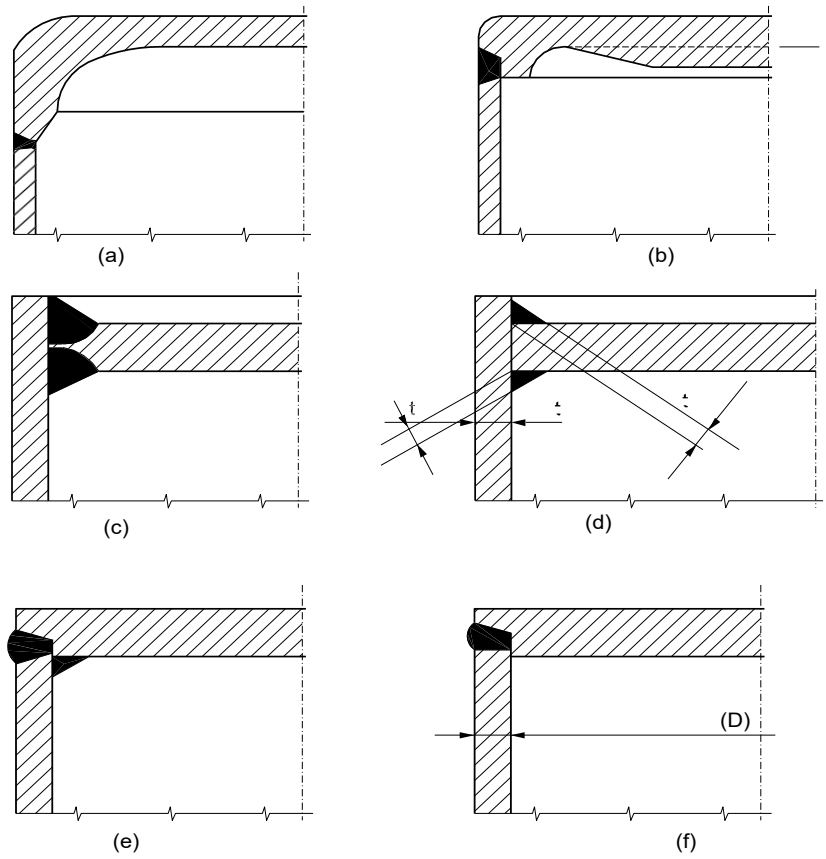


Figure 21 : Types of joint for unstayed flat heads (2)

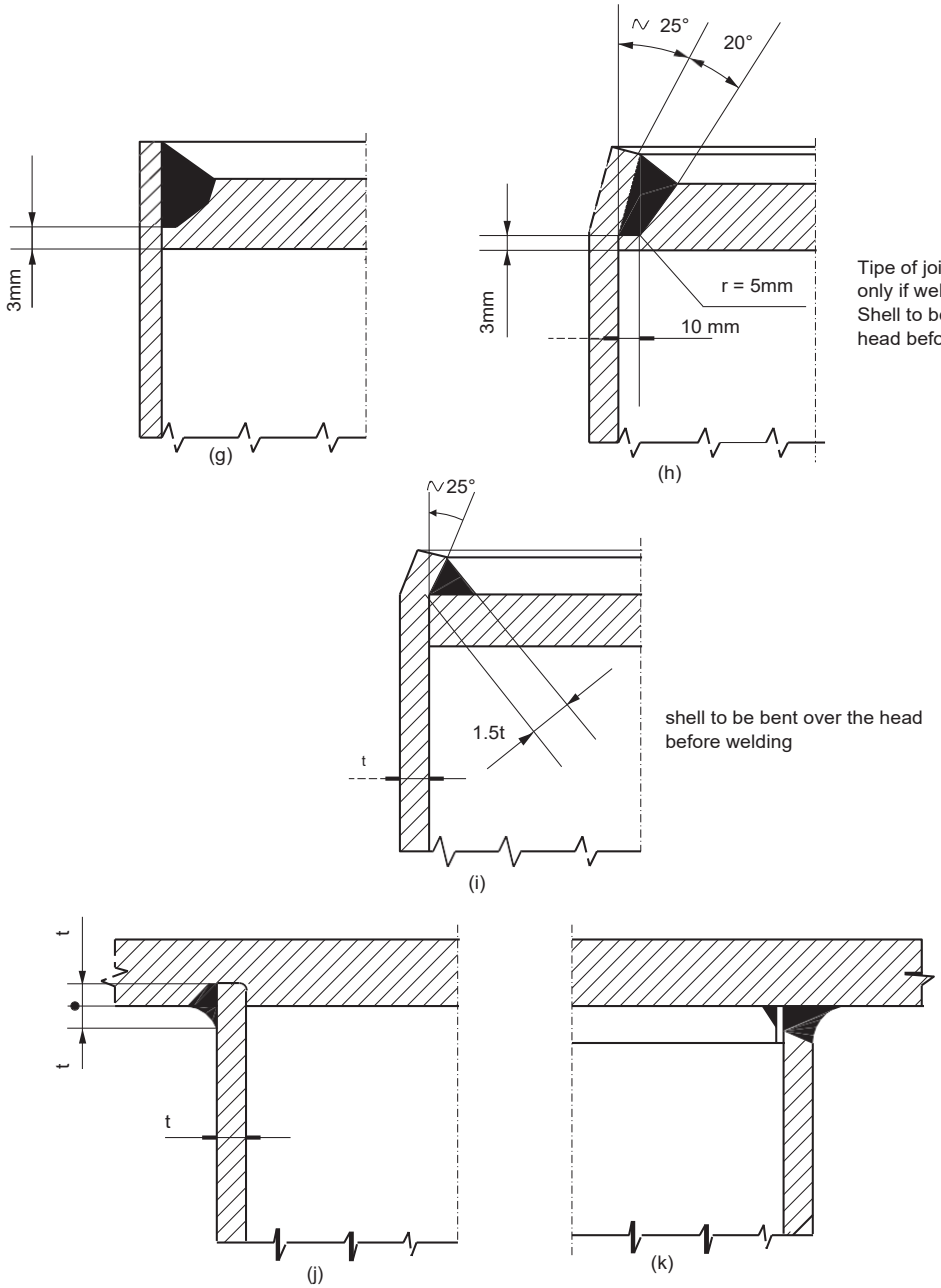


Figure 22 : Types of joints for nozzles and reinforcing rings (1)

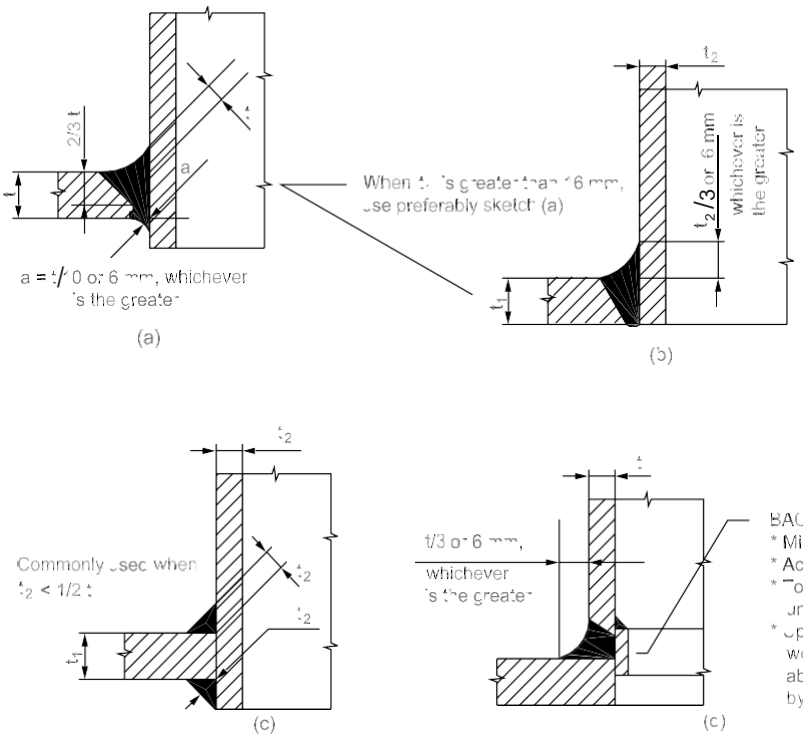


Figure 23 : Types of joint for nozzles and reinforcing rings (2)

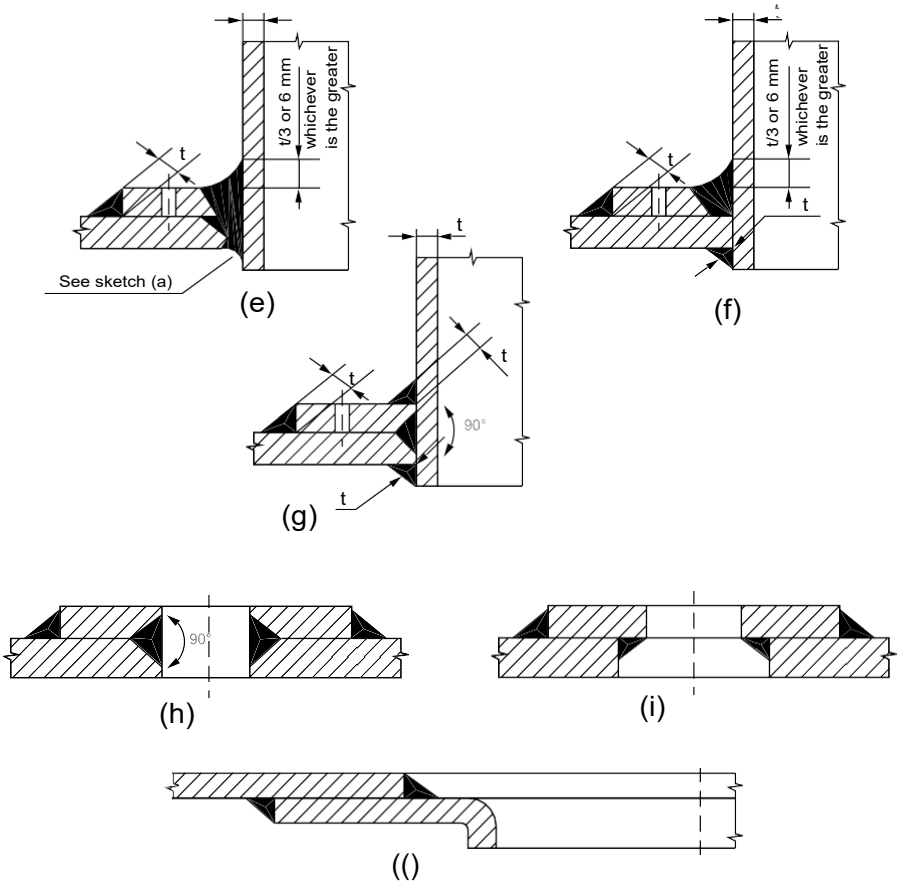


Figure 24 : Types of joint for nozzles and reinforcing rings (3)

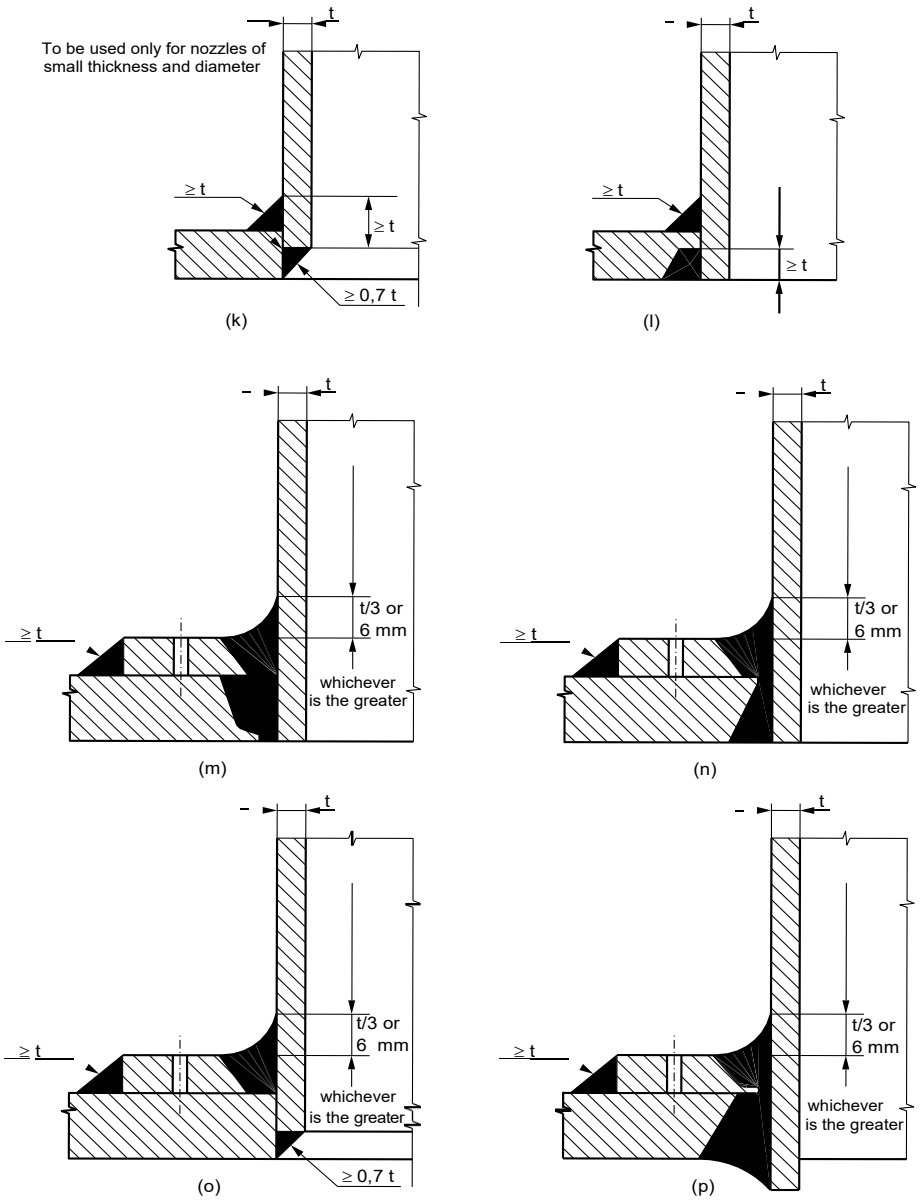
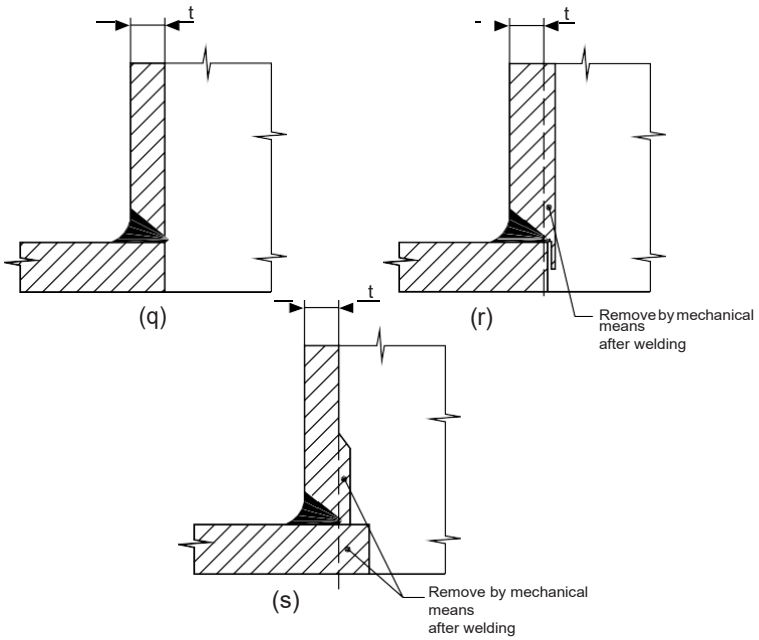


Figure 25 : Types of joints for nozzles (4)



Note: Where preparations of Fig 25 are carried out, the shell is to be carefully inspected to ascertain the absence of lamination.

Figure 26 : Types of joint for flanges to nozzles

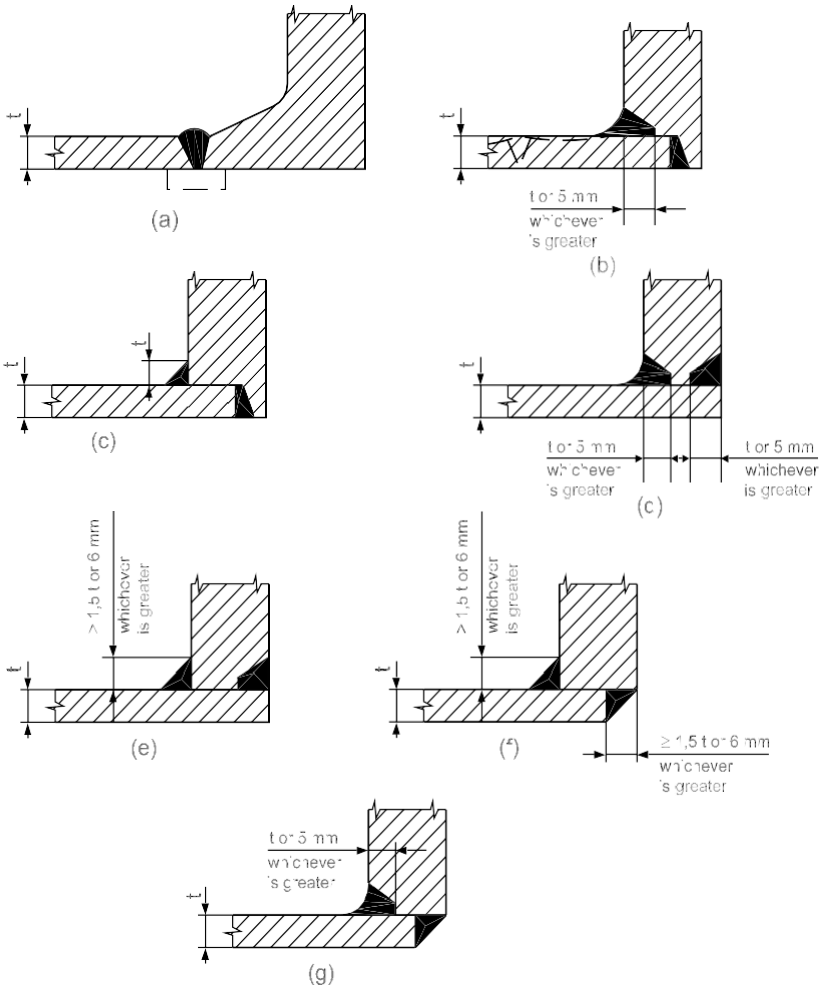


Figure 27 : Types of joint for tubesheets to shells (direct connection)

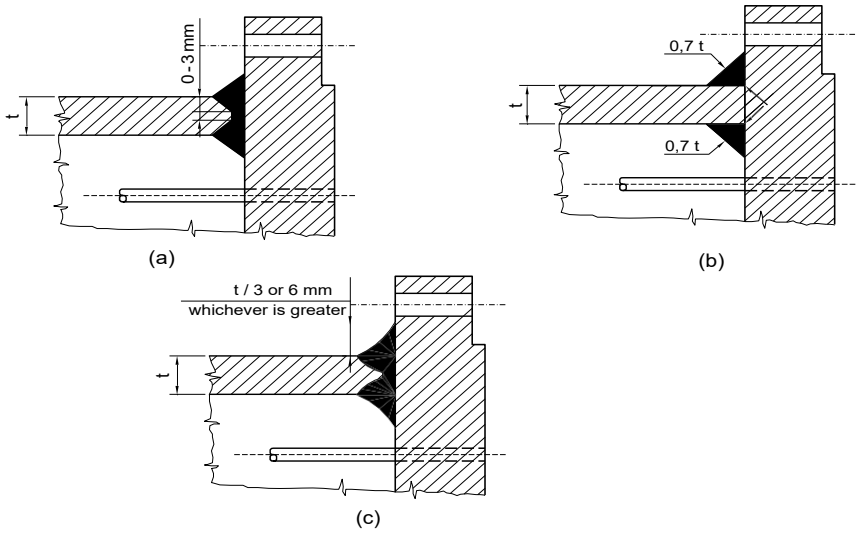
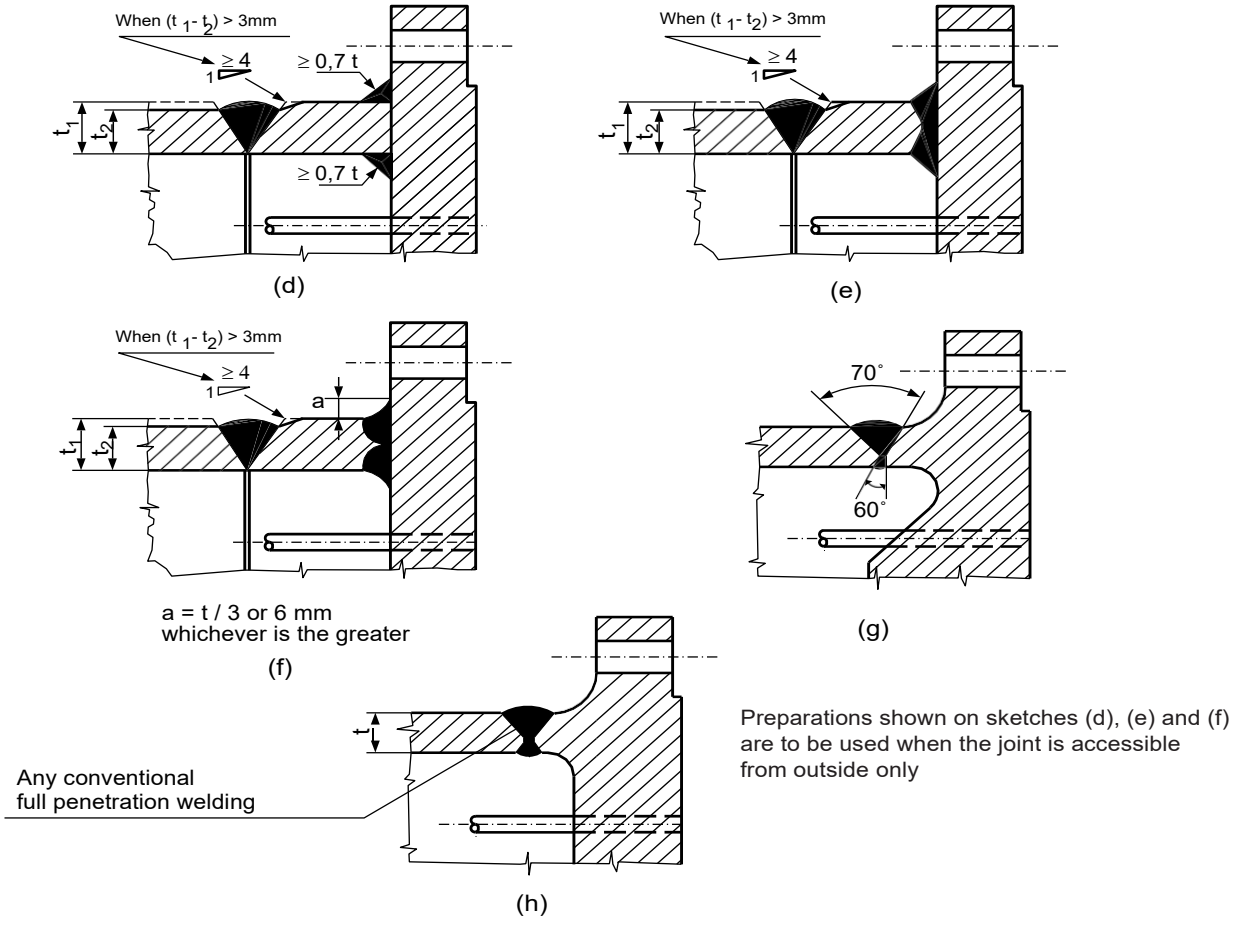
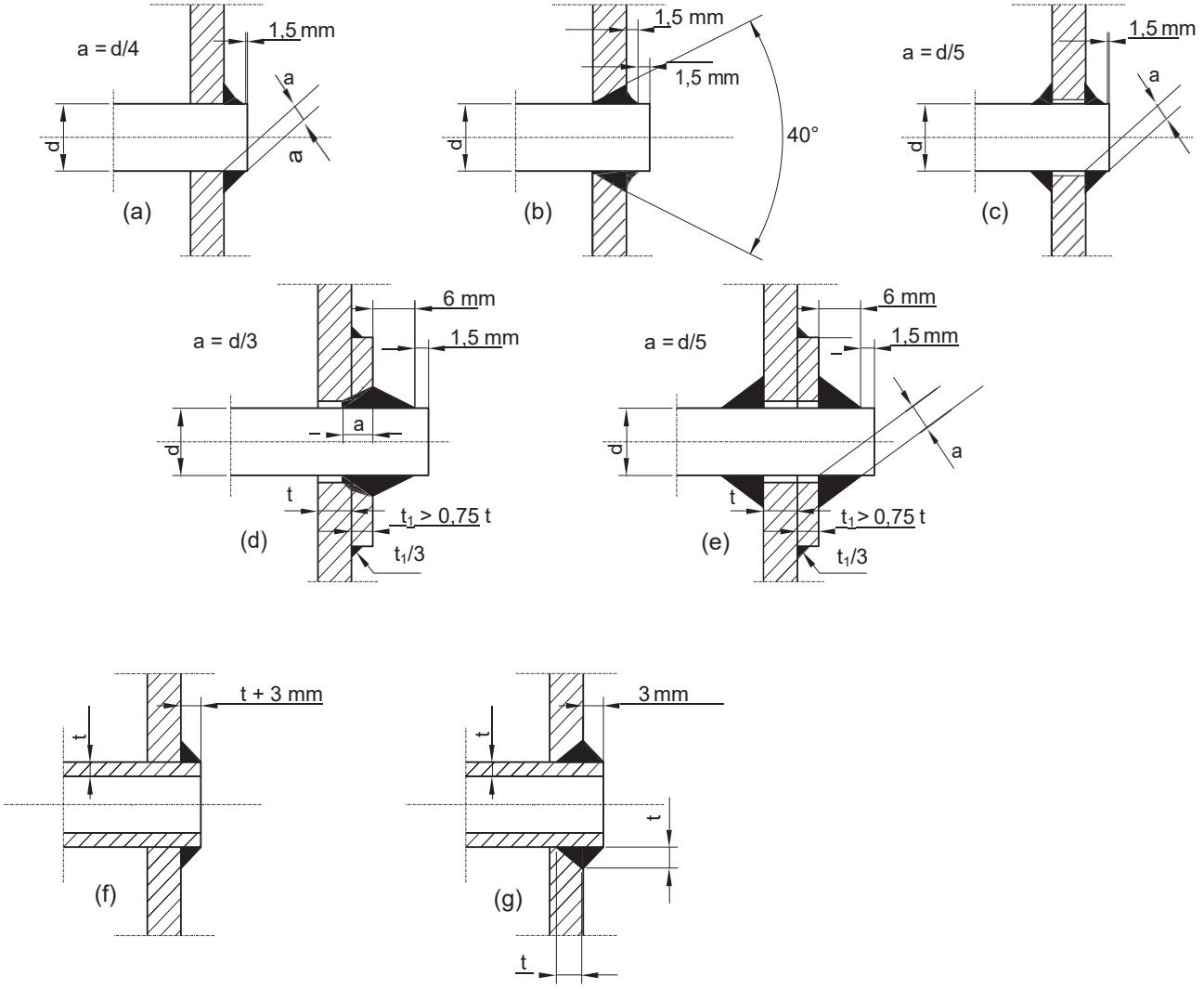


Figure 28 : Types of joints for tubesheets to shells (butt welded)



Preparations shown on sketches (d), (e) and (f) are to be used when the joint is accessible from outside only

Figure 29 : Type of joints for stays and stay tubes



4.4.2 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.

4.5 Tolerances after construction

4.5.1 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.

4.5.2 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.

4.5.3 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.

4.5.4 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.

4.6 Preheating

4.6.1

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 will 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.

4.7 Post-weld heat treatment

4.7.1 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.

4.7.2 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 16
- 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 will be the subject of special consideration by the Society.

Stress relieving heat treatment will not 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).

Pressure vessels and pipes of class 3 and associated parts are not required to be stress relieved, except in specific cases.

4.7.3 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:
   1) 220°C per hour if the maximum thickness is not more than 25 mm, or
   2) $(5500/t_A)$°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 absolute value of the cooling rate in the furnace is not to exceed:
   1) 280°C per hour if the maximum thickness is not more than 25 mm, or
   2) $(7000/t_A)$°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 17.

Table 16 : 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	30
R_m = 360 N/mm² Grade HD R_m = 410 N/mm² Grade HD	20	38
R_m = 460 N/mm² Grade HB R_m = 510 N/mm² Grade HB	20	25
R_m = 460 N/mm² Grade HD R_m = 510 N/mm² Grade HD	20	35
0,3Mo 1Mn 0,5Mo 1Mn 0,5MoV 0,5Cr 0,5Mo	20	20
1Cr 0,5Mo 2,25Cr1Mo	all	all

Table 17 : 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

Grade	Temperatures	Time per 25 mm of maximum thickness	Minimum time
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			

4.7.4 Alternatives

When, for special reasons, heat treatment is carried out in conditions other than those given in [4.7.2], 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.

4.7.5 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.

4.7.6 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.

4.7.7 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.

4.8 Welding samples

4.8.1 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 [4.7.6]).

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.

4.8.2 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 Part D 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.

4.8.3 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.

4.9 Specific requirements for class 1 vessels

4.9.1 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.

4.9.2 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

4.9.3 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 [4.8.2].

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 [4.8.2].

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.

4.10 Specific requirements for class 2 vessels

4.10.1 General

For vessels whose scantlings have been determined using an efficiency of welded joint e greater than 0,90, see [4.9.1].

4.10.2 Non-destructive tests *(1/7/2004)*

All longitudinal and circumferential joints of class 2 vessels are to be subjected to 10% radiographic or equivalent examination. This extension may be extended at the Society's discretion based on the actual thickness of the welded plates.

As specified in Tab 10, where a joint efficiency of 0,75 is used in the formula for the calculation of the thickness of the vessel, the radiographic and the ultrasonic examinations may be omitted.

This assumes, however, that the Surveyor of the Society will adequately follow all the welding phases and that checks are completed by any non-destructive examinations deemed necessary.

4.10.3 Number of test samples

In general, the same requirements of [4.9.3] apply also to class 2 pressure vessels. However, test plates are required for each 50 m of longitudinal and circumferential weldings (or fraction).

4.11 Specific requirements for Class 3 vessels

4.11.1 For vessels whose scantlings have been determined using an efficiency of welded joint e greater than 0,90, see [4.9.1].

Heat treatment, mechanical tests and non-destructive tests are not required for welded joints of other Class 3 vessels.

5 Design and construction - Control and monitoring

5.1 Boiler control and monitoring system

5.1.1 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.

5.1.2 Emergency shut-off

Means are to be provided to shut down boiler forced draft or induced draft 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.

5.1.3 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.

5.1.4 Water level indicators - Special requirements for water tube boilers

a) For water tube boilers having an athwarships 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 shall be fitted with a high-water-level audible and visual alarm (see also Tab 19).

5.1.5 Water level indicators - Special requirements for fire tube boilers (vertical and cylindrical boilers)

a) For cylindrical boilers, the two water level indicators mentioned in [5.1.3] 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.

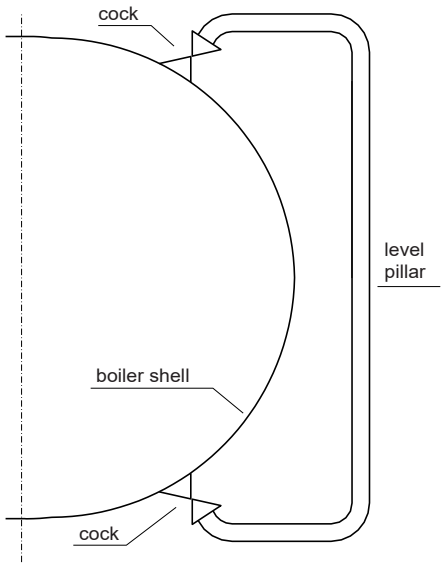
b) A system of at least two suitably located and remote controlled gauge-cocks may be considered as the equivalent device mentioned in [5.1.3] for cylindrical boilers having a design pressure lower than 1 MPa, for cylindrical boilers having a diameter lower than 2 m and for vertical boilers having height 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 18. 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 18. 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 30 shows the sketch of a level pillar arrangement.

Table 18 : 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

Figure 30 : Level pillar arrangement



5.1.6 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.

5.1.7 Temperature control devices

Each boiler fitted with a superheater is to have an indicator or recorder for the steam temperature at the superheater outlet.

5.1.8 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.

5.1.9 Alarms

Any actuation of the fuel-oil shut-off listed in [5.1.8] is to operate a visual and audible alarm.

5.1.10 Additional requirements for boilers fitted with automatic control systems

a) The flame scanner required in [5.1.8] 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 Chapter 3.

5.2 Pressure vessel instrumentation

5.2.1

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 is to be fitted with a local manometer.

5.3 Thermal oil heater control and monitoring

5.3.1 Local control and monitoring

Suitable means to effectively operate, control and monitor the operation of oil fired thermal oil heaters and their associated auxiliaries are to be provided locally. The functional condition of the fuel, thermal oil circulation, forced draft and flue gas systems is to be indicated by pressure gauges, temperature indicators, flow-meter, lights or other similar devices.

5.3.2 Flow control and monitoring

a) A flow indicator of the thermal oil is to be provided.

b) Oil fired or exhaust gas heaters are to be provided with a flow monitor limit-switch. If the flow rate falls below a minimum value the firing system is to be switched off and interlocked.

5.3.3 Manual control

At least the temperature control device on the oil side and flow monitoring are to remain operative in manual operation.

5.3.4 Leakage monitoring

Oil tanks are to be equipped with a leakage detector which, when actuated, shuts down and interlocks the thermal oil firing system. If the oil fired heater is on standby, the starting of the burner is to be blocked if the leakage detector is actuated.

5.4 Control and monitoring

5.4.1 *(1/7/2006)*

In addition to those of this item [5.4], the general requirements given in Chapter 3 apply.

In the case of ships with automation notations, the requirements in Pt F Ch 3 also apply.

5.4.2 *(1/7/2006)*

Tab 19, Tab 20, Tab 21 and Tab 22 summarise the control and monitoring requirements for main propulsion boilers, auxiliary boilers, oil fired thermal oil heaters and exhaust gas thermal oil heaters and incinerators, respectively.

Note 1: Some departures from Tab 19, Tab 20, Tab 21 and Tab 22 may be accepted by the Society in the case of ships with a restricted navigation notation.

6 Arrangement and installation

6.1 Foundations

6.1.1 For boilers and pressure vessels bolting down to their foundations, see Sec 1, [3.3.1]. 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.

6.2 Boilers

6.2.1 Thermal expansion

Means are to be provided to compensate thermal expansion of boilers.

6.2.2 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.

Table 19 : Main propulsion boilers *(1/7/2023)*

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						
• 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 (see [5.1.3]).

Table 20 : Auxiliary boilers *(1/7/2023)*

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 (3)					
	LL			X			
Circulation stopped (when forced circulation boiler)	X			X			
Fuel oil temperature or viscosity **(2)**	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.
(2) Where heavy fuel is used.
(3) Duplication of level indicator is required for every boiler essential for the safety of the ship and designed to contain water at a specified level (see [5.1.3]).

Table 21 : Thermal oil 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		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Thermal fluid temperature heater outlet	H	local		X			
Thermal fluid pressure pump discharge	H	local		X			
Thermal fluid flow through each heating element	L	local		X			
Expansion tank level	L	local		X **(1)**			
Expansion tank temperature	H						
Forced draft fan stopped	X			X			
Heavy fuel oil temperature or viscosity	H+L	local					
Burner flame failure	X			X			
Flue gas temperature heater inlet (When exhaust gas heater)	H			X **(2)**			

(1) Stop of burner and fluid flow
(2) Stop of the flue gas only

Table 22 : Incinerators

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				
			Incinerator			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Flame failure	X			X			
Furnace temperature	H			X			

(1) Where heavy fuel is used

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				
			Incinerator			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Exhaust gas temperature	H						
Fuel oil pressure		local					
Fuel oil temperature or viscosity **(1)**	H+L	local					
(1) Where heavy fuel is used							

6.2.3 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.

6.2.4 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.

6.2.5 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.

6.2.6 Hot surfaces

Hot surfaces with which the crew are likely to come into contact during operation are to be suitably guarded or insulated. See Sec 1, [3.7.1].

6.2.7 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.

6.3 Pressure vessels

6.3.1 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.

6.4 Thermal oil heaters

6.4.1 In general, the requirements of [6.2] for boilers are also applicable to thermal oil heaters.

7 Material test, workshop inspection and testing, certification

7.1 Material testing

7.1.1 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.

7.1.2 Boilers, other steam generators, and oil fired and exhaust gas thermal oil heaters

In addition to the requirement in [7.1.1], testing of materials intended for the construction of pressure parts of boilers, other steam generators, oil fired thermal oil heaters and exhaust gas thermal oil heaters is to be witnessed by the Surveyor.

7.1.3 Class 1 pressure vessels and heat exchangers

In addition to the requirement in [7.1.1], testing of materials intended for the construction of pressure parts of class 1 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.).

7.2 Workshop inspections

7.2.1 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.

7.2.2 Mass produced pressure vessels

Construction of mass produced pressure vessels which are type approved by the Society need not be attended by the Surveyor.

7.3 Hydrostatic tests

7.3.1 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 [7.2.2].

7.3.2 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.

7.3.3 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.

7.3.4 Hydraulic test procedure

a) The hydraulic test specified in [7.3.1] 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 bepartially 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.

7.3.5 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.

7.4 Certification

7.4.1 Certification of boilers and individually produced pressure vessels

Boilers and individually produced pressure vessels of classes 1 and 2 are to be certified by the Society in accordance with the procedures stated in Part D.

7.4.2 Mass produced pressure vessels

Small mass produced pressure vessels of classes 1 and 2 may be accepted provided they are type approved by the Society in accordance with the procedures stated in Part A.

7.4.3 Pressure vessels not required to be certified

The Manufacturer's certificate, including detail of tests and inspections, is to be submitted to the Society for pressure vessels not required to be certified by the Society. The Society reserves the right to require confirmatory hydrostatic tests in the presence of the Surveyor on a case by case basis, based on the criticality and service of the pressure vessel.

SECTION 4 STEAM TURBINES

1 General

1.1 Application

1.1.1 Propulsion turbines and turbines for essential services

The requirements of this Section apply to:

a) all propulsion turbines

b) turbines intended for auxiliary services essential for safety and navigation, or for driving cargo pumps in tankers.

1.1.2 Auxiliary turbines driving generators

In addition to the requirements contained in this Section, auxiliary turbines driving electric generators are to comply with those of Chapter 2.

1.2 Documentation to be submitted

1.2.1 For propulsion turbines and turbines intended for driving machinery for essential services, the plans and data listed in Tab 1 are to be submitted.

All listed plans are to be constructional plans complete with all dimensions and are to contain full indication of the types of materials employed.

2 Design and construction

2.1 Materials

2.1.1 Rotating components

a) Rotors, shafts and discs of turbines are to be of forged steel. In general, the forgings are to have minimum tensile strength R_m within the limits in Tab 2.

b) Rotors of small turbines may be built of special cast steels.

c) Turbine blades are to be built of corrosion-resistant materials.

2.1.2 Static components

The casings and diaphragms of turbines are to be built of forged or cast steels capable of withstanding the pressures and temperatures to which they are subjected. Cast iron may be used for temperatures up to 300°C.

2.2 Design and constructional details

2.2.1 Rotors and stators

a) All components of turbines are to be free from defects and are to be built and installed with tolerances and clearances such as to allow thermal expansion and to minimise the distortions of casings and rotors in all expected service conditions.

b) Particular care is to be devoted to preventing condensation water from accumulating in the blade spaces of the casings. Adequate drain tubes and cocks are to be arranged in a suitable position, in the lower parts of the casings. Cocks are to be easy to operate.

c) When labyrinth packings are used, the steam supply pipes to the sealing system are to be so arranged that condensed steam may not enter the turbine.

d) Particular attention is to be paid to the connection of pipes to the turbine stators in order to avoid abnormal loads in service.

e) Smooth fillets are to be provided at changes of section of rotors, discs and blade roots. The holes in discs are to be well rounded and polished.

2.2.2 Bearings

a) Turbine bearings are to be so located that their lubrication is not impaired by overheating from adjacent hot parts.

b) Lubricating oil is to be prevented from dripping on high temperature parts.

c) Suitable arrangements for cooling the bearings after the turbines have been stopped may also be required, at the discretion of the Society.

2.2.3 Turning gear

a) Main propulsion turbines are to be equipped with turning gear for both directions of rotation. The rotors of auxiliary turbines are to be capable of being turned by hand.

b) The engagement of turning gear is to be visually indicated at the control platform.

c) An interlock is to be provided to ensure that the turbine cannot be started up when the turning gear is engaged.

2.2.4 Astern power for main propulsion *(1/1/2026)*

a) The main propulsion turbine is to have sufficient power for running astern. The astern power is considered to be sufficient if it is capable of operating at the maximum permissible astern power (MPAP) for a period of at least 15 minutes.

b) For main propulsion machinery with reverse gearing, controllable pitch propellers or an electrical transmission system, astern running is not to cause any overloading of the propulsion machinery.

c) During astern running, the main condenser and the ahead turbines are not to be excessively overheated.

Table 1 : Documents to be submitted

No.	A/I **(1)**	ITEM
1	I	Sectional assembly
2	A	Rotors and discs, revolving and stationary blades for each turbine
3	A	Fastening details of revolving and stationary blades
4	A	Casings
5	A	Schematic diagram of control and safety devices
6	I	General specification of the turbine, including an operation and instruction manual
7	I	Maximum power and corresponding maximum rotational speed, and the values of pressure and temperature at each stage
8	A	Material specifications of the major parts, including their physical, chemical and mechanical properties, the data relevant to rupture and creep at elevated temperatures, when the service temperature exceeds 400°C, the fatigue strength, the corrosion resistance and the heat treatments
9	I	Distribution box
10	A	Strength calculations of rotors, discs and blades and blade vibration calculations
11	A	Where the rotors, stators or other components of turbines are of welded construction, all particulars on the design of welded joints, welding conditions, heat treatments and non-destructive examinations after welding

(1) A = to be submitted for approval in four copies
I = to be submitted for information in duplicate

Table 2 : Limits of R_m

STEEL	R_m limits (N/mm^2)
Carbon and carbon-manganese steel	$400 < R_m < 600$
Alloy steels for rotors	$500 < R_m < 800$
Alloy steels for discs and other forgings	$500 < R_m < 1000$

2.2.5 Interlock

The simultaneous admission of steam to the ahead and astern turbines is to be prevented by interlocks. Brief overlapping of the ahead and astern valves during manoeuvring may be permitted.

2.2.6 Turbine exhaust *(1/7/2005)*

a) To provide a warning to personnel in the vicinity of the exhaust end steam turbines of excessive pressure, sentinel valves or other equivalent means are to be provided at the exhaust end of all turbines. The valve discharge outlets are to be clearly visible and suitably guarded, as necessary.

b) Where, in auxiliary steam turbines, the inlet steam pressure exceeds the pressure for which the exhaust casing and associated piping up to the exhaust valve are designed, means to relieve the excess pressure are to be provided.

2.2.7 Water accumulation prevention

a) Non-return valves or other approved means are to be fitted in bled steam connections to prevent steam and water returning into the turbines.

b) Bends are to be avoided in steam piping in which water may accumulate.

2.2.8 Steam strainers

Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines or alternatively at the inlets to manoeuvring valves.

2.2.9 Emergency arrangements *(1/1/2006)*

a) In single screw ships fitted with cross-compound main turbine installations the arrangements are to be such as to enable safe navigation when the steam supply to any one of the turbines is required to be isolated. For this emergency operation purpose the steam may be led directly to the low pressure (L.P.) turbine and either the high pressure (H.P.) or medium pressure (M.P.) turbine can exhaust direct to the condenser.

b) Adequate arrangements and controls are to be provided for these operating conditions so that the pressure and temperature of the steam do not exceed those which the turbine and condenser can safely withstand.

c) The necessary pipes and valves for these arrangements are to be readily available and properly marked.

d) A fit-up test of all combinations of pipes and valves is to be performed prior to the first sea trials.

e) The permissible power/speed when operating without one of the turbines (all combinations) is to be specified and information provided on board.

f) The operation of the turbines under emergency conditions is to be assessed for the potential influence on shaft alignment and gear teeth loading conditions.

g) Ships classed for unrestricted service and fitted with a steam turbine propulsion plant and only one main boiler are to be provided with means to ensure emergency propulsion in the event of failure of the main boiler.

2.3 Welded fabrication

2.3.1 The manufacturer's requirements relative to the welding of turbine rotors or major forged or cast pieces, where permitted, are to be readily identifiable when the plans are submitted to the Society for approval. Requirements relative to fabrication, welding, heat treatments, examinations, testing and acceptance will be stipulated on a case by case basis.

In general, all weldings are to be carried out by qualified welders in accordance with qualified welding procedures and using approved consumables.

2.4 Control and monitoring

2.4.1 General *(1/7/2006)*

In addition to those of this item [2.4], the general requirements given in Chapter 3 apply.

In the case of ships with automation notations, the requirements in Part F, Chapter 3 also apply.

2.4.2 Governors

a) Turbines for main propulsion machinery equipped with controllable pitch propellers, disengaging couplings or electrical transmission systems are to be fitted with an additional speed governor which, in the event of a sudden loss of load, prevents the revolutions from increasing to the trip speed given in [2.4.3].

b) The speed increase of turbines driving electric generators - except those for electrical propeller drive - resulting from a change from full load to no-load may not exceed 5% on the resumption of steady running conditions. The transient speed increase resulting from a sudden change from full load to no-load conditions is not to exceed 10% and is to be separated by a sufficient margin from the trip speed.

2.4.3 Overspeed devices

a) Each main and auxiliary turbine is to be provided with an overspeed protective device to prevent the rotational speed from exceeding the maximum rotational by more than 15%. The device is to be actuated by the turbine shaft.

b) Where two or more steam turbines are coupled to the same gear wheel, the Society may accept the fitting of only one overspeed device for all the coupled turbines.

c) For turbines driving electric generators, the overspeed protective device mentioned in a) is also to be fitted with a means for manual tripping.

d) Where exhaust steam from auxiliary systems is led to the main turbine, provision is to be made to cut off the steam automatically when the overspeed protective device is activated.

2.4.4 Rotor axial displacement

A quick-closing valve is to be provided which automatically shuts off the steam supply in the event of axial displacement of the rotor beyond the permissible limits stated by the manufacturer. The device controlling the valve is to be actuated by the turbine shaft.

2.4.5 Emergency oil supply

For the emergency lubricating oil supply, see Sec 10, [12.5].

2.4.6 Bearing lubrication failure *(1/7/2005)*

a) Main ahead turbines are to be provided with a quick-closing valve which automatically shuts off the steam supply in the event of a dangerous reduction in oil pressure in the bearing lubricating system.

b) This arrangement is to be such as to ensure the admission of steam to the astern turbine for braking purposes.

c) Auxiliary turbines having governors operated other than hydraulically in which the lubricating oil is inherent in the system, are to be provided with an alarm device and a means of shutting off the steam supply in the case of lowering of oil pressure in the bearing lubricating oil system.

2.4.7 Shut-off arrangement

a) Arrangements are to be provided for shutting off the steam to the main turbines by a suitable hand trip device controlling the steam admisson valve situated at the control platform and at the turbine itself.

b) Hand tripping for auxiliary turbines is to be arranged in the proximity of the turbine overspeed protective device.

c) The hand trip device is any device which is operated manually irrespective of the way the action is performed, i.e. mechanically or by means of external power.

d) The quick-closing valves are also to be manually operable at the turbine and from the control platform.

e) Re-setting of the quick-closing valve device may be effected only at the turbine or from the control platform with the control valves in the closed position.

f) Where the valves are operated by hydraulic oil systems fitted for automatic operation, they are to be fed by two pumps: one main pump and one standby pump. In any event, the standby pump is to be independent. In special cases, at the Society's discretion, a hand-operated pump may be accepted as a standby pump.

g) The starting up of any turbine is to be possible only when the quick-closing devices are ready for operation.

h) A quick-closing device is to be provided which automatically shuts off the steam supply in the event of an increase in pressure or water level in the condenser beyond the permissible limits.

2.4.8 Summary Tables *(1/7/2006)*

Tab 3 and Tab 4 summarise the minimum control and monitoring requirements for main propulsion and auxiliary turbines, respectively.

Note 1: Some departures from Tab 3 and Tab 4 may be accepted by the Society in the case of ships with a restricted navigation notation.

3 Arrangement and installation

3.1 Foundations

3.1.1 Foundations of turbines and connected reduction gears are to be designed and built so that hull movements do not give rise to significant movements between reduction gears and turbines. In any event, such movements are to be absorbed by suitable couplings.

3.2 Jointing of mating surfaces

3.2.1 The mating flanges of casings are to form a tight joint without the use of any interposed material.

3.3 Piping installation

3.3.1 Pipes and mains connected to turbine casings are to be fitted in such a way as to minimise the thrust loads and moments.

3.4 Hot surfaces

3.4.1 Hot surfaces with which the crew are likely to come into contact during operation are to be suitably guarded or insulated. See Sec 1, [3.7].

Table 3 : Main propulsion turbine

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				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
• Main turbine speed		local					
	H			X			
					X		
• Main turbine axial displacement	X	local		X			
• Main turbine vibration	H	local					
Lubricating oil							
• Supply pressure		local					
	L			X **(2)**			
• Level of gravity tank	L **(1)**	local					
(1) Sensor to be located near the normal level **(2)** This is not to prevent astern operation for braking							

Table 4 : Auxiliary turbine

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				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Overspeed	H	local		X			
Rotor displacement	X	local		X			
Vibration	H	local					
Lubricating oil supply pressure	L			X			
Lubricating oil level in gravity tank	L						

3.5 Alignment

3.5.1 Particular care is to be taken in the alignment of turbine-reduction gearing, taking account of all causes which may alter the alignment from cold conditions to normal service conditions.

When a structural tank is fitted in way of the turbine or gearing foundations, the expected tank temperature variations are to be taken into account during alignment operations.

Propulsion turbines are to be fitted with indicators showing the axial movements of rotors with respect to casings and the sliding movements of casings on the sliding feet.

3.6 Circulating water system

3.6.1 The circulating water system with vacuum ejectors is to be so arranged that water may not enter the low pressure turbines.

3.7 Gratings

3.7.1 Gratings and any other structures in way of the sliding feet or flexible supports are to be so arranged that turbine casing expansion is not restricted.

3.8 Drains

3.8.1 Turbines and the associated piping systems are to be equipped with adequate means of drainage.

3.9 Instruments

3.9.1 Main and auxiliary turbines are to be fitted with callipers and micrometers of a suitable type for verifying the alignment of rotors and pinion and gear-wheel shafts.

This check is to be performed to the Surveyor's satisfaction at the time of installation.

4 Material tests, workshop inspection and testing, certification

4.1 Material tests

4.1.1 Parts to be tested

The materials for the construction of the parts listed in Tab 5 are to be tested in compliance with the requirements of Part D of the Rules.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 5 and are to be effected in positions mutually agreed upon by the manufacturer and the Surveyor, where experience shows defects are most likely to occur.

For important structural parts of the turbine, in addition to the above-mentioned non-destructive tests, examination of welded seams by approved methods of inspection may be required.

Where there is evidence to doubt the soundness of any turbine component, non-destructive tests using approved detecting methods may be required.

4.1.2 Special auxiliary turbines

In the case of auxiliary turbines with a steam inlet temperature of up to 250°C, the extent of the tests stated in Tab 5 may be limited to the disc and shaft materials.

4.2 Inspections and testing during construction

4.2.1 Inspections during construction

The following inspections and tests are to be carried out in the presence of the Surveyor during the construction of all turbines which are indicated in [1.1.1]. For shipboard tests, see Sec 16, [3.5].

- material tests, as required (see [4.1])
- welded fabrication (see [4.2.2])
- non-destructive examination of turbine blades (see [4.2.3])
- hydrostatic tests (see [4.2.4])
- safety valves (see [4.2.5])
- thermal stability test of rotor (see [4.2.6])
- rotor balancing and overspeed test (see [4.2.7] and [4.2.8])
- shop trials (see [4.2.9]).

4.2.2 Welded fabrication

Welded fabrication and testing is to be attended by the Surveyor, as may be deemed necessary by the Society.

4.2.3 Turbine blades

When turbine blades are calculated using a permissible stress K > R_m/4, all turbine rotor blades are to be checked by dye penetrants or other equivalent method.

4.2.4 Hydrostatic tests

a) Turbine and nozzle casings are to be subjected to a hydrostatic test at the greater of the following test pressures:

b) 1,5 times the working pressure

c) 1,5 times the starting pressure

d) However, the test pressure is not to be less than 0,2 N/mm^2.

e) The turbine casings may be temporarily subdivided by diaphragms in order to obtain different pressure values for the various stages, if necessary.

f) Where it is not possible to perform hydrostatic tests, the manufacturer may submit to the Society, for consideration, alternative proposals for testing the integrity of turbine casings and the absence of defects therein.

g) For the bodies of quick-closing, safety, manoeuvring and control valves, the test pressure is to be 1,5 times the maximum allowable working pressure of the boiler (approval pressure). The sealing efficiency of these valves when closed is to be tested at 1,1 times the working pressure.

h) Intermediate coolers and heat exchangers are to be subjected to a hydrostatic test at 1,5 times the working pressure.

i) Pressure piping, valves and other fittings are to be subjected to hydrostatic tests in compliance with the normal requirements for these items.

4.2.5 Safety valves

All valves required in [2.4] are to be tested at their setting pressure in the presence of the Surveyor, as specified by the turbine manufacturer.

4.2.6 Thermal stability test of rotors

Solid forged and welded rotors of propulsion turbines are to be subjected to a thermal stability test where the service temperature exceeds 400°C. This test is to be carried out after heat treatment and rough machining or at a later stage of fabrication, in accordance with a procedure approved by the Society.

4.2.7 Balancing of rotors

Finished rotors, complete with all fittings and blades, are to be dynamically balanced in a balancing machine of appropriate sensitivity in relation to the size of the rotor. Normally this test is to be carried out with the primary part of the flexible coupling, if any.

4.2.8 Overspeed test of rotors

Finished rotors, complete with all fittings and blades, are to be subjected for at least 3 minutes to an overspeed test at the greater of the following values:

- 5% above the setting speed of the overspeed tripping device
- 15% above the maximum design speed.

The Society may waive this requirement provided that it can be demonstrated by the manufacturer, using an acceptable direct calculation procedure, that the rotor is able to safely withstand the above values of overspeed and that rotors are free from defects, as verified by means of non-destructive tests.

4.2.9 Shop trials

Where turbines are subjected to a trial run at the factory, the satisfactory functioning of the control, safety and monitoring equipment is to be verified during the trial run. Such verification is in any event to take place not later than the commissioning of the plant aboard ship.

In general, propulsion steam turbines are to be subjected to a works trial under steam but without load, up to the service rotational speed, as far as possible. In the course of the works trials, the overspeed devices for both main and auxiliary turbines are to be set.

4.3 Certification

4.3.1 Turbines required to be certified

For turbines required to be certified as per [1.1.1], Society's certificates (C) (see Pt D, Ch 1, Sec 1, [4.2.1]) are required for material tests of rotating components and blades listed in Tab 4 and for works trials as per [4.2.1]. Provided the

manufacturer has a quality assurance system accepted by the Society, a reduced number of inspections and tests in the presence of the Surveyor may be agreed.

4.3.2 Turbines not required to be certified

For turbines not required to be certified as per [1.1.1], manufacturer's certificates including details of tests and inspections carried out at the shop are to be submitted. The acceptance of these turbines is, however, subject to their satisfactory performance during dock and sea trials.

4.3.3 Type approved turbines

For mass produced turbines which are requested to be type approved by the Society, the tests and trials on a prototype are to be carried out in the presence of the Surveyor as stated in [4.3.1]. The minimum required attendance of the Surveyor at the production tests and trials will be agreed between the manufacturer and the Society on a case by case basis.

Table 5 : Material and non-destructive tests

Turbine component	Material tests (Mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic or radiographic examination
Rotating parts (turbine rotors, shafts, stiff and flexible couplings, bolts for couplings and other dynamically stressed parts, integral pinions and gears)	all	all	sample
Stationary parts (castings and plates for casings)	all	spot as agreed between the Manufacturer and the Surveyor	-
Blades	sample	sample	sample
Piping and associated fittings	as required in the appropriate section of the Rules	as required in the appropriate section of the Rules	as required in the appropriate section of the Rules

SECTION 5 GAS TURBINES

1 General

1.1 Application

1.1.1 Propulsion turbines and turbines for essential services

The requirements of this Section apply to:

a) all propulsion turbines

b) turbines intended for auxiliary services essential for safety and navigation.

1.1.2 Turbines for auxiliary generators

In addition to the requirements contained in this Section, auxiliary turbines driving electric generators are to comply with the applicable requirements of Chapter 2 of the Rules.

1.1.3 Type approval

Turbines intended for propulsion and essential services are to be type approved by the Society.

1.2 Definition of rated power

1.2.1 Rated power is the maximum constant power that the turbine can develop at constant speed in the range of air inlet temperature between 0°C and 35°C. This power is to be considered with 0 intake and exhaust losses and with an air relative humidity of 60%.

1.3 Documentation to be submitted

1.3.1 For propulsion turbines and turbines intended for driving machinery for essential services, the plans listed in Tab 1 are to be submitted.

The listed constructional plans are to be complete with all dimensions and are to contain full indication of the types of materials used.

2 Design and Construction

2.1 Materials

2.1.1 Approved materials

a) Gas turbine materials are to fulfil 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.

2.2 Stress analyses

2.2.1 Calculation

a) The manufacturer is to submit the results of calculation of the stresses on each rotor under the most severe service conditions.

b) Fatigue analysis on each rotor, taking into account the stress concentrations, is also to be submitted.

c) The results of previous in-service experience on similar applications may be considered by the Society as an alternative to items a) and b) above.

The calculations and analyses (see also [1.3.1]) are to be carried out in accordance with criteria agreed by the Society. Data on the design service life and test results used to substantiate calculation assumptions are also to be provided.

2.2.2 Vibrations

The range of service speeds is not to give rise to unacceptable bending vibrations or to vibrations affecting the entire installation. Calculations of the critical speeds including details of their basic assumptions are to be submitted.

2.3 Design and constructional details

2.3.1 Rotors and stators

a) 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 minimise the distortions of casings and rotors in all expected service conditions.

b) 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.

c) 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.

d) 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.

e) 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.

Table 1 : Documents to be submitted *(1/1/2023)*

No.	A/I **(1)**	ITEM
1	I	Sectional assembly
2	A	Detailed drawings of rotors, casings, blades, combustion chambers and heat exchangers **(2)**
3	A	Material specifications of the major parts, including their physical, chemical and mechanical properties, the data relevant to rupture and creep at elevated temperatures, the fatigue strength, the corrosion resistance and the heat treatments **(2)**
4	A	Where the rotors, stators or other components of turbines are of welded construction, all particulars on the design of welded joints, welding procedures and sequences, heat treatments and non-destructive examinations after welding **(2)**
5	I	General specification of the turbine, including instruction manual, description of structures and specification of the properties of fuel and lubricating oil to be used
6	I	Details of operating conditions, including the pressure and temperature curves in the turbine and compressor at the rated power and corresponding rotational speeds, and details of permissible temporary operation beyond the values for the rated power
7	A	Diagrammatic layout of the fuel system, including control and safety devices, and of the lubricating oil system
8	A	Cooling system layout, if applicable
9	I	Where applicable, background information on previous operating experience in similar applications
10	I	Maintenance and overhaul procedures
11	A	Stress and temperature analysis in blades, rotors and combustion chamber **(2)**
12	A	Life time calculation of hot and high stress parts **(2)**
13	A	Blade and rotor vibration analysis **(2)**
14	A	Details of automatic safety devices together with failure mode and effect analysis (FMEA) **(2)**

(1) A = to be submitted for approval in four copies
I = to be submitted for information in duplicate

(2) As an alternative, the Society may, on a case by case basis, consider reviewing a number of selected packages relative to important and critical parts of the turbine, where all the design, construction, inspection, testing and acceptance criteria used by the manufacturer are clearly described, provided the Quality Assurance system of the manufacturer is approved and certified by the Society.

2.3.2 Access and inspection openings

a) Access to the combustion chambers is to be ensured. Means are to be provided to inspect the burner cans or combustion chamber without having to remove the gas generator.

b) 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.

2.3.3 Bearings

a) Turbine bearings are to be so located that their lubrication is not impaired by overheating from hot gases or adjacent hot parts.

b) Lubricating oil or fuel oil is to be prevented from dripping on high temperature parts.

c) Suitable arrangements for cooling the bearings after the turbines have been stopped are to be provided, if necessary to prevent bearing cooking.

d) 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.

2.3.4 Turning gear

a) Main propulsion turbines are to be equipped with turning gear or a starter for cranking. The rotors of auxiliary turbines are to be capable of being turned by hand.

b) The engagement of the turning gear or starter is to be visually indicated at the control platform.

c) An interlock is to be provided to ensure that the main turbine cannot be started up when the turning gear is engaged.

2.3.5 Cooling

The turbines and their external exhaust system are to be suitably insulated or cooled to avoid excessive outside temperature.

2.3.6 Air supply

a) The air intake ducting is to be equipped to prevent extraneous substances from entering the compressor and turbine.

b) Measures are to be taken to control the salinity of the combustion air, to meet the manufacturer’s specification.

c) Cleaning equipment is to be provided to remove deposits from compressors and turbines.

d) Means are to be provided to prevent the formation of ice in the air intake.

2.3.7 Turbine exhaust arrangement

a) The gas exhaust arrangement is to be designed in such a way as to prevent the entrance of gases into the compressor.

b) Silencers or other equivalent arrangements are to be provided in the gas exhaust, to limit the airborne noise at one metre distance from the turbine to not more than 110 dB (A) in unmanned machinery spaces and not more than 90 dB (A) in manned spaces.

2.3.8 Multi-turbine installations

Multi-turbine installations are to have separate air inlets and exhaust systems to prevent recirculation through the idle turbine.

2.3.9 Fuel

a) Where the turbine is designed to burn non-distillate fuels, a fuel treatment system is to be provided to remove, as far as practicable, the corrosive constituents of the fuel or to inhibit their action in accordance with the manufacturer’s specification.

b) Suitable means are to be provided to remove the deposits resulting from the burning of the fuel while avoiding abrasive or corrosive action, if applicable.

c) Gas turbines burning boil-off gases of liquefied gas cargo tanks will be specially considered by the Society taking into account the requirements of Pt E, Ch 9, Sec 16.

2.3.10 Start-up equipment

a) Gas turbines are to be fitted with start-up equipment enabling them to be started up from the "shutdown" condition.

b) Provisions are to be made so that any dangerous accumulation of liquid or gaseous fuel inside the turbines is thoroughly removed before any attempt at starting or restarting.

c) Starting devices are to be so arranged that firing operation is discontinued and the main fuel valve is closed within a pre-determined time when ignition is failed.

d) The minimum number of starts is to be such as to satisfy the requirements of Sec 1, [1.4.4].

2.3.11 Astern power

For main propulsion machinery with reverse gearing, controllable pitch propellers or an electrical transmission system, astern running is not to cause any overloading of the propulsion machinery.

2.3.12 Emergency operation

a) In installations with more than one propeller and connected shafting and more than one turbine, the failure of any gas turbine unit connected to a shafting line is not to affect the continued, independent operation of the remaining units.

b) In installations with only one propeller and connected shafting, driven by two or more main turbines, care is to be taken to ensure that, in the event of one of the turbines failing, the others are able to continue operation independently.

c) Ships classed for unrestricted service and fitted with only one propeller and connected shafting driven by a gas turbine are to be provided with means to ensure emergency propulsion in the event of failure of the main turbine.

2.4 Welded fabrication

2.4.1 The manufacturer's requirements relative to the welding of turbine rotors or major forged or cast pieces, where permitted, are to be readily identifiable by the Society in the plans submitted for approval.

In general, all weldings are to be carried out by qualified welders in accordance with qualified welding procedures using approved consumables.

2.5 Control and monitoring

2.5.1 General *(1/7/2006)*

In addition to those of this item [2.5], the general requirements given in Chapter 3 apply.

In the case of ships with automation notations, the requirements in Part F, Chapter 3 also apply.

2.5.2 Governors and speed control system

a) Propulsion turbines which may be operated in no-load conditions are to be fitted with a control system capable of limiting the speed to a value not exceeding 10% of the maximum continuous speed.

b) Turbines for main propulsion machinery equipped with controllable pitch propellers, disengaging couplings or an electrical transmission system are to be fitted with a speed governor which, in the event of a sudden loss of load, prevents the revolutions from increasing to the trip speed.

c) In addition to the speed governor, turbines driving electric generators are to be fitted with a separate overspeed protective device, with a means for manual tripping, adjusted so as to prevent the rated speed from being exceeded by more than 15%.

d) The speed increase of turbines driving electric generators - except those for electrical propeller drive - resulting from a change from full load to no-load is not to exceed 5% on the resumption of steady running conditions. The transient speed increase resulting from a sudden change from full load to no-load conditions is not to exceed 10% and is to be separated by a sufficient margin from the trip speed. Alternative requirements may be considered by the Society on a case by case basis based on the actual turbine design and arrangement.

2.5.3 Monitoring system

The main operating parameters (pressure, temperature, rpm, etc.) are to be adequately monitored and displayed at the control console.

2.5.4 Emergency shut-off

a) An emergency push-button shut-off device is to be provided at the control console.

b) Any shut-off device provided in pursuance of the above is to shut off the fuel supply as near the burners as possible.

2.5.5 Quick-closing devices

a) Re-setting of the quick-closing device may be effected only at the turbine or from the control platform with the fuel supply control valve in the closed position.

b) When the devices are operated by hydraulic oil systems fitted for automatic operation, they are to be fed by two pumps: one main pump and one standby pump. In any event, the standby pump is to be independent. In special cases, a hand-operated pump may be accepted as a standby pump.

c) The starting up of any turbine is to be possible only when the quick-closing devices are ready for operation.

2.5.6 Automatic temperature controls

The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions within the normal operating range of the main gas turbine:

a) lubricating oil supply and discharge

b) fuel oil supply (or, alternatively, automatic control of fuel oil viscosity)

c) exhaust gas in specific locations of the flow gas path as determined by the manufacturer.

2.5.7 Summary table *(1/1/2023)*

Tab 2 indicates the minimum control, monitoring and shutdown requirements for main propulsion and auxiliary turbines.

Unless the FMEA required in this Section proves otherwise, the shutdown functions for gas turbines are to be provided in accordance with Tab 2.

Although in principle alarming devices listed in Tab 2 are to be provided, they can be added or omitted, taking into account the result of FMEA.

Note 1: Some departures from Tab 2 may be accepted by the Society in the case of ships with a restricted navigation notation.

Table 2 : Main propulsion and auxiliary turbines *(1/1/2023)*

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				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
• Control system failure	X						
• Automatic starting failure	X						
Mechanical monitoring of gas turbine							
• Speed		local					
					X		
	H			X			
• Rotor axial displacement (Not applicable to roller bearing)		local					
	H			X			
• Vibration	H*	local		X			
• Performed number of cycle of rotating part	H						
Gas generator monitoring							
• Flame and ignition failure	X			X			
• Fuel oil supply pressure	L	local					
• Fuel oil supply temperature	H	local					
• Cooling medium temperature	H	local					
• Exhaust gas temperature or gas temperature in specific locations of flow gas path. (Alarm before shutdown)		local					
	H*			X			
• Vacuum pressure at the compressor inlet (alarm before shutdown)		local					
	H*			X			
Lubricating oil							
• Turbine supply pressure		local					
	L*			X			

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				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
• Lubricating oil pressure of reduction gear		local					
	L*			X			
• Differential pressure across lubricating oil filter	H	local					
• Bearing or lubricating oil (discharge) temperature	H	local					
Notes: 1) Alarms marked with "*" are to be activated at the suitable setting points prior to arriving the critical condition for the activation of shutdown devices.							

3 Arrangement and installation

3.1 Foundations

3.1.1 Foundations of turbines and connected reduction gears are to be designed and built so that hull movements do not give rise to significant movements between reduction gears and turbines. In any event, such movements are to be absorbed by suitable couplings.

3.2 Joints of mating surfaces

3.2.1 The mating flanges of casings are to form a tight joint without the use of any interposed material.

3.3 Piping installation

3.3.1 Pipes and mains connected to turbine and compressor casings are to be fitted in such a way as to minimise the thrust loads and moments. If flexible hoses are used for this purpose, they are to comply with the requirements in Sec 10, [2.6].

3.4 Hot surfaces

3.4.1 Hot surfaces with which the crew are likely to come into contact during operation are to be suitably guarded or insulated. See Sec 1, [3.7].

3.5 Alignment

3.5.1

a) Particular care is to be taken in the alignment of turbine-reduction gearing, taking account of all causes which may alter the alignment from cold conditions to normal service conditions.

b) When a structural tank is fitted in way of the turbine or gearing foundations, the expected tank temperature variations are to be taken into account during alignment operations.

c) Propulsion turbines are to be fitted with indicators showing the axial movements of rotors with respect to casings and the sliding movements of casings on the sliding feet. Such indicators are to be fitted in an easily visible position. This requirement does not apply to turbines fitted with roller bearings.

3.6 Gratings

3.6.1 Gratings and any other structures in way of the sliding feet or flexible supports are to be so arranged that turbine casing expansion is not restricted.

3.7 Drains

3.7.1 Turbines and the associated piping systems are to be equipped with adequate means of drainage.

3.8 Instruments

3.8.1 Main and auxiliary turbines are to be fitted with callipers and micrometers of a suitable type for verifying the alignment of rotors and pinion and gear-wheel shafts, when necessary.

At the time of installation on board, this check is to be performed in the presence and to the satisfaction of the Surveyor.

4 Material tests, workshop inspection and testing, certification

4.1 Type tests - General

4.1.1 Upon finalisation of the design for production of every new turbine type intended for installation on board ships, one turbine is to be presented for type testing as required below.

A type test carried out for a particular type of turbine at any manufacturer's works will be accepted for all turbines of the same type built by licensees and licensors.

Turbines which are subjected to type testing are to be tested in accordance with the scope specified below, it being taken for granted that:

- the turbine is optimised as required for the conditions of the type test
- the investigations and measurements required for reliable turbine operation have been carried out during preliminary internal tests by the turbine manufacturer
- the documentation to be submitted as required in [1.3.1] has been examined and, when necessary, approved by the Society and the latter has been informed regarding the nature and extent of investigations carried out during pre-production stages.

4.2 Type tests of turbines not admitted to an Alternative Certification Scheme

4.2.1 General

Turbines for which the Manufacturer is not admitted to testing and inspections according to an Alternative Certification Scheme (see Pt D, Ch 1, Sec 1, [3.2]), are to be type tested in the presence of the Surveyor in accordance with the following requirements.

The type test is subdivided into three stages:

a) Stage A - Preliminary internal tests carried out by the manufacturer

   Stage A includes functional tests and collection of operating values including testing hours during the internal tests, the relevant results of which are to be presented to the Surveyor during the type test. Testing hours of components which are inspected are 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 turbine components

   After completion of the test programme, the main turbine components are to be inspected.

The turbine manufacturer is to compile all results and measurements for the turbine 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 (functional tests and collection of operating data)

a) During the internal tests the turbine is to be operated at the load points considered important by the turbine manufacturer and the relevant operating values are to be recorded.

b) The load points may be selected according to the range of application.

c) Functional tests under normal operating conditions include:

   1) The load points 25%, 50%, 75%, 100% of the rated power for which type approval is requested, to be carried out:
      - along the nominal (theoretical) propeller curve and at constant speed, for propulsion turbines
      - at constant speed, for turbines intended for generating sets.
   2) The limit points of the permissible operating range.

      These limit points are to be defined by the turbine manufacturer.

d) An alternative testing program may be agreed between the manufacturer and the Society on a case by case basis.

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 turbine manufacturer and the Surveyor.

Any departures from this programme are to be agreed upon by the manufacturer and the Society.

a) Load points

The load points at which the turbine is to be operated according to the power/speed diagram are those listed below. The data to be measured and recorded when testing the turbine at various load points are to include all necessary parameters for turbine operation.

The operating time per load point depends on the turbine 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 maximum permissible torque (normally 110% of nominal torque T) at 100% speed; or test at maximum permissible power and speed according to the nominal propeller curve.
3) tests at partial loads, e.g. 75%, 50%, 25% of maximum continuous power P and speed according to the nominal propeller curve.

b) Additional tests

- test at lowest turbine speed according to the nominal propeller curve
- starting tests
- governor tests
- testing and rating of the safety systems.

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].

The values of temperatures and pressures of media, such as cooling media, lubricating oil, exhaust gases, etc., are to be within limits which, in the opinion of the Surveyor, are appropriate for the characteristics of the turbine tested.

4.2.5 Stage C - Inspection of turbine components

Immediately after the test run as per [4.2.3], a selected number of components agreed between the manufacturer and the Society are to be presented for inspection to the Surveyor.

4.3 Type tests of turbines admitted to an Alternative Certification Scheme

4.3.1 General

Turbines admitted to testing and inspections according to an Alternative Certification Scheme (see Pt D, Ch 1, Sec 1, [3.2]) are to be type tested in the presence of the Surveyor in accordance with the following requirements.

The selection of the turbine 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 rated power and n the corresponding speed.

Any departures from this programme are to be agreed upon by the manufacturer and the Society.

a) 6 hours at full power

b) 10 hours shared at different partial loads (25%, 50%, 75% and 90% of power P);

c) 2 hours at intermittent loads

d) starting tests

e) testing of speed governor, overspeed device and lubricating oil system failure alarm device

f) testing of the minimum speed along the nominal (theoretical) propeller curve, for main propulsion turbines driving fixed pitch propellers, and of the minimum speed with no brake load, for main propulsion turbines driving controllable pitch propellers or for auxiliary turbines.

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 full power test is to be carried out at the end of each cycle.

The partial load tests specified in (b) are to be carried out:

- along the nominal (theoretical) propeller curve and at constant speed, for propulsion turbines
- at constant speed, for turbines intended for generating sets.

In the case of prototype turbines, the duration and programme of the type test will be specially considered by the Society.

4.3.3 Alternatives

In cases of turbines for which the manufacturer submits documentary evidence proving successful service experience or results of previous bench tests, the Society may, at its discretion, 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.

4.3.4 Data to be recorded

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 medium temperature at the inlet of the turbine

c) characteristics of the fuel and lubricating oil used during the test

d) turbine speed

e) brake power

f) brake torque

g) intake and exhaust losses

h) lubricating oil pressure and temperature

i) exhaust gas temperature in locations of the flow gas path selected by the manufacturer

j) minimum starting air pressure and flow rate necessary to purge and start the turbine in cold condition, if applicable.

4.3.5 Inspection of main turbine 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 tests

4.4.1 The materials for the construction of the parts listed in Tab 3 are to be tested in compliance with the requirements of Part D.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 3 and are to be effected in positions mutually agreed upon by the manufacturer and the Surveyor, where experience shows defects are most likely to occur.

For important structural parts of the turbine, in addition to the above-mentioned non-destructive tests, examination of welded seams by approved methods of inspection may be required.

Where there is evidence to doubt the soundness of any turbine component, non-destructive tests using approved detecting methods may be required.

4.5 Inspections and testing during construction

4.5.1 Inspections during construction

The following inspections and tests are to be carried out in the presence of a Surveyor during the construction of all turbines which are indicated in [1.1.1]. For on-board trials see Sec 16, [3.6].

- Material tests as required (See [4.4]).
- Welding fabrication (See [4.5.2]).
- Hydrostatic tests (See [4.5.3]).
- Rotor balancing and overspeed test (See [4.5.4], [4.5.5]).
- Shop trials (See [4.5.6]).

4.5.2 Welding fabrication

Welding fabrication and testing is to be attended by the Surveyor, as may be deemed necessary by the Society.

4.5.3 Hydrostatic tests

Finished casing parts and heat exchangers are to be subjected to hydrostatic testing at 1,5 times the maximum permissible working pressure. If it is demonstrated by other means that the strength of casing parts is sufficient, a

tightness test at 1,1 times the maximum permissible working pressure may be accepted by the Society. Where the hydrostatic test cannot be performed, alternative methods for verifying the integrity of the casings may be agreed between the manufacturer and the Society on a case by case basis.

4.5.4 Balancing of rotors

Finished rotors, complete with all fittings and blades, are to be dynamically balanced in a balancing machine of appropriate sensitivity in relation to the size of the rotor. Normally this test is to be carried out with the primary part of the flexible coupling, if any.

4.5.5 Overspeed test of rotors

Finished rotors, complete with all fittings and blades, are to be subjected for at least 3 minutes to an overspeed test at the greater of the following values:

- 5% above the setting speed of the overspeed tripping device
- 15% above the maximum design speed.

The Society may waive this requirement provided that it can be demonstrated by the manufacturer, using an acceptable direct calculation procedure, that the rotor is able to safely withstand the above overspeed values and that rotors are free from defects, as verified by means of non-destructive tests.

4.5.6 Shop trials

For shop trials, see [4.2.3] and [4.3.2].

4.6 Certification

4.6.1 Type approval certificate and its validity

Subject to the satisfactory outcome of the type tests and inspections specified in [4.2] or [4.3], the Society will issue to the turbine manufacturer a "Type Approval Certificate" valid for all turbines of the same type.

4.6.2 Testing certification

a) Turbines admitted to an Alternative Certification Scheme

Work's Certificate (W) (see Pt D, Ch 1, Sec 1, [4.2.3]) is required for components and tests indicated in Tab 3 and tests and trials listed in [4.5.1]. However, the Society reserves the right to request that the shop trials be witnessed by a Surveyor on a case by case basis.

b) Turbines not admitted to an Alternative Certification Scheme

Society Certificate (C) (see Pt D, Ch 1, Sec 1, [4.2.1]) is required for material tests of rotating components and blades listed in Tab 3 and for works trials as per [4.5.3] and [4.5.4].

Work's Certificate (W) (see Pt D, Ch 1, Sec 1, [4.2.3]) is required for the other items listed in Tab 3 and for trials described in [4.5.2] [4.5.5] and [4.5.6].

Table 3 : Material and non-destructive tests

Turbine component	Material tests (Mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic or radiographic examination
Rotating parts (compressors and turbine rotors, shafts, stiff and flexible couplings, bolts for couplings and other dynamically stressed parts, integral pinions and gears)	all	all	all
Stationary parts (castings for casings intended for a temperature exceeding 230°C and plates for casings intended for a temperature exceeding 370°C or pressure exceeding 4 Mpa)	all	spot as agreed between the Manufacturer and the Surveyor	-
Blades	sample	sample	sample
Piping and associated fittings	as required in the appropriate section of the Rules	as required in the appropriate section of the Rules	as required in the appropriate section of the Rules

SECTION 6 GEARING

1 General

1.1 Application

1.1.1 *(1/1/2015)*

Unless otherwise specified, the requirements of this section apply to:

- reduction and/or reverse gears intended for propulsion plants with a transmitted power of 220 kW and above
- other reduction and step-up gears with a transmitted power of 110 kW and above, intended for essential service auxiliary machinery.

All other gears are to be designed and constructed according to sound marine practice and delivered with the relevant works' certificate (see Pt D, Ch 1, Sec 1, [4.2.3]).

Gearing approved prior to the application date and having a documented satisfactory service experience may be exempted from application of these Rules.

The provisions of Article [2] apply only to cylindrical involute spur or helical gears with external or internal teeth.

Additional requirements for gears fitted to ships having an ice notation are given in Part F, Chapter 9.

Some departure from the requirements of this Section may be accepted by the Society in cases of gears fitted to ships having a restricted navigation notation.

Alternative calculations based on a recognized standard may be submitted by the manufacturer of the gears and will be given special consideration by the Society.

1.2 Documentation to be submitted

1.2.1 Documents

Before starting construction, all plans, specifications and calculations listed in Tab 1 are to be submitted to the Society.

Table 1 : Documents to be submitted for gearing *(1/7/2023)*

No.	I/A **(1)**	Document **(2)**
1	A	Constructional drawings of shafts and flanges
2	A	Constructional drawings of pinions and wheels, including: a) specification and details of hardening procedure: • core and surface mechanical characteristics • diagram of the depth of the hardened layer as a function of hardness values b) specification and details of the finishing procedure: • finishing method of tooth flanks (hobbing, shaving, lapping, grinding, shot-peening) • surface roughness for tooth flank and root fillet • tooth flank corrections (helix modification, crowning, tip-relief, end-relief), if any • grade of accuracy according to ISO 1328-1:2013
3	A	Shrinkage calculation for shrunk-on pinions, wheels rims and/or hubs with indication of the minimum and maximum shrinkage allowances
4	A	Calculation of load capacity of the gears
5	A / I **(3)**	Constructional drawings of casings
6	A	Functional diagram of the lubricating system, with indication of: • specified grade of lubricating oil • expected oil temperature in service • kinematic viscosity of the oil
7	A	Functional diagram of control, monitoring and safety systems

No.	I/A **(1)**	Document **(2)**
8	I	Longitudinal and transverse cross-sectional assembly of the gearing, with indication of the type of clutch
9	I	Data form for calculation of gears

(1) A = to be submitted for approval, in four copies
I = to be submitted for information, in duplicate.

(2) Constructional drawings are to be accompanied by the specification of the materials employed including the chemical composition, heat treatment and mechanical properties and, where applicable, the welding details, welding procedure and stress relieving procedure.

(3) "A" for welded casing, "I" otherwise

1.2.2 Data

The data listed in Tab 2 are to be submitted with the documents required in [1.2.1].

Table 2 : Data to be submitted for gearing

No.	Description of the data
1	Type of driving and driven machines and, if provided, type of flexible coupling
2	Maximum power transmitted by each pinion in continuous running and corresponding rotational speed, for all operating conditions, including clutching-in
3	Modules of teeth for pinion and wheels
4	Pressure angle and helix angle
5	Tooth profiles of pinions and wheels together with tip diameters and fillet radii
6	Operating centre distance
7	Addendum of the cutting tool
8	Common face width, operating pitch diameter
9	Data related to the bearings: • type, characteristics and designed service life of roller bearings • materials and clearances of plain bearings • position of each gear in relation to its bearings
10	Torsional vibration data (inertia and stiffness)

2 Design of gears - Determination of the load capacity

2.1 Symbols, units, definitions

2.1.1 Symbols and units *(1/7/2023)*

The meaning of the main symbols used in this Section is specified below.

Other symbols introduced in connection with the definition of influence factors are defined in the appropriate articles.

a : Centre distance, in mm

b : Common face width (for double helix gear, width of one helix), in mm

$b_{1,2}$: Face width of pinion, wheel

d : Reference diameter, in mm

d_a : Tip diameter, in mm

d_b : Base diameter, in mm

d_f : Root diameter, in mm

$d_{w1,2}$: Working diameter of pinion, wheel, in mm

x : Addendum modification coefficient

z : Number of teeth

z_n : Virtual number of teeth

n : Rotational speed, in rpm

U : Reduction ratio

m_n : Normal module, in mm

h : Tooth depth, in mm

α_{Fen} : Pressure angle at the outer point of single tooth pair contact in the normal section

α_n : Normal pressure angle at reference cylinder, in degrees

α_t : Transverse pressure angle at reference cylinder, in degrees

α_{tw} : Transverse pressure angle at working pitch cylinder, in degrees

β : Helix angle at reference cylinder, in degrees

β_b : Base helix angle, in degrees

ε_α : Transverse contact ratio

ε_β : Overlap ratio

ε_γ : Total contact ratio

ρ_{ao} : Tip radius of the tool,

ρ_F : Tooth root radius at the critical section, in mm to be calculated according to the procedure in ISO 6336-3:2019.

h_{Fe} : Bending moment arm for tooth root bending stress for application of load at the outer point of single tooth pair contact, in mm

h_{fp} : Basic rack dedendum, in mm

s_{Fn} : Tooth root normal chord at critical section, in mm

χ_B : Running-in factor (mesh misalignment)

Q : Gearing quality class according to ISO 1328-1:2013

HB : Brinell Hardness

HV : Vickers hardness

R : Minimum tensile strength of gear material, in N/mm^2

$R_{z(f)}$: Mean flank peak-to-valley roughness, in μm (R_z as defined in the reference standard ISO 6336-2:2019)

$R_{z(r)}$: Mean root peak-to-valley roughness, in μm (R_z as defined in the reference standard ISO 6336-2:2019)

F_t : Nominal tangential load, in N

σ_F : Tooth root bending stress, in N/mm^2

σ_{FE} : Endurance limit for tooth root bending stress, in N/mm^2

σ_{FP} : Permissible tooth root bending stress, in N/mm^2

σ_H : Contact stress (Hertzian pressure), in N/mm^2

$\sigma_{H,lim}$: Endurance limit for contact stress (Hertzian pressure), in N/mm^2

σ_{HP} : Permissible contact stress (Hertzian pressure), in N/mm^2

v : Linear velocity at working pitch diameter, in m/s

Subscripts:

- 1 for pinion, i.e. the gear having the smaller number of teeth
- 2 for wheel.

2.1.2 Geometrical definitions *(1/1/2015)*

In the calculation of surface durability, b is the common face width on the working pitch diameter.

In tooth strength calculations, b_1, b_2 are the face widths at the respective tooth roots. In any case b_1 and b_2 are not to be taken as greater than b by more than one module (m_n) on either side

For internal gears, z_2 , a, d_2 , d_{a2} , d_{b2} and d_{w2} are to be taken negative.

$$u = \frac{z_2}{z_1}$$

Note 1: u > 0 for external gears, u < 0 for internal gears.

$$\tan\alpha_t = \frac{\tan\alpha_n}{\cos\beta}$$

$$d_{1,2} = \frac{z_{1,2} \cdot m_n}{\cos\beta}$$

$$d_{1,2b} = d_{1,2} \cdot \cos\alpha_t$$

$$d_{w1} = \frac{2a}{u+1}$$

$$d_{w2} = \frac{2au}{u+1}$$

where $a = 0{,}5\,(d_{w1} + d_{w2})$

$$Z_{n1,2} = \frac{z_{1,2}}{\cos^2\beta_b \cos\beta}$$

$$m_t = \frac{m_n}{\cos\beta}$$

$$\text{inv}\,\alpha = \tan\alpha - \frac{\Pi\alpha}{180}; \quad \alpha[°]$$

$$\text{inv}\,\alpha_{tw} = \text{inv}\,\alpha_t + 2\tan\alpha_n \frac{x_1 + x_2}{z_1 + z_2} \text{ or}$$

$$\cos\alpha_{tw} = \frac{m_t(z_1 + z_2)}{2a}\cos\alpha_t$$

for external gears:

$$\varepsilon_\alpha = \frac{0{,}5 \cdot (d_{a1}^2 - d_{b1}^2)^{\frac{1}{2}} + 0{,}5 \cdot (d_{a2}^2 - d_{b2}^2)^{\frac{1}{2}} - (a \cdot \sin\alpha_{tw})}{\pi \cdot m_t \cdot \cos\alpha_t}$$

for internal gears:

$$\varepsilon_\alpha = \frac{0{,}5 \cdot (d_{a1}^2 - d_{b1}^2)^{\frac{1}{2}} - 0{,}5 \cdot (d_{a2}^2 - d_{b2}^2)^{\frac{1}{2}} - (a \cdot \sin\alpha_{tw})}{\pi \cdot m_t \cdot \cos\alpha_t}$$

$$\varepsilon_\beta = \frac{b \cdot \sin\beta}{\pi \cdot m_n}$$

$$\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta$$

$$v = \pi d_{1,2}\, n_{1,2} / 60 \cdot 10^3$$

2.2 Principle

2.2.1 *(1/1/2015)*

a) The following requirements apply to cylindrical involute spur or helical gears with external or internal teeth, and provide a method for the calculation of the load capacity with regard to:
   - the surface durability (contact stress), and
   - the tooth root bending stress.

   The relevant formulae are provided in [2.4] and [2.5].

   The influence factors common to the formuale are given in [2.3].

b) Gears for which the conditions of validity of some factors or formulae are not satisfied will be given special consideration by the Society.

c) Other methods of determination of load capacity will be given special consideration by the Society.

The nominal tangential load, F_t, tangential to the reference cylinder and perpendicular to the relevant axial plane, is calculated directly from the maximum continuous power transmitted by the gear set by means of the following equations:

$$T_{1,2} = \frac{30 \cdot 10^3 P}{\pi \cdot n_{1,2}}$$

$$F_t = 2000 \cdot T_{1,2} / d_{1,2}$$

2.3 General influence factors

2.3.1 General

General influence factors are defined in [2.3.2], [2.3.3], [2.3.4], [2.3.5] and [2.3.6]. Alternative values may be used provided they are derived from appropriate measurements.

2.3.2 Application factor K_A

The application factor K_A accounts for dynamic overloads from sources external to the gearing.

The values of K_A are given in Tab 3.

Table 3 : Values of K_A

Type of installation			K_A
Main gears (propulsion)	Diesel engine	with hydraulic coupling	1,00
		with elastic coupling	1,30
		with other type of coupling	1,50
	Turbine		1,00
	Electric motor		1,00
Auxiliary gears	Diesel engine	with hydraulic coupling	1,00
		with elastic coupling	1,20
		with other type of coupling	1,40
	Electric motor		1,00

2.3.3 Load sharing factor K_γ *(1/1/2015)*

The load sharing factor K_γ accounts for the uneven sharing of load on multiple path transmissions, such as epicyclic gears or dual tandem gears.

The values of K_γ are given in Tab 4.

Table 4 : Values of K_γ

Type of gear		K_γ
Dual tandem gear	without quill shaft **(1)**	1,15
	with quill shaft **(1)**	1,10
Epicyclic gear	with 3 planetary gears and less	1,00
	with 4 planetary gears	1,20
	with 5 planetary gears	1,30
	with 6 planetary gears and more	1,40
(1) A quill shaft is a torsionally flexible shaft intended for improving the load distribution between the gears.		

2.3.4 Dynamic factor K_V *(1/7/2022)*

The internal dynamic factor K_V accounts for the additional internal dynamic loads acting on the tooth flanks and due to the vibrations of pinion and wheel.

The values of K_V are given in Tab 5. They apply to cases where all the following conditions are satisfied:

$$\frac{v \cdot Z_1}{100}\sqrt{\frac{u^2}{1+u^2}} < 10 \text{m/s}$$

- spur gears ($\beta = 0°$) and helical gears with $\beta \leq 30°$
- pinion with relatively low number of teeth, $z_1 < 50$
- solid disc wheels or heavy steel gear rim

and also when

$$\frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}} < 3 m/s$$

in this case it is also applicable to gears having $\beta > 30°$.

Table 5 : Values of K_V *(1/1/2015)*

Type of gear	K_V		K_2
Spur gear	$K_V = 1 + \left(\frac{K_1}{\frac{F_t}{K_A \frac{}{b}} + K_2}\right) \cdot \frac{v \cdot z_1}{100} K_3 \sqrt{\frac{u^2}{1+u^2}}$ where K_1 has the values specified in Tab 6		$K_2 = 0,0193$
Helical gear	• if $\varepsilon_\beta \geq 1$:	$K_V = 1 + \left(\frac{K_1}{K_A \frac{F_t}{b}} + K_2\right) \cdot \frac{v \cdot z_1}{100} K_3 \sqrt{\frac{u^2}{1+u^2}}$ where K_1 has the values specified in Tab 6	$K_2 = 0,0087$
	• if $\varepsilon_\beta < 1$:	$K_V = K_{V\alpha} - \varepsilon_\beta \cdot (K_{V\alpha} - K_{V\beta})$ where $K_{V\alpha}$ is calculated as if the gear were of spur type	

Table 6 : Values of K_1 *(1/7/2023)*

	ISO grade of accuracy **(1)**					
Type of gear	3	4	5	6	7	8
Spur gear	2,1	3,9	7,5	14,9	26,8	30,1
Helical gear	1,9	3,5	6,7	13,3	23,9	34,8
(1) ISO accuracy grades according to ISO 1328-1:2013. In case of mating gears with different accuracy grades, the grade corresponding to the lower accuracy is to be used.						

For gears other than above, reference is to be made to ISO 6336-1:2019 method B.

Factor K_3 is to be in accordance with the following:

- if

  $$\frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}} \leq 0,2$$

  then $K_3 = 2,0$
- if

  $$\frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}} > 0,2$$

  then $K_3 = 2,071 - 0,357\frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}}$

2.3.5 Face load distribution factors $K_{H\beta}$ and $K_{F\beta}$ *(1/7/2022)*

a) The face load distribution factors, $K_{H\beta}$ for contact stress and $K_{F\beta}$ for tooth root bending stress, account for the effects of non-uniform distribution of load across the face width.

b) The values of $K_{H\beta}$ and $K_{F\beta}$ are to be determined according to method C of ISO 6336-1:2019:

F_m : mean transverse tangential load at the reference circle relevant to mesh calculation,

$F_m = F_t \cdot K_A \cdot K_V$

Note 1: The value of $K_{H\beta}$ is to be submitted and documented by the manufacturer of the gears.

c) If the hardest contact is at the end of the face width $K_{F\beta}$ is:

$K_{F\beta} = K^N_{H\beta}$

$$N = \frac{(b/h)^2}{1 + (b/h) + (b/h)^2}$$

where b/h is the smaller of b_1/h_1 and b_2/h_2 but is not to be taken lower than 3.

For double helical gears, the face width of only one helix is to be used.

d) In case of end relief or crowing: $K_{F\beta} = K_{H\beta}$

2.3.6 Transverse load distribution factors $K_{H\alpha}$ and $K_{F\alpha}$ *(1/7/2022)*

The transverse load distribution factors, $K_{H\alpha}$ for contact stress, and $K_{F\alpha}$ for tooth root bending stress, account for the effects of pitch and profile errors on the transversal load distribution between two or more pairs of teeth in mesh.

The values of $K_{H\alpha}$ and $K_{F\alpha}$ are to be determined according to Method B of ISO 6336-1:2019.

2.4 Calculation of surface durability

2.4.1 General

The criterion for surface durability is based on the contact stress (Hertzian pressure) on the pitch point or at the inner point of single pair contact.

The contact stress σ_H is not to exceed the permissible contact stress σ_{HP}.

2.4.2 Contact stress σ_H *(1/1/2015)*

The contact stress σ_H is to be determined as follows.

- for the pinion

$$\sigma_H = Z_B \cdot \sigma_{H0} \sqrt{K_A \cdot K_\gamma \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha}}$$

- for the wheel

$$\sigma_H = Z_D \cdot \sigma_{H0} \sqrt{K_A \cdot K_\gamma \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha}}$$

where:

σ_{H0} : calculated from the following formulae:

for external gears:

$$\sigma_{H0} = Z_H \cdot Z_E \cdot Z_\varepsilon \cdot Z_\beta \sqrt{\frac{F_t}{d_1 \cdot b} \cdot \frac{u+1}{u}}$$

for internal gears:

$$\sigma_{H0} = Z_H \cdot Z_E \cdot Z_\varepsilon \cdot Z_\beta \sqrt{\frac{F_t}{d_1 \cdot b} \cdot \frac{u-1}{u}}$$

K_A : Application factor (see [2.3.2]),

K_γ : Load sharing factor (see [2.3.3]),

K_V : Dynamic factor (see [2.3.4]),

$K_{H\beta}$: Face load distribution factors (see [2.3.5]),

$K_{H\alpha}$: Transverse load distribution factors (see [2.3.6]),

Z_B : Single pair tooth contact factor for pinion (see [2.4.4]),

Z_D : Single pair tooth contact factor for wheel (see [2.4.4]),

Z_H : Zone factor (see [2.4.5]),

Z_E : Elasticity factor (see [2.4.6]),

Z_ε : Contact ratio factor (see [2.4.7]),

Z_β : Helix angle factor (see [2.4.8]).

2.4.3 Permissible contact stress σ_{HP} *(1/7/2022)*

The permissible contact stress σ_{HP} is to be determined separately for pinion and wheel using the following formula:

$$\sigma_{HP} = \frac{\sigma_{H,lim}}{S_H} \cdot Z_L \cdot Z_V \cdot Z_R \cdot Z_W \cdot Z_X \cdot Z_N$$

where:

Z_L : Lubricant factor (see [2.4.9]),

Z_V : Velocity factor (see [2.4.9]),

Z_R : Roughness factor (see [2.4.9]),

Z_W : Hardness ratio factor (see [2.4.10]),

Z_X : Size factor for contact stress (see [2.4.11]),

Z_N : :Life factor for contact stress is to be determined according to method B of ISO 6336-2:2019, or assumed to be 1,

S_H : Safety factor for contact stress (see [2.4.12]).

2.4.4 Single pair tooth contact factors Z_B and Z_D *(1/1/2015)*

The single pair tooth contact factors Z_B for pinion and Z_D for wheel account for the influence of the tooth flank curvature on contact stresses at the inner point of single pair contact in relation to Z_H. These factors transform the contact stress determined at the pitch point to contact stresses considering the flank curvature at the inner point of single pair contact.

Z_B and Z_D are to be determined as follows:

a) for spur gears ($\varepsilon_\beta = 0$):

- $Z_B = M_1$ or 1, whichever is the greater, where

$$M_1 = \frac{\tan\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - \frac{2\pi}{z_1}\right]\left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} - (\varepsilon_\alpha - 1)\frac{2\pi}{z_2}\right]}}$$

- $Z_D = M_2$ or 1, whichever is the greater, where

$$M_2 = \frac{\tan\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} - \frac{2\pi}{z_2}\right]\left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - (\varepsilon_\alpha - 1)\frac{2\pi}{z_1}\right]}}$$

b) for helical gears:

- with $\varepsilon_\beta \geq 1$: $Z_B = Z_D = 1$.
- with $\varepsilon_\beta < 1$: Z_B and Z_D are to be determined by linear interpolation between:
  - Z_B and Z_D for spur gears, and
  - Z_B and Z_D for helical gears with $\varepsilon_\beta \geq 1$,

  thus
  - $Z_B = M_1 - \varepsilon_\beta (M_1 - 1)$ and $Z_B \geq 1$
  - $Z_D = M_2 - \varepsilon_\beta (M_2 - 1)$ and $Z_D \geq 1$

For internal gears, Z_D is to be taken as 1,0.

2.4.5 Zone factor Z_H *(1/1/2015)*

The zone factor Z_H accounts for the influence on the Hertzian pressure of tooth flank curvature at the pitch point and transforms the tangential load at the reference cylinder to normal load at the pitch cylinder.

Z_H is to be determined as follows:

$$Z_H = \sqrt{\frac{2 \cdot \cos\beta_b \cdot \cos\alpha_{tw}}{(\cos\alpha_t)^2 \cdot \sin\alpha_{tw}}}$$

2.4.6 Elasticity factor Z_E *(1/7/2022)*

The elasticity factor Z_E accounts for the influence of the metal properties (module of elasticity E and Poisson's ratio ν) on the Hertzian pressure.

For steel gears, $Z_E = 189{,}8\ N^{1/2}/mm$.

In other cases, reference is to be made to ISO 6336-2:2019.

2.4.7 Contact ratio factor Z_ε

The contact ratio factor Z_ε accounts for the influence of the transverse contact ratio and the overlap ratio on the specific surface load of gears.

Z_ε is to be determined as follows:

a) for spur gears:

$$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}}$$

b) for helical gears:

- for $\varepsilon_\beta < 1$

$$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}\cdot(1-\varepsilon_\beta)+\frac{\varepsilon_\beta}{\varepsilon_\alpha}}$$

- for $\varepsilon_\beta \geq 1$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}}$$

2.4.8 Helix angle factor Z_β *(1/1/2015)*

The helix angle factor Z_β accounts for the influence of helix angle on surface durability, allowing for such variables as the distribution of load along the lines of contact.

Z_β is to be determined as follows:

$$Z_\beta = \sqrt{\frac{1}{\cos\beta}}$$

2.4.9 Lubrication, speed and roughness factors Z_L , Z_V and Z_R *(1/7/2022)*

The lubricant factor Z_L accounts for the influence of the type of the lubricant and of its viscosity. The velocity factor Z_V accounts for the influence of the pitch line velocity. The roughness factor Z_R accounts for the influence of the surface roughness on the surface endurance capacity.

The factors are to be determined for the softer material where gear pairs are of different hardness.

These factors are to be determined as follows:

a) Lubricant factor Z_L

$$Z_L = C_{ZL} + \frac{4\cdot(1,0-C_{ZL})}{\left(1,2+\frac{134}{\nu_{40}}\right)^2}$$

where:

ν_{40} : nominal kinematic viscosity of the oil at 40°C, mm²/s

C_{ZL} :

- for $\sigma_{H,lim} < 850$ N/mm²
  $C_{ZL} = 0,83$
- for 850 N/mm² $\leq \sigma_{H,lim} \leq$ 1200 N/mm²
  $$C_{ZL} = 0,08\left(\frac{\sigma_{H,lim}-850}{305}\right)+0,83$$
- for $\sigma_{H,lim} >$ 1200 N/mm²
  $C_{ZL} = 0,91$

b) Velocity factor Z_V

$$Z_V = C_{ZV} + \frac{2\cdot(1,0-C_{ZV})}{\sqrt{0,8+\frac{32}{v}}}$$

where:

- for $\sigma_{H,lim} <$ 850 N/mm²
  $C_{ZV} = 0,85$
- for 850 N/mm² $\leq \sigma_{H,lim} \leq$ 1200 N/mm²
  $C_{ZV} = C_{ZL} + 0,02$
- for $\sigma_{H,lim} >$ 1200 N/mm²
  $C_{ZV} = 0,93$

c) Roughness factor Z_R

$$Z_R = \left(\frac{3}{R_{Z10(f)}}\right)^{C_{ZR}}$$

where:

$R_{Z10(f)}$: Mean relative flank peak-to-valley roughness for the gear pair

$$R_{Z10(f)} = R_{Z(f)} \sqrt[3]{\frac{10}{\rho_{red}}}$$

$R_{Z(f)}$: Mean flank peak-to-valley roughness of the gear pair,

$$R_{Z(f)} = \frac{R_{Z(f)1} + R_{Z(f)2}}{2}$$

where $R_{Z(f)1}$ and $R_{Z(f)2}$ are mean values measured on several tooth flanks

ρ_{red} : Relative radius of curvature, equal to:

$$\rho_{red} = \frac{\rho_1 \cdot \rho_2}{\rho_1 + \rho_2} \quad \text{with:}$$

$$\rho_1 = 0{,}5 \cdot d_{b1} \cdot \tan\alpha_{tw}$$

$$\rho_2 = 0{,}5 \cdot d_{b2} \cdot \tan\alpha_{tw}$$

d_b being taken negative for internal gears,

If the roughness stated is an arithmetic mean roughness, i.e. R_a value (=CLA value) (=AA value) the following approximate relationship may be applied:

R_a = CLA = AA = R_z / 6

C_{ZR} : Coefficient having the following values:

- for $\sigma_{H,lim} < 850$ N/mm^2
  $C_{ZR} = 0{,}15$
- for 850 N/mm^2 $\leq \sigma_{H,lim} \leq$ 1200 N/mm^2
  $$C_{ZR} = 0{,}32 - \frac{\sigma_{H,lim}}{5000}$$
- for $\sigma_{H,lim} >$ 1200 N/mm^2
  $C_{ZR} = 0{,}08$

2.4.10 Hardness ratio factor Z_W *(1/1/2026)*

The hardness ratio factor Z_W accounts for the increase of surface durability in the case of a soft steel gear meshing with a significantly (≥ 200HV) harder gear with a smooth surface in the following cases:

a) Surface-hardened pinion with through-hardened wheel

- for HB < 130
  $$Z_W = 1{,}2 \cdot \left(\frac{3}{R_{ZH}}\right)^{0,15}$$
- for 130 ≤ HB ≤ 470
  $$Z_W = \left(1{,}2 - \frac{HB - 130}{1700}\right) \cdot \left(\frac{3}{R_{ZH}}\right)^{0,15}$$
- for HB > 470
  $$Z_W = \left(\frac{3}{R_{ZH}}\right)^{0,15}$$

where:

HB : Brinell hardness of the tooth flanks of the softer gear of the pair

R_{zH} : equivalent roughness, μm

$$R_{ZH} = \frac{R_{Z1} \cdot (10/\rho_{red})^{0,33} \cdot (R_{Z1}/R_{Z2})^{0,66}}{(V \cdot \nu_{40}/1500)^{0,33}}$$

If $R_{zH} > 16$ then $R_{zH} = 16$ μm

If $R_{zH} < 3$ then $R_{zH} = 3$ μm

ρ_{red} : relative radius of curvature

b) Through-hardened pinion and wheel

When the pinion is substantially harder than the wheel, the work hardening effect increases the load capacity of the wheel flanks. Z_W applies to the wheel only, not to the pinion.

- If $HB_1 / HB_2 < 1,2$

  $Z_W = 1$

- if $1,2 \leq HB_1 / HB_2 \leq 1,7$

  $$Z_W = 1 + \left(0,00898 \frac{HB_1}{HB_2} - 0,00829\right) \cdot (u - 1)$$

- if $HB_1 / HB_2 > 1,7$

  $$Z_W = 1 + 0,00698 \cdot (u - 1)$$

  If gear ratio $u > 20$ then the value $u = 20$ is to be used.

  In any case, if calculated $Z_W < 1$ then the value $Z_W = 1,0$ is to be used.

2.4.11 Size factor Z_X

The size factor Z_X accounts for the influence of tooth dimensions on permissible contact stress and reflects the non-uniformity of material properties.

Z_X is to be determined as follows:

- for through-hardened steel: $Z_X = 1$
- for nitrided or nitrocarburised steel:

  $Z_X = 1,08 - 0,011\ m_n$ with $0,75 \leq Z_X \leq 1$
- for case-hardened steels:

  $Z_X = 1,05 - 0,005\ m_n$ with $0,90 \leq Z_X \leq 1$

2.4.12 Safety factor for contact stress S_H

The values to be adopted for the safety factor for contact stress S_H are given in Tab 7.

Table 7 : Safety factor for contact stress S_H

Type of installation		S_H
Main gears (propulsion)	single machinery	1,25
	duplicate machinery	1,20
Auxiliary gears		1,15

2.4.13 Endurance limit for contact stress $\sigma_{H,lim}$ *(1/7/2022)*

The endurance limit for contact stress $\sigma_{H,lim}$ is the limit of repeated contact stress which can be permanently endured.

The endurance limit for contact stress $\sigma_{H,lim}$ is to be determined, in general, making reference to values indicated in the standard ISO 6336-5:2016, for material quality MQ or as given in Tab 8 in relation to the type of steel employed and the heat treatment performed.

Table 8 : Endurance limit for contact stress $\sigma_{H,lim}$ *(1/1/2001)*

Type of steel and heat treatment	$\sigma_{H,lim}$ in N/mm^2
through-hardened carbon steels	0,26 R + 350
through-hardened alloy steels	0,42 R + 330
case-hardened alloy steels	1500
nitrided (nitriding steels)	1250
nitrided or induction-hardened (other steels)	1000

2.5 Calculation of tooth bending strength

2.5.1 General *(1/7/2022)*

The criterion for tooth bending strength is the permissible limit of local tensile stress in the root fillet.

The root stress σ_F is not to exceed the permissible tooth root bending stress σ_{FP}.

The root stress σ_F and the permissible root stress σ_{FP} are to be calculated separately for the pinion and the wheel.

The result of rating calculations made by following this method are acceptable for normal pressure angles up to 25° and reference helix angles up to 30°.

For larger pressure angles and large helix angles, the calculated results should be confirmed by experience as by Method A of the reference standard ISO 6336-3:2019.

2.5.2 Tooth root bending stress σ_F *(1/1/2015)*

The tooth root bending stress σ_F is to be determined as follows:

$$\sigma_F = \frac{F_t}{b \cdot m_n} \cdot Y_F \cdot Y_S \cdot Y_\beta \cdot Y_B \cdot Y_{DT} \cdot K_A \cdot K_\gamma \cdot K_V \cdot K_{F\beta} \cdot K_{F\alpha} \leq \sigma_{FP}$$

where:

Y_F : Tooth form factor (see [2.5.4])

Y_S : Stress correction factor (see [2.5.5])

Y_β : Helix factor (see [2.5.6])

Y_B : Rim thickness factor (see [2.5.7]).

Y_{DT} : Deep tooth factor (see [2.5.8]).

K_A : Application factor (see [2.3.2])

K_γ : Load sharing factor (see [2.3.3])

K_V : Dynamic factor (see [2.3.4])

$K_{F\beta}$: Face load distribution factor (see [2.3.5])

$K_{F\alpha}$: Transverse load distribution factor (see [2.3.6]).

2.5.3 Permissible tooth root bending stress σ_{FP}

The permissible tooth root bending stress σ_{FP} is to be determined separately for pinion and wheel using the following formula:

$$\sigma_{FP} = \frac{\sigma_{FE} \cdot Y_d \cdot Y_N}{S_F} \cdot (Y_{\delta relT} \cdot Y_{RrelT} \cdot Y_X)$$

where:

σ_{FE} : Endurance limit for tooth root bending stress (see [2.5.9])

Y_d : Design factor (see [2.5.10])

Y_N : Life factor for bending stress (see [2.5.11])

$Y_{\delta relT}$: Relative notch sensitive factor (see [2.5.12])

Y_{RrelT} : Relative surface factor (see [2.5.13])

Y_X : Size factor (see [2.5.14])

S_F : Safety factor for tooth root bending stress (see [2.5.15]).

2.5.4 Tooth form factor Y_F *(1/7/2022)*

The tooth form factor Y_F takes into account the effect of the tooth form on the nominal bending stress assuming the load applied at the outer point of a single pair tooth contact.

In the case of helical gears, the form factors are to be determined in the normal section, i.e. for the virtual spur gear with the virtual number of teeth z_n.

Y_F is to be determined separately for the pinion and the wheel using the following formula:

$$Y_F = \frac{6 \cdot \frac{h_{Fe}}{m_n} \cdot \cos\alpha_{Fen}}{\left(\frac{s_{Fn}}{m_n}\right)^2 \cdot \cos\alpha_n}$$

where h_{Fe}, α_{Fen} and s_{Fn} are shown in Fig 1.

The parameters required for the calculation of Y_F are to be determined according to Method B of ISO 6336-3:2019.

2.5.5 Stress correction factor Y_S *(1/1/2015)*

The stress correction factor Y_S is used to convert the nominal bending stress.

Y_S is to be determined separately for the pinion and for the wheel.

Y_S is to be determined as follows:

$$Y_S = (1,2 + 0,13L) \cdot q_s^{\left(\frac{1}{1,21 + (2,3/L)}\right)}$$

where:

- $L = \frac{s_{Fn}}{h_{Fe}}$

  s_{Fn} and h_{Fe} are taken from [2.5.4]
- the notch parameter q_S as defined in [2.5.12] is assumed to be within the range $1 \leq q_s < 8$.

2.5.6 Helix angle factor Y_β *(1/1/2015)*

The helix angle factor Y_β converts the tooth root stress of a virtual spur gear to that of the corresponding helical gear, taking into account the oblique orientation of the lines of mesh contact.

Y_β is to be determined as follows:

- for $\varepsilon_\beta < 1$:

  $Y_\beta = 1 - \varepsilon_\beta (\beta/120)$
- for $\varepsilon_\beta > 1$:

  $Y_\beta = 1 - \beta/120$

Where $\beta > 30°$, the value $\beta = 30°$ is to be substituted for β in the above formulae.

2.5.7 Rim thickness factor Y_B *(1/1/2015)*

The rim thickness factor Y_B is a simplified factor used to de-rate thin rimmed gears. For critically loaded applications, this method should be replaced by a more comprehensive analysis.

Factor Y_B is to be determined as follows:

a) for external gears:
   - If $s_R / h \geq 1,2$

     $Y_B = 1$
   - if $0,5 < s_R / h < 1,2$

     $$Y_B = 1,6 \cdot \ln\left(2,242 \frac{h}{s_R}\right)$$

     where:

     s_R : Rim thickness of external gears, mm

     h : Tooth height, mm

     The case $s_R / h \leq 5,0$ is to be avoided.

b) for internal gears:
   - If $s_R / m_n \geq 3,5$

     $Y_B = 1$
   - if $1,75 < s_R / m_n < 3,5$

     $$Y_B = 1,15 \cdot \ln\left(8,324 \frac{m_n}{s_R}\right)$$

     where:

     s_R : Rim thickness of internal gears, mm

     The case $s_R / m_n \leq 1,75$ is to be avoided.

2.5.8 Deep tooth factor Y_{DT} *(1/1/2015)*

The deep tooth factor Y_{DT} adjusts the tooth root stress to take into account high precision gears and contact ratios within the range of virtual contact ratio $2,05 \leq \varepsilon_{\alpha n} \leq 2,5$, where:

$$\varepsilon_{\alpha n} = \frac{\varepsilon_{\alpha}}{\cos^2 \beta_b}$$

Factor Y_{DT} is to be determined as follows:

- if ISO accuracy grade ≤ 4 and $\varepsilon_{\alpha n} > 2,5$
  $Y_{DT} = 0,7$
- if ISO accuracy grade ≤ 4 and $2,05 \leq \varepsilon_{\alpha n} \leq 2,5$
  $Y_{DT} = 2,366 - 0,666\ \varepsilon_n$
- in all other cases
  $Y_{DT} = 1,0$

2.5.9 Endurance limit for tooth root bending stress σ_{FE} *(1/7/2022)*

The endurance limit for tooth root bending stress σ_{FE} is the local tooth root bending stress which can be permanently endured.

The bending endurance limit is to be determined, in general, according to ISO 6336-5:2016, for material quality MQ or as given in Tab 9 in relation to the type of steel employed.

Figure 1 : Geometric elements of teeth *(1/1/2001)*

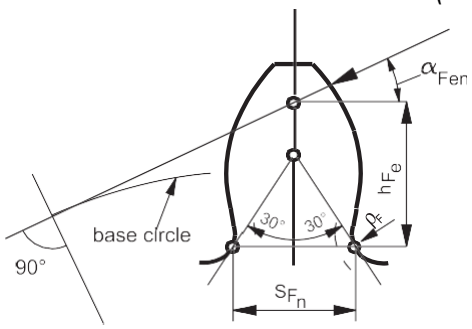


Table 9 : Values of endurance limit for tooth root bending stress σ_{FE} *(1/1/2001)*

Type of steel	σ_{FE}, in N/mm^2
Through-hardened carbon steel	0,17 R + 300 **(1)**
Through-hardened alloy steel	0,22 R + 340 **(1)**
Surface-hardened by means of flame or induction hardening	0,66 HV + 270
Nitriding steel, surface-hardened by means of gas nitriding	740
Alloy steels, surface-hardened by means of bath or gas nitriding	640 **(1)**
Case-hardened steels	840 **(1)**
(1) In case of shot peened tooth root the given value can be increased up to 20% for case hardened steels and up to 10% for through hardened steels.	

2.5.10 Design factor Y_d *(1/1/2001)*

The design factor Y_d takes into account the influence of load reversing and shrinkfit prestressing on the tooth root strength.

Y_d is to be determined as follows:

$$Y_d = Y_{dr} \cdot Y_{ds}$$

- for gears with occasional part load in reverse direction, such as main wheel in reverse gearboxes: $Y_{dr} = 0,9$
- for idler gears: $Y_{dr} = 0,7$
- otherwise $Y_{dr} = 1$
- for shrunk on pinions and wheel rims:

  $$Y_{ds} = 1 - \frac{\sigma_t}{\sigma_{FE}}$$

  where:

σ_t : shrinkage induced tangential stress in way of the tooth root.

- otherwise: $Y_{ds} = 1$

2.5.11 Life factor for bending stress Y_N *(1/7/2022)*

The life factor for bending stress Y_N accounts for the higher tooth root bending stress permissible if a limited life (number of cycles) is required.

Y_N assumed equal to Y_{NT} according to method B ISO 6336-3:2019 or assumed to be as follows:

- for gears intended for ahead running: $Y_N = 1$
- for gear intended for astern running only: $Y_N = 1,25$
- for other intermittent running, Y_N will be specially considered by the Society.

2.5.12 Relative notch sensitivity factor $Y_{\delta rel\ T}$ *(1/1/2015)*

The relative notch sensitivity factor $Y_{\delta rel\ T}$ indicates the extent to which the theorically concentrated stress lies above the fatigue endurance limit.

$Y_{\delta rel\ T}$ is to be determined as follows:

$$Y_{\delta relT} = \frac{1 + 0,2\sqrt{2\rho'(1 + 2q_s)}}{1 + \sqrt{1,2\rho'}}$$

where:

$$q_s = \frac{s_{Fn}}{2 \cdot \rho_F}$$

q_s : notch parameter

ρ' : slip-layer thickness, mm, taken from Tab 10

Table 10 *(1/1/2015)*

Material	ρ', in mm
Case hardened steels, flame or induction hardned steels	0,0030
through hardened steels **(1)**, yield point R_e =	
500 N/mm²	0,0281
600 N/mm²	0,0194
800 N/mm²	0,0064
1000 N/mm²	0,0014
nitrided steels	0,1005
(1) The given values of ρ' can be interpolated for values of R_e not stated above	

2.5.13 Relative surface factor $Y_{Rrel\ T}$ *(1/1/2015)*

The relative surface factor $Y_{Rrel\ T}$, takes into account the dependence of the root strength on the surface condition on the tooth root fillet, mainly the dependence on the peak to valley surface roughness.

The values to be adopted for $Y_{Rrel\ T}$ are given in Tab 11 in relation to the type of steel employed. They are valid only when scratches or similar defects deeper than 2 R_Z are not present.

Table 11 : Values of relative surface factor $Y_{Rrel\ T}$ *(1/1/2015)*

Material	$R_Z < 1$	$1 \le R_Z \le 40$
Case-hardened steels, through-hardened steels ($\sigma_B \ge 800$ N/mm²)	1,120	$1,674 - 0,529\ (R_Z + 1)^{0,1}$
Normalised steels ($\sigma_B < 800$ N/mm²)	1,070	$5,306 - 4,203\ (R_Z + 1)^{0,01}$
Nitrided steels	1,025	$4,299 - 3,259\ (R_Z + 1)^{0,0058}$

2.5.14 Size factor Y_X

The size factor Y_X takes into account the decrease of the strength with increasing size.

The values to be adopted for Y_X are given in Tab 12 in relation to the type of steel employed and the value of the normal module m_n.

Table 12 : Values of size factor Y_X *(1/1/2001)*

Type of steel	Normal module	Value of Y_X
All types of steel	$m_n \leq 5$	1
Normalised through-hardened	$5 < m_n < 30$	$1,03 - 0,006\ m_n$
	$m_n \geq 30$	0,85
Surface-hardened steels	$5 < m_n < 25$	$1,05 - 0,01\ m_n$
	$m_n \geq 25$	0,80

2.5.15 Safety factor for tooth root bending stress S_F

The values to be adopted for the safety factor for tooth root bending stress S_F are given in Tab 13.

Table 13 : Values of safety factor for tooth root bending stress S_F

Type of installation		S_F
Main gears (propulsion)	single machinery	1,55
	duplicate machinery	1,4
Auxiliary gears	single machinery	1,4
	duplicate machinery	1,3

3 Design and construction - except tooth load capacity

3.1 Materials

3.1.1 General

a) Forged, rolled and cast materials used in the manufacturing of shafts, couplings, pinions and wheels are to comply with the requirements of Part D.

b) Materials other than steels will be given special consideration by the Society.

3.1.2 Steels for pinions and wheel rims

a) Steels intended for pinions and wheels are to be selected considering their compatibility in service. In particular, for through-hardened pinion / wheel pairs, the hardness of the pinion teeth is to exceed that of the corresponding wheel. For this purpose, the minimum tensile strength of the pinion material is to exceed that of the wheel by at least 15 %.

b) The minimum tensile strength of the core is not to be less than:

- 750 N/mm^2 for case-hardened teeth
- 800 N/mm^2 for induction-hardened or nitrided teeth

3.2 Teeth

3.2.1 Manufacturing accuracy *(1/7/2023)*

a) The standard of accuracy of teeth of propulsion machinery gearing transmitting a power of 1000 kW and above is to correspond to that of quality class 4 as defined by ISO 1328-1:2013.

b) The standard of accuracy of teeth of propulsion machinery gearing transmitting a power lower than 1000 kW is to correspond to that of quality class 6 as defined by ISO 1328-1:2013.

c) A lower standard of accuracy (i.e. higher ISO quality classes) may be accepted for auxiliary machinery gearing and for particular cases of propulsion machinery gearing, subject to special consideration.

d) Mean roughness (peak-to-valley) of shaved or ground teeth is not to exceed 4 μm.

e) Wheels are to be cut by cutters with a method suitable for the expected type and quality. Whenever necessary, the cutting is to be carried out in a temperature-controlled environment.

3.2.2 Tooth root

Teeth are to be well faired and rounded at the root. The fillet radius at the root of the teeth, within a plane normal to the teeth, is to be not less than 0,25 m_n.

Profile-grinding of gear teeth is to be performed in such a way that no notches are left in the fillet.

3.2.3 Tooth tips and ends

a) All sharp edges on the tips and ends of gear teeth are to be removed after cutting and finishing of teeth.

b) Where the ratio b/d exceeds 0,3, the ends of pinion and wheel are to be chamfered to an angle between 45 and 60 degrees. The chamfering depth is to be at least equal to 1,5 m_n.

3.2.4 Surface treatment

a) The hardened layer on surface-hardened gear teeth is to be uniform and extended over the whole tooth flank and fillet.

b) Where the pinions and the toothed portions of the wheels are case-hardened and tempered, the teeth flanks are to be ground while the bottom lands of the teeth remain only case-hardened. The superficial hardness of the case-hardened zone is to be at least equal to 56 C Rockwell units.

c) Where the pinions and the toothed portions of the wheels are nitrided, the hardened layer is to comply with Tab 14.

d) The use of other processes of superficial hardening of the teeth, such as flame hardening, will be given special consideration, in particular as regards the values to be adopted for $\sigma_{H,lim}$ and σ_{FE}.

Table 14 : Characteristics of the hardened layer for nitrided gears

Type of steel	Minimum thickness of hardened layer (mm) **(1)**	Minimum hardness (HV)
Nitriding steel	0,6	500 (at 0,25 mm depth)
Other steels	0,3	450 (surface)

(1) Depth of the hardened layer to core hardness.
When the grinding of nitrided teeth is performed, the depth of the hardened layer to be taken into account is the depth after grinding.

3.3 Wheels and pinions

3.3.1 General

Wheel bodies are to be so designed that radial deflexions and distorsions under load are prevented, so as to ensure a satisfactory meshing of teeth.

3.3.2 Welding

a) Where welding is employed for the construction of wheels, the welding procedure is to be submitted to the Society for approval. Welding processes and their qualification are to comply with Part D.

b) Stress relieving treatment is to be performed after welding.

c) Examination of the welded joints is to be performed by means of magnetic particle or dye penetrant tests to the satisfaction of the Surveyor. Suitable arrangements are to be made to permit the examination of the internal side of the welded joints.

3.3.3 Shrink-fits *(1/1/2001)*

The shrink assembly of:

- rim and wheel body
- wheel body and shaft

is to be designed according to Sec 7.

3.3.4 Bolting *(1/1/2001)*

The bolting assembly of:

- rim and wheel body
- wheel body and shaft

is to be designed according to Sec 7.

The nuts are to be suitably locked by means other than welding.

3.4 Shafts and bearings

3.4.1 General

Shafts and their connections, in particular flange couplings and shrink-fits connections, are to comply with the provisions of Sec 7.

3.4.2 Pinion and wheel shafts *(1/7/2002)*

The minimum diameter of pinion and gear wheel shafts is not to be less than the value d_S, in mm, given by the following formula:

$$d_S = \left\{ \left[10{,}2 \left(\frac{28000}{R_{S,min}} \right) T \right]^2 + \left[\frac{170000}{412 + R_{s,min}} M \right]^2 \right\}^{\frac{1}{6}} \left(\frac{1}{1 - K_d^4} \right)^{\frac{1}{3}}$$

where:

$R_{S,min}$: minimum yield strength of the shaft material, in N/mm^2

T : nominal torque transmitted by the shaft, in Nm

M : bending moment on the shaft, in Nm

K_d : coefficient having the following values:

- for solid shafts: $K_d = 0$
- for hollow shafts, K_d is equal to the ratio of the hole diameter to the outer shaft diameter. Where $K_d \leq 0{,}3$: $K_d = 0$ may be taken.

Note 1: The values of d_S, T and M refer to the cross-section of the shaft concerned.

Note 2: In correspondence of keyways d_S shall be increased by 10%.

As an alternative to the above given formula, the Society may accept direct strength calculations showing that the equivalent stress represented in a diagram alternate stress/average stress falls below the lines defined by the points having coordinates:

$(R_m;0)$, $(0;\sigma_{fa}/1,5)$

and

$(0,8R_s;0)$, $(0;0,8R_s)$

where σ_{fa} is the pure alternate bending fatigue limit for a survival probability not less than 80%.

3.4.3 Quill shafts

The minimum diameter of quill shafts subject to torque only is not to be less than the value d_{QS}, in mm, given by the following formula:

$$d_{QS} = \left[\left(7{,}65 + \frac{27000}{R_{S,min}} \right) \cdot \frac{T}{1 - K_d^4} \right]^{\frac{1}{3}}$$

$R_{S,min}$ and K_d being defined in [3.4.2].

3.4.4 Bearings

a) Thrust bearings and their supports are to be so designed as to avoid detrimental deflexions under load.

b) Life duration of bearings L_{10h} calculed according to ISO 281-1, is not be less than 40000 hours. Shorter durations may be accepted on the basis of the actual load time distribution, and subject to the agreement of the owner.

3.5 Casings

3.5.1 General

Gear casings are to be of sufficient stiffness such that misalignment, external loads and thermal effects in all service conditions do not adversely affect the overall tooth contact.

3.5.2 Welded casings

a) Carbon content of steels used for the construction of welded casings is to comply with the provisions of Part D.

b) The welded joints are to be so arranged that welding and inspection can be performed satisfactorily. They are to be of the full penetration type.

c) Welded casings are to be stress-relieved after welding.

3.5.3 Openings

Access or inspection openings of sufficient size are to be provided to permit the examination of the teeth and the structure of the wheels.

3.6 Lubrication and clutch control

3.6.1 General

a) Manufacturers are to take care of the following points :
   - reliable lubrication of gear meshes and bearings is ensured :
     - over the whole speed range, including starting, stopping and, where applicable, manoeuvring
     - for all angles stated in Sec 1, [2.4]
   - in multi-propellers plants not fitted with shaft brakes, provision is to be made to ensure lubrication of gears likely to be affected by windmilling.

b) Lubrication by means other than oil circulation under pressure will be given special consideration.

3.6.2 Pumps *(1/7/2005)*

a) Gears intended for propulsion or other essential services are to be provided with:
   1) one main lubricating pump, capable of maintaining a sufficient lubrication of the gearbox in the whole speed range
   2) and one standby pump independently driven of at least the same capacity.
   3) an additional standby pump to the one required above, in case the failure of any pump prevents the propulsion from starting.

b) In the case of:
   1) gears having a transmitted power not exceeding 375 kW
   2) or multi-engines plants,

   one of the pumps mentioned in a) may be a spare pump ready to be connected to the reduction gear lubricating oil system, provided disassembling and reassembling operations can be carried out on board in a short time.

c) The requirements in a) 1), a) 2) and b) 1), b) 2) also apply to clutch control oil supply pumps.

   With reference to the requirements in a) 1) and a) 2), in case the failure of any pump prevents the operation of the clutch, an additional stand-by pump is to be fitted.

3.6.3 Filtration

a) Forced lubrication systems are to be fitted with a device which efficiently filters the oil in the circuit.

b) When fitted to gears intended for propulsion machinery or machinery driving electric propulsion generators, such filters are to be so arranged that they can be easily cleaned without stopping the lubrication of the machines.

3.7 Control and monitoring

3.7.1 *(1/7/2006)*

In addition to those of this item [3.7], the general requirements given in Chapter 3 apply.

In the case of ships with automation notations, the requirements in Part F, Chapter 3 also apply.

3.7.2 *(1/7/2006)*

Gears are to be provided with the alarms and safeguards listed in Tab 15.

Note 1: Some departures from Tab 15 may be accepted by the Society in the case of ships with a restricted navigation notation.

4 Installation

4.1 General

4.1.1 Manufacturers and shipyards are to take care directly that stiffness of gear seating and alignment conditions of gears are such as not to adversely affect the overall tooth contact and the bearing loads under all operating conditions of the ship.

4.2 Fitting of gears

4.2.1 Means such as stoppers or fitted bolts are to be arranged in the case of gears subject to propeller thrust. However, where the thrust is transmitted by friction and the relevant safety factor is not less than 2, such means may be omitted.

5 Certification, inspection and testing

5.1 General

5.1.1

a) Inspection and testing of shafts and their connections (flange couplings, hubs, bolts, pins) are to be carried out in accordance with the provisions of Sec 7.

b) For inspection of welded joints of wheels, refer to [3.3.2].

5.2 Workshop inspection and testing

5.2.1 Testing of materials

Chemical composition and mechanical properties are to be tested in accordance with the applicable requirements of Pt D, Ch 2, Sec 3 for the following items:

- pinions and wheel bodies
- rims
- plates and other elements intended for propulsion gear casings of welded construction.

5.2.2 Testing of pinion and wheel forgings

a) Mechanical tests of pinions and wheels are to be carried out in accordance with:
   - Pt D, Ch 2, Sec 3, [5.6] for normalised and tempered or quenched and tempered forgings
   - Pt D, Ch 2, Sec 3, [5.7] for surface-hardened forgings.

b) Non-destructive examination of pinion and wheel forgings is to be performed in accordance with Pt D, Ch 2, Sec 3, [5.8].

5.2.3 Balancing test

Rotating components, in particular gear wheel and pinion shaft assemblies with the coupling part attached, are to undergo a static balancing test.

Where $n^2.d \geq 1{,}5.10^9$, gear wheel and pinion shaft assemblies are also to undergo a dynamic balancing test.

5.2.4 Verification of cutting accuracy

Examination of the accuracy of tooth cutting is to be performed in the presence of the Surveyor. Records of measurements of errors, tolerances and clearances of teeth are to be submitted at the request of the Surveyor.

5.2.5 Meshing test

a) A tooth meshing test is to be performed in the presence of the Surveyor. This test is to be carried out at a load sufficient to ensure tooth contact, with the journals located in the bearings according to the normal running conditions. Before the test, the tooth surface is to be coated with a thin layer of suitable coloured compound.

b) The results of such test are to demonstrate that the tooth contact is adequately distributed on the length of the teeth. Strong contact marks at the end of the teeth are not acceptable.

c) A permanent record of the tooth contact is to be made for the purpose of subsequent checking of alignment following installation on board.

5.2.6 Hydrostatic tests

a) Hydraulic or pneumatic clutches are to be hydrostatically tested before assembly to 1,5 times the maximum working pressure of the pumps.

b) Pressure piping, pumps casings, valves and other fittings are to be hydrostatically tested in accordance with the requirements of Sec 10, [21].

Table 15 : Reduction gears / reversing gears and clutch monitoring *(1/7/2005)*

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
Lubricating oil temperature		local					
Lubricating oil pressure		local					
	L						
Oil tank level		local					
Clutch control oil pressure	L						

SECTION 7 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, turbines, gears and thrusters, see Sec 2, Sec 4, Sec 5, Sec 6 and Sec 12, respectively; for propellers, see Sec 8.

For vibrations, see Sec 9.

Additional requirements for navigation in ice are given in Pt F, Ch 9, Sec 3.

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 *(1/7/2006)*

In general, shafts are to be of forged steel having tensile strength, R_m, between 400 and 800 N/mm^2.

Where shafts may experience vibratory stresses close (i.e. higher than 80%) to the permissible stresses for transient operation, the materials are to have a specified minimum ultimate tensile strength (R_m) of 500 N/mm^2. Otherwise, materials having a specified minimum ultimate tensile strength (R_m) of 400 N/mm^2 may be used.

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	Sterntube
9	Details of sterntube glands
10	Oil piping diagram for oil lubricated propeller shaft bearings

No.	Document (drawings, calculations, etc.)
11	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 (see Sec 9), 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.

2.1.3 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 40m/s.

2.1.4 Coupling bolts *(1/7/2010)*

Coupling bolts are to be of forged, rolled or drawn steel.

2.1.5 Shaft liners

Liners are to be of metallic corrosion resistant material complying with the applicable requirements of Part D and with the approved specification, if any; in the case of liners fabricated in welded lengths, the material is to be recognised 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.

2.1.6 Sterntubes

Sterntubes are to comply with the requirements of Pt B, Ch 9, Sec 2, [6.7].

2.2 Shafts - Scantling

2.2.1 General *(1/7/2006)*

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.

Transitions of diameters are to be designed with either a smooth taper or a blending radius. For guidance, a blending radius equal to the change in diameter is recommended.

2.2.2 Intermediate and thrust shafts *(1/1/2017)*

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 $Q \leq 0,4$, $Q = 0$ 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 : • 95 for main propulsion systems powered by diesel engines fitted with slip type coupling, by turbines or by electric motors;

• 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 the Table, 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 is not to exceed the following:

- for carbon and carbon manganese steels, a minimum specified tensile strength not exceeding 760 N/mm^2
- for alloy steels, a minimum specified tensile strength not exceeding 800 N/mm^2.

Where materials with greater specified or actual tensile strengths than the limitations given above are used, reduced shaft dimensions are not acceptable when derived from the formula in this item [2.2.2] unless the Society verifies that the materials exhibit similar fatigue life as conventional steels (see Pt D, Ch 2, Sec 3, [3.8]).

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 [2.4.7] are to be applied.

Table 2 : Values of factor k *(1/7/2015)*

For intermediate shafts with					For thrust shafts external to engines	
integral coupling flange and straight sections	shrink fit coupling	keyways, tapered or cylindrical connection	radial hole	longitudinal slot	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 **(2)**	1,10 **(3) (4)**	1,10 **(5)**	1,20 **(6)**	1,10 **(1)**	1,10

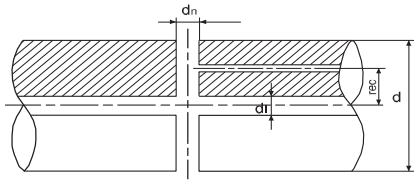
(1) Value applicable in the case of fillet radii in accordance with the provisions of [2.5.1].

(2) k refers to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2 % and a blending radius as described in [2.2.1].

(3) Keyways are, in general, not to be used in installations with a barred speed range.

(4) At 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.

(5) Value applicable in the case of diameter of radial bore d_h not exceeding 0,3 d, d being as defined in **(4)**.
Cases foreseeing intersection between a radial and an eccentric (r_{ec}) axial bore (see figure below) are specially considered by the Society.



(6) Subject to limitations: slot length (l)/outside diameter < 0,8, inner diameter (d_i)/outside diameter < 0,7 and slot width (e)/outside diameter > 0,15. The end rounding of the slot is not to be less than e/2. An edge rounding is preferably to be avoided as this increases the stress concentration slightly.The k values are valid for 1, 2 and 3 slots, i.e. with slots at, respectively, 360, 180 and 120 degrees apart.

Note 1: Explanation of k and C_K (for C_K see Sec 9, Tab 1)

The factors k (for low cycle fatigue) and C_K (for high cycle fatigue) take into account the influence of:

- the stress concentration factors (scf) relative to the stress concentration for a flange with fillet radius of 0,08 d (geometric stress concentration of approximately 1,45)

$$C_K = \frac{1,45}{scf} \quad \text{and} \quad k = \left(\frac{scf}{1,45}\right)^x$$

  where the exponent x considers low cycle notch sensitivity.
- the notch sensitivity. The chosen values are mainly representative for soft steels (R_m < 600), while the influence of steep stress gradients in combination with high strength steels may be underestimated.
- the fact that that the size factor c_D being a function of diameter only does not purely represent a statistical size influence, but rather a combination of this statistical influence and the notch sensitivity.

The actual values for k and C_K are rounded off.

Note 2: Stress concentration factor of slots

The stress concentration factor (scf) at the end of slots can be determined by means of the following empirical formulae using the symbols in **(4)**

$$scf = \alpha_{t(hole)} + 0,8 \cdot \frac{(l-e)/d}{\sqrt{\left(1-\frac{d_i}{d}\right)\cdot\frac{e}{d}}}$$

This formula applies to:

- slots at 120 or 180 or 360 degrees apart.
- slots with semicircular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula.
- slots with no edge rounding (except chamfering), as any edge rounding increases the scf slightly.

$\alpha_{t(hole)}$ represents the stress concentration of radial holes (in this context e = hole diameter) and can be determined as :

$$\alpha_{t(hole)} = 2,3 - 3 \cdot \frac{e}{d} + 15 \cdot \left(\frac{e}{d}\right)^2 + 10 \cdot \left(\frac{e}{d}\right)^2 \cdot \left(\frac{d}{d}\right)^2$$

or simplified to $\alpha_{t(hole)}$ = 2,3.

Note 3: The determination of k factors for shafts other than those provided in this table will be given special consideration by the Society.

2.2.3 Propeller shafts *(1/7/2006)*

For propeller shafts in general a minimum specified tensile strength R_m to be introduced in the following formula not exceeding 600 N/mm^2 is to be taken for carbon, carbon manganese and alloy steel.

Where materials with greater specified or actual tensile strengths than the limitations given above are used, reduced shaft dimensions are not acceptable when derived from the formula in this item [2.2.3].

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].

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 : k_P = 1,26, for propeller shafts where:

- the propeller is keyed on to the shaft taper in compliance with the requirements of [2.5.5]

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 Sec 8, [3.1.2], or the propeller boss is attached to an integral propeller shaft flange in compliance with [2.5.1]
- the sterntube of the propeller shaft is oil lubricated and provided with oil sealing glands approved by the Society or when the sterntube is water lubricated and the propeller shaft is fitted with a 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.

For the length of the propeller shaft between the forward edge of the aftermost shaft bearing and the forward edge of the forward sterntube seal:

- k_P = 1,15 is to be taken in any event.

2.2.4 Direct stress calculation method *(1/7/2006)*

Alternative calculation methods may be considered by the Society. Any alternative calculation method is to include all relevant loads on the complete dynamic shafting system under all permissible operating conditions. Consideration is to be given to the dimensions and arrangements of all shaft connections.

Moreover, an alternative calculation method is to take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and for peak operating loads (dimensioning for yield strength). The fatigue strength analysis may be carried out separately according to different criteria corresponding to different load assumptions, for example the following:

- low cycle fatigue criterion (typically lower than 10^4), i.e. the primary cycles represented by zero to full load and back to zero, including reversing torque if applicable
- high cycle fatigue criterion (typically much higher than 10^7), i.e. torsional vibration stresses permitted for continuous operation, reverse bending stresses and operation passing through a barred speed range or any other transient condition.

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 is to be not 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.

Between the sternbushes, the above thickness t may be reduced by 25%.

2.4 Aftmost propeller shaft bearings

The requirements in [2.4.1] to [2.4.5] are valid only for the aftmost propeller shaft bearing, next to and carrying the propeller, whether the bearing is in a stern tube or in a strut.

2.4.1 Oil lubricated bearings of antifriction metal

a) The length of bearings lined with white metal or other antifriction metal and with oil glands of a type approved by the Society is to be not less than twice the rule diameter of the shaft in way of the bearing.

b) The length of the bearing may be less than that given in (a) above, provided the nominal bearing pressure is not more than 0,8 N/mm^2, as determined by static bearing reaction calculations taking into account shaft and propeller weight, as exerting solely on the aft bearing, divided by the projected area of the shaft.

However, the minimum bearing length is to be not less than 1,5 times its actual inner diameter.

2.4.2 Oil lubricated bearings of synthetic rubber, reinforced resin or plastic materials *(1/1/2026)*

a) For bearings of synthetic rubber, reinforced resin or plastics material which are approved by the Society for use as oil lubricated sternbush bearings, the length of the bearing is to be not less than twice the rule diameter of the shaft in way of the bearing.

b) The length of the bearing may be less than that given in (a) above provided the nominal bearing pressure is not more than 0,6 N/mm^2, as determined according to [2.4.1] b).

However, the minimum length of the bearing is to be not less than 1,5 times its actual inner diameter.

Where the material has proven satisfactory testing and operating experience, consideration may be given to an increased bearing pressure.

c) Synthetic materials used for oil lubricated aftmost propeller shaft bearings are to be Type Approved.

The type approval requirements in this clause apply to all aftmost propeller shaft bearings made of synthetic materials.

d) For type approval testing requirements of synthetic material for the aftmost propeller shaft bearing, refer to App 19.

2.4.3 Water lubricated bearings of lignum vitae or antifriction metal

Where the bearing comprises staves of wood (known as "lignum vitae") or is lined with antifriction metal, the length of the bearing is to be not less than 4 times the rule diameter of the shaft in way of the bearing.

2.4.4 Water lubricated bearings of synthetic materials *(1/1/2026)*

a) 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 of synthetic material, 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, provided the bearing design and material is substantiated by experiments to the satisfaction of the Society.

c) Synthetic materials used for water lubricated aftmost propeller shaft bearings are to be Type Approved. The type approval requirements in this clause apply to all aftmost propeller shaft bearings made of synthetic materials.

d) For type approval testing requirements of synthetic material for the aftmost propeller shaft bearing, refer to App 19.

2.4.5 Grease lubricated bearings *(1/1/2021)*

The length of grease lubricated bearings is to be not less than 4 times the rule diameter of the shaft in way of the bearing.

2.4.6 Oil or grease lubrication system

a) For oil lubricated bearings, provision for oil cooling is to be made.

A gravity tank is to be fitted to supply lubricating oil to the sterntube; the tank is to be located above the full load waterline.

Oil sealing glands are to be suitable for the various sea water temperatures which may be encountered in service.

b) Grease lubricated bearings will be specially considered by the Society.

2.4.7 Water circulation system

For water lubricated bearings, means are to be provided to ensure efficient water circulation. In the case of bearings lined with "lignum vitae" of more than 400 mm in diameter and bearings lined with synthetic materials, means for forced water circulation are to be provided. In the case of bearings of synthetic materials, water flow indicators or pump outlet pressure indicators are to be provided.

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.

The shut-off valve or cock controlling the water supply is to be fitted direct to the stuffing box bulkhead or in way of the water inlet to the sterntube, when this is fitted forward of such bulkhead.

2.5 Couplings

2.5.1 Flange couplings *(1/7/2010)*

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.

Special consideration will be given by the Society to flanges having non-parallel faces, but in no case is the thickness of the flange to be less than the coupling bolt diameter.

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.

For non-solid forged flange couplings, the above fillet radius is not to cause a stress in the fillet higher than that caused in the solid forged flange as above.

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) Non-solid forged flange couplings and associated keys are to be of a strength equivalent to that of the shaft.

They are to be carefully fitted and shrunk on to the shafts, and the connection is to be such as to reliably resist the vibratory torque and astern pull.

d) 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, taking into account the ice strengthening requirements of Pt F, Ch 9, Sec 3, where applicable

n_B : Number of fitted coupling bolts

D_C : Pitch circle diameter of coupling bolts, in mm

R_m : Value of the minimum tensile strength of intermediate shaft material taken for calculation of d, in N/mm^2

R_{mB} : Tensile strength of the fitted coupling bolts material taken for calculation, in N/mm^2. The value of the tensile strength of the bolt material taken for calculation R_{mB} is to comply with the following requirements:

- $R_m \le R_{mB} \le 1{,}7\ R_m$
- $R_{mB} \le 1000$ N/mm^2

e) 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 above-mentioned: 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:

- 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 Sec 9.

2.5.2 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.

The value 2,8 above may be reduced to 2,5 in the cases specified under item e) of [2.5.1].

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.

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 under item e) of [2.5.1].

For the determination of the thrust, see Sec 8, [3.1.2].

2.5.3 Other couplings

Types of couplings other than those mentioned in [2.5.1] and [2.5.2] above will be specially considered by the Society.

2.5.4 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.

2.5.5 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.

When these constructional features are intended to obtain an extension of the interval between surveys of the propeller shaft in accordance with the relevant provisions of Pt A, Ch 2, Sec 2, [8.1], they are to be in compliance with Fig 1.

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.

b) The sectional area of the key subject to shear stress is to be not less than the value A, in mm^2, given by the following formula:

$$A = 0,4 \cdot \frac{d^3}{d_{PM}}$$

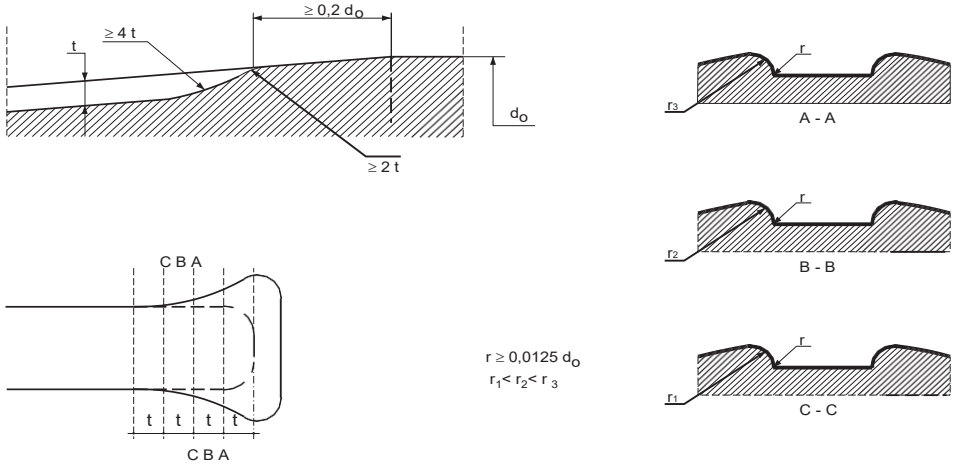
where:

d : Rule diameter, in mm, of the intermediate shaft calculated in compliance with the requirements of [2.2.2], assuming:

R_m = 400 N/mm^2

d_{PM} : Actual diameter of propeller shaft at mid-length of the key, in mm.

Figure 1 : Details of forward end of propeller shaft keyway



2.6 Control and monitoring

2.6.1 General *(1/7/2006)*

In addition to those given in this item [2.6], the requirements of Chapter 3 apply.

In the case of ships with automation notations, the requirements in Part F, Chapter 3 also apply.

2.6.2 Propeller shaft monitoring

For the assignment of the propeller shaft monitoring system notation, see Pt F, Ch 5, Sec 2.

2.6.3 Indicators *(1/7/2006)*

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. For monitoring of engines, turbines, gears, controllable pitch propellers and thrusters, see Sec 2, Sec 4, Sec 6, Sec 8 and Sec 12, respectively.

The indicators listed in Tab 3 are to be fitted at a normally attended position.

Note 1: Some departures from Tab 3 may be accepted by the Society in the case of ships with a restricted navigation notation

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.

Table 3 : Shafting of propulsion machinery *(1/7/2005)*

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		X				
Stern tube bush oil gravity tank level	L						

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 Definitions *(15/2/2024)*

a) Shaft alignment

Shaft alignment is the configuration of the shafts and bearings relative to the centerlines of the bearings from the theoretical straight-line condition, so that an acceptable bearing load distribution is achieved and satisfy the limits for: the bearing loading conditions, the shaft-bearing misalignment angles, the bending moments and shear force in the shafts, the stresses in the shaft, and other parameters imposed by designer, such as displacement of shafts in way of gears.

b) Shaft alignment optimization

Alignment optimization is a method to identify a condition (such as a set of bearing offsets) which, when applied in the dry dock or at the light ship draft condition produces the most favorable bearing load distribution for more than one alignment condition and will satisfy the bearing loading conditions, the limits prescribed by the Manufacturers of shaft line components including machineries and the limits stated in the Rules, in all service drafts of the vessel (e.g., from ballast to fully-laden).

For new vessels under construction to which shaft alignment optimization is foreseen by designers, the assignment of the additional class notation "Optimized Shaft Alignment" OSA or OSA-PR may be required.

c) Misalignment Angle (for bearing modeled as single point of support)

Misalignment angle is defined as the angle between the bearing axis and the tangent line to the shaft at the equivalent point of support. (See Fig 2)

d) Mean shaft misalignment (for bearing modeled as multiple point of support)

The Mean shaft misalignment angle (in radians) is defined as the difference between the displacement of the shaft centerline relative to the bearing centerline calculated at the aftmost point of support and the forwardmost point of support of the considered bearing divided by the bearing effective length.

3.3.2 Shaft alignment *(15/2/2024)*

The shaft alignment calculation is to be submitted for approval for all ships having propulsion shafting with turbines, direct coupled engines, or bearings with offsets from a reference line.

The Society may also require the above calculation and/or impose additional requirements in the case of non-conventional propulsion systems or arrangements which are considered critical (e.g. Propulsion shafting with no forward stern tube bearing).

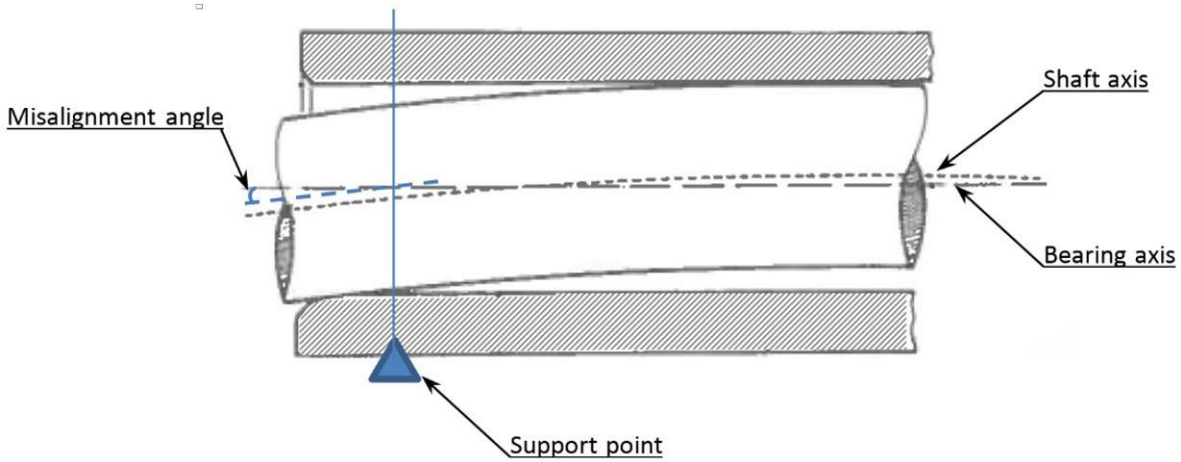
The calculation is to consider thermal, static and dynamic effects (e.g. external loads) and buoyancy effects in water on propeller and on shaft sections operating in water or oil; the results are to include the reaction forces of bearings, bending moments, shear stresses and other parameters (such as gap and sag of each flanged coupling or jacking loads) and instructions for the alignment procedure.

Bearings are to be modelled as follow:

a) For aftmost bearing:
   1) In case where only one support point is used, the axial position of the single point of support may vary and it is to be evaluated by the designer for each shaft alignment condition presented.
   2) In case where two support points are used, their locations are to be at each end of such bearings.
   3) In case of more than two support points are used, their locations are to be defined by designer, but one point of support is to be at each end of such bearings.

b) For other bearings, the location of the support point is to be at the mid-length of bearing.

Figure 2 : Misalignment angle *(15/2/2024)*



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.

Bearing reactions are to be always positive (i.e. pushing the shafts upward). If any shaftline bearing load is lower than 5% of manufacturer's maximum limits, whirling behavior are to be investigated in that condition.

Aftmost bearings with no-slope or single slope boring;

- if a single point of support is utilized for the bearing model, the misalignment angle between the propeller shaft and the aftmost bearing bush, (stern tube or strut), should not exceed 0.3mm/m or 0.3 mrad under all analyzed static conditions. The axial position of the single point of support may vary and it is to be appropriately evaluated for each shaft alignment condition presented. In case that the 0.3 mrad misalignment angle criterion cannot be met under a single-point-of-support bearing modelling then a multi-point of support bearing modelling and criteria are to be used.
- If the bearing is modelled as multi-point of support, the mean shaft misalignment is to be considered. For aftmost bearings modelled as multi-point of support, the mean shaft misalignment is not to exceed the minimum value between 0.3mm/m and the ratio of radial clearance divided by the bearing effective length.

Failing the above provisions, one of the following ways to reduce the shaft misalignment is to be adopted: bearing inclination or bearing having single-slope boring or bearing having multiple slope boring.

The slope boring angle calculation (for bearing having single or multiple slope boring) is to be based on a static afloat condition with a hot engine and fully immersed propeller.

Aft stern tube bearing with multiple slope boring is to have the aftmost transition point between two slopes located in between D/3 and L/4 distance from the aft bearing edge, where D is the actual shaft diameter and L is the actual length of aft stern tube bearing.

The slope design angles are to be such to result in heaviest reaction load at the point of the slope transition, and as close to zero load as possible at the aft and forward edge of the bearing.

In case aftmost sterntube bearings with multi-slope boring will be fitted, requirements related to calculation acceptance conditions and acceptance of the proposed alignment procedure will be stipulated on a case-by-case basis.

The alignment is to be checked on board by a suitable measurement method.

3.3.3 Optimized Shaft Alignment *(15/2/2024)*

Where one of the "Optimized Shaft Alignment" additional notations **OSA** or **OSA-PR** is requested, the requirements in TASNEEF "Guide for Optimized Shaft Alignment" are to be complied with, as applicable, in lieu of the above requirements.

4 Material tests, workshop inspection and testing, certification

4.1 Material and non-destructive tests, workshop inspections and testing

4.1.1 Material tests *(1/7/2006)*

Shafting components are to be tested in accordance with Tab 4 and in compliance with the requirements of Part D.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 4 and are to be effected in positions mutually agreed upon by the Manufacturer and the Surveyor, where experience shows defects are most likely to occur.

4.1.2 Hydrostatic tests

Parts of hydraulic couplings, clutches of hydraulic reverse gears and control units, hubs and hydraulic cylinders of controllable pitch propellers, including piping systems and associated fittings, are to be hydrostatically tested to1,5 times the maximum working pressure.

Sterntubes, when machine-finished, and 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 MPa.

4.2 Certification

4.2.1 Testing certification

Society's certificates (C) (see Pt D, Ch 1, Sec 1, [4.2.1]) are required for material tests of components in items 1 to 5 of Tab 4.

Works' certificates (W) (see Pt D, Ch 1, Sec 1, [4.2.3]) are required for hydrostatic tests of components indicated in [4.1.2] and for material and non-destructive tests of components in items of Tab 4 other than those for which Society's certificates (C) are required.

Table 4 : 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	-	-
9) Coupling bolts or studs	all	-	-
10) Flexible couplings (metallic parts only)	all	-	-
11) Thrust sliding-blocks (frame only)	all	-	-

SECTION 8 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 and controllable pitch propellers, including those ducted in fixed nozzles.

Additional requirements for navigation in ice are given in Pt F, Ch 9, Sec 3.

1.1.2 Manoeuvring thruster propellers *(1/7/2002)*

For manoeuvring thruster propellers see Sec 12.

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 Controllable pitch propellers

Controllable pitch propellers are built-up propellers which include in the hub a mechanism to rotate the blades in order to have the possibility of controlling the propeller pitch in different service conditions.

1.2.4 Nozzle

A nozzle is a circular structural casing enclosing the propeller.

1.2.5 Ducted propeller

A ducted propeller is a propeller installed in a nozzle.

1.2.6 Skewed propellers

Skewed propellers are propellers whose blades have a skew angle other than 0.

1.2.7 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°.

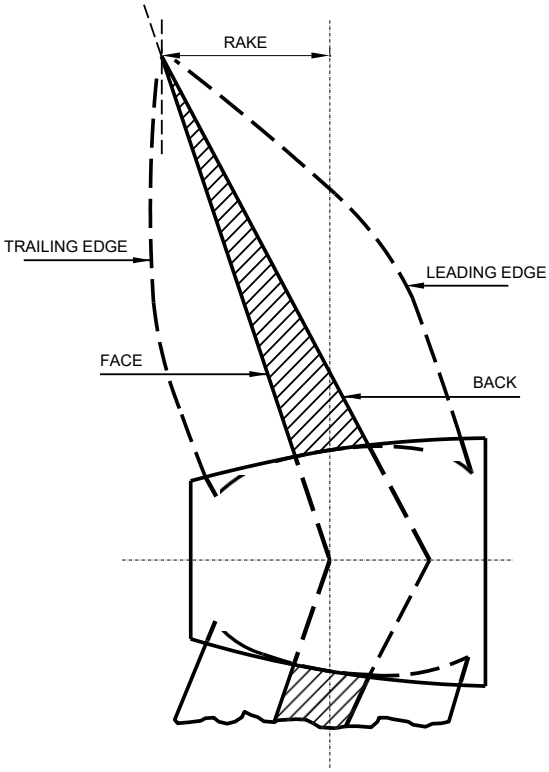
1.2.8 Leading edge

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).

1.2.9 Trailing edge

The trailing edge of a propeller blade is the edge of the blade opposite the leading edge (see Fig 1).

Figure 1 : Rake



1.2.10 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 and controllable pitch propellers

The documents listed in Tab 2, as applicable, are to be submitted for built-up and controllable pitch propellers intended for propulsion.

Table 2 : Documents to be submitted for built-up and controllable pitch propellers

No.	A/I **(1)**	ITEM
1	A/I	Same documents requested for solid propellers
2	A	Blade bolts and pre-tensioning procedures
3	I	Pitch corresponding to maximum propeller thrust and to normal service condition

No.	A/I **(1)**	ITEM
4	A	Pitch control mechanism
5	A	Pitch control hydraulic system
(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 [2.4.2]).

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 brass	400	8,3	7,6
Manganese brass (Cu1)	440	8,3	7,6
Nickel-manganese brass (Cu2)	440	8,3	7,9
Aluminium bronze (Cu3 and Cu4)	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 - Blade thickness

2.2.1 *(1/7/2002)*

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:

$$t_{0,25} = 3,2\left[f\cdot\frac{1,5.10^{6}.\rho.M_T + 51.\delta.\left(\frac{D}{100}\right)^3.B.I.N^2.h}{I\cdot z\cdot R_m}\right]^{0,5}$$

where:

f : Material factor as indicated in Tab 3

ρ : D/H

H : Mean pitch of propeller, in m. When H is not known, the pitch $H_{0.7}$ at 0,7 radius from the propeller axis, 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 : Expanded area ratio

h : Rake, in mm

l : Developed 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:

$$t_{0,6} = 1{,}9 \left[f \frac{1{,}5.10^6.\rho_{0,6}.M_T + 18{,}4.\delta.\left(\frac{D}{100}\right)^3.B.l.N^2.h}{l_{0,6}.z.R_m} \right]^{0,5}$$

where:

$\rho_{0,6}$: $D/H_{0.6}$

$H_{0.6}$: Pitch at 0,6 radius from the propeller axis, in m

$l_{0.6}$: Developed 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 ¾ of the required minimum thickness $t_{0,25}$. 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 to the above formulae, a detailed hydrodynamic load and stress analysis carried out by the propeller designer may be considered by the Society, on a case by case basis. The safety factor to be used in this analysis is not to be less than 8 with respect to the ultimate tensile strength of the propeller material R_m.

2.3 Built-up propellers and controllable pitch propellers

2.3.1 Blade thickness *(1/7/2002)*

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:

$$t_{0,35} = 2{,}7 \left[f \frac{1{,}5.10^6.\rho_{0,7}.M_T + 41.\delta\left(\frac{D}{100}\right)^3.B.l_{0,35}.N^2.h}{l_{0,35}.z.R_m} \right]^{0,5}$$

where:

$\rho_{0,7}$: $D/H_{0.7}$

$H_{0.7}$: Pitch at 0,7 radius from the propeller axis, in m. The pitch to be used in the formula is the actual pitch of the propeller when the propeller develops the maximum thrust.

$l_{0.35}$: Developed width of blade section at 0,35 radius from propeller axis, in mm.

b) The maximum thickness $t_{0.6}$, in mm, of the 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 ¾ of the required minimum thickness $t_{0,35}$. 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 to the above formulae, a detailed hydrodynamic load and stress analysis carried out by the propeller designer may be considered by the Society, on a case by case basis. The safety factor to be used in this analysis is not to be less than 8 with respect to the ultimate tensile strength of the propeller blade material R_m.

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:

$$D_F = D_C + 1{,}8d_{PR}$$

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.

2.3.3 Connecting studs *(1/7/2002)*

a) The diameter d_{PR}, in mm, at the bottom of the thread of the studs is not to be less than that obtained from the following formula:

$$d_{PR} = \left(\frac{4{,}6.10^{7}.\rho_{0,7}.M_T + 0{,}88.\delta.\left(\frac{D}{10}\right)^3.B.l_{0,35}^{2}.N.h_1}{n_{PR}\cdot z\cdot D_C\cdot R_{m,PR}} \right)^{0,5}$$

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, highly skewed propellers may be accepted on the basis of a stress analysis, as stated in [2.4.3] for very highly skewed propellers.

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 9 with respect to the ultimate tensile strength of the propeller blade material, R_m.

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.

2.6.2 Controllable pitch propellers pitch control system *(1/7/2006)*

a) The general requirements given in Sec 10, [14] apply.

b) Separate oil systems intended for the control of controllable pitch propellers are to include at least two power pumps, of such a capacity as to maintain normal control with any one pump out of action.

c) In the case of propulsion plants comprising:

- more than one shaft line with the propellers fitted with their own control system,
- or one engine with an output not exceeding 375 kW,

one of the pumps mentioned in b) may be a spare pump ready to be connected to the oil control system, provided disassembling and reassembling operations can be carried out on board in a short time.

d) However, when the propulsion plant comprises one or more engines, each with an output not exceeding 375 kW, the standby or spare pump may be omitted for the controllable pitch propellers provided that they are so designed as to be fixed mechanically in the "forward" position and that the capacity of the starting means ensures the numbers of starts required in such conditions.

e) Pitch control systems are to be provided with an engine room indicator showing the actual setting of the blades. Further blade position indicators are to be mounted on the bridge and in the engine control room, if any.

f) Suitable devices are to be fitted to ensure that an alteration of the blade setting cannot overload the propulsion plant or cause it to stall.

g) Steps are to be taken to ensure that, in the event of failure of the control system, the setting of the blades

- does not change, or
- assumes a final position slowly enough to allow the emergency control system to be put into operation.

h) Controllable pitch propeller systems are to be equipped with means of emergency control enabling the controllable pitch propeller to operate should the remote control system fail. This requirement may be complied with by means of a device which locks the propeller blades in the "ahead" setting.

i) Tab 4 indicates the monitoring requirements to be displayed at the control console. In addition, the general requirements given in Chapter 3 apply. In the case of ships with automation notations, the requirements in Part F, Chapter 3 also apply.

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.

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.

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 Sec 7, [2.5.5].

3.1.2 Shrinkage of keyless propellers *(1/7/2006)*

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 : $K = d_H/d_{PM}$

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 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: 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) 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.

d) The taper of the propeller shaft cone is not to exceed 1/15.

e) 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.

f) 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.

g) 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.

h) For the oil injection method, the coefficient of friction μ is to be 0,13 in the case of bosses made of copper-based alloy and steel. For other methods, the coefficient of friction will be considered in each case by the Society.

i) 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.

j) For the formulae given below, the material properties indicated in the following items are to be assumed:

- Modulus of elasticity, in N/mm²:
  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: ν = 0,29
  Cast iron: ν = 0,26
  All copper based alloys: ν = 0,33
- Coefficient of linear expansion in mm/(mm°C)
  Cast and forged steel and cast iron: $\alpha = 12{,}0\ 10^{-6}$
  All copper based alloys: $\alpha = 17{,}5\ 10^{-6}$

k) 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:

$W_T = Ap_T \cdot (\mu + \theta)$

- Maximum permissible surface pressure at 0°C:

$$p_{MAX} = \frac{0,7R_{S,MIN} \cdot (K^2 - 1)}{(3K^4 + 1)^{0,5}}$$

- Corresponding maximum permissible pull-up length at 0°C:

$$d_{MAX} = d_{35} \cdot \frac{p_{MAX}}{p_{35}}$$

- Tangential force at interface:

$$F = \frac{2000CM_T}{d_{PM}}$$

- 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. A description of the type of protection provided and its maintenance is to be kept on board.

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 Part D of the Rules in the presence of the Surveyor.

4.1.2 Built-up propellers and controllable pitch 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.

4.2.2 Controllable pitch propellers *(1/1/2025)*

The complete hydraulic system for the control of the controllable pitch propeller mechanism is to be hydrotested at a pressure equal to 1,5 times the design pressure. The proper operation of the safety valve is to be tested in the presence of the Surveyor.

For tests on board of control system of controllable pitch propellers see Sec 16, [3.9.6].

4.2.3 Balancing *(1/1/2009)*

Finished propellers are to be statically balanced. For built-up and controllable pitch propellers, the required static balancing of the complete propeller may be replaced by an individual check of blade weight and gravity centre position.

In addition, for propellers running above 500 rpm, dynamic balancing:

- is required, for cast copper alloy propellers
- may be required, for cast steel propellers.

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.

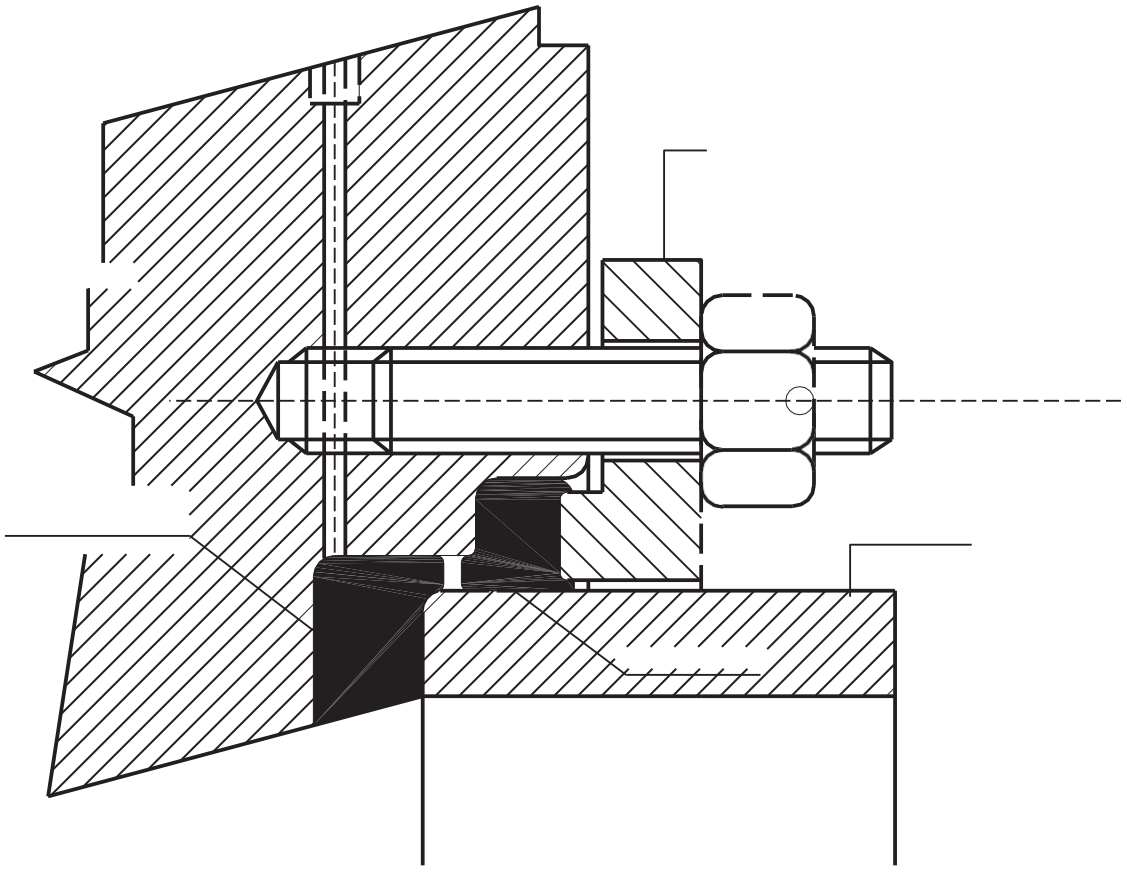
4.3.2 Mass produced propellers

Mass produced propellers may be accepted within the framework of the type approval program of the Society.

Table 4 : Controllable pitch propeller monitoring *(1/7/2005)*

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
Pump pressure	L						
Oil tank level	L						

Figure 2 : Example of sealing arrangement



SECTION 9 SHAFT VIBRATIONS

1 General

1.1 Application

1.1.1 The requirements of this Section 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.

1.1.2 **Exemptions** *(1/7/2015)*

The requirements of this Section may be waived at the Society's discretion in cases where satisfactory service operation of similar installations is demonstrated or in the case of ships classed for restricted navigation.

The requirements given in [3] may also be waived for ships fitted with two or more independent propulsion shaft lines, when the transmitted power per shaft line is below 2000 kW.

1.2 Submission of documentation

1.2.1 *(20/12/2005)*

As the analysis of the vibration behaviour of systems is part of their design, the relevant documentation, as listed in [3.2] is to be promptly submitted for approval.

2 Design of systems in respect of vibrations

2.1 Principle

2.1.1 General

a) Special consideration shall be given 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.

b) Calculations are to be carried out for all the configurations of the system likely to have any influence on the torsional, bending or axial vibrations.

c) Where torsional and axial vibrations may be coupled (e.g. due to helical gears), the effect of such vibrations is to be investigated.

2.1.2 Vibration levels

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 designer or 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.

2.1.3 **Condition of components** *(1/7/2002)*

Systems are to be designed considering essential components in a non-ideal condition. In particular, the following conditions are to be considered:

- propulsion 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.

2.2 Modifications of existing plants

2.2.1 Where substantial modifications of existing plants, such as:

- change of the running speed or power of the engine,
- replacement of an essential 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.

3 Torsional vibrations

3.1 General

3.1.1 The torsional vibration torques (or stresses) calculated in the various components of the installation are additional to those resulting from the mean power transmitted by such components. Where the scantling formulae given in Sec 7 and App 1 are applied, the vibratory torques are not to be taken into account unless otherwise stated.

3.2 Documentation to be submitted

3.2.1 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.

3.2.2 Particulars to be submitted

The following particulars are to be submitted with the torsional vibration calculations:

a) 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

b) for installations with controllable pitch propellers, the power/rotational speed values resulting from the combinator operation

c) for prime movers, the service speed range and the minimum speed at no load

d) 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 App 1.

e) 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)

f) for reduction or step-up gears, the speed ratio for each step

g) for flexible couplings, the data required in Note 2 of Sec 7, Tab 1

h) for torsional vibration dampers:

- the manufacturer and type
- the permissible heat dissipation
- the damping coefficient
- the inertial and stiffness properties, as applicable

i) for propellers:

- the number of blades
- the excitation and damping data, if available

j) for electric motors, generators and pumps, the drawing of the rotating parts, with their mass moment of inertia and main dimensions.

3.3 Definitions, symbols and units

3.3.1 Definitions

a) 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.

b) 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).

3.3.2 Symbols, units

The main symbols used in this Article are defined as follows:

τ : Torsional vibration stress, as defined in [3.3.1], 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:

$$0,35 + 0,93\ d^{-0,2}$$

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:

- $3 - 2\ \lambda^2$ for $\lambda < 0,9$
- 1,38 for $0,9 \leq \lambda \leq 1,05$

C_k : Factor depending on the shaft design features given in Tab 1.

Table 1 : Values of C_k factors *(1/7/2015)*

Intermediate shafts						Thrust shafts external to engines		Propeller shafts	
with integral coupling flanges and straight sections	with shrink-fit couplings	with keyways, tapered connection	with keyways, cylindrical connection	with radial holes	with longitudinal slots	on both sides of thrust collar	in way of axial bearing where a roller bearing is used as a thrust bearing	for which **(5)** k = 1,22 or k = 1,26	for which **(5)** k = 1,15
1,00 **(1)**	1,00 **(2)**	0,60 **(3)**	0,45 **(3)**	0,50	0,30 **(4)**	0,85	0,85	0,55	0,80

(1) Value applicable in the case of fillet radii in accordance with the provisions of Sec 7, [2.5.1].

(2) C_K refers to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2 % and a blending radius as described in Sec 7, [2.2.1]

(3) Keyways are, in general, not to be used in installations with a barred speed range.

(4) C_K = 0,3 is a safe approximation within the limitations in (6) of Sec 7, Tab 2. More accurate estimate of the stress concentration factor (scf) may be determined from Note 2 of Sec 7, Tab 2 or by direct application of FE calculation. In which case:

C_K = 1,45/scf

Note that the scf is defined as the ratio between the maximum local principal stress and $3^{0,5}$ times the nominal torsional stress (determined for the bored shaft without slots).

(5) k is defined in Sec 7.

Note 1: For explanation of c_K and stress concentration factor of slots, see Sec 7, Tab 2.

Note 2: The determination of C_K factors for shafts other than those given in this table will be given special consideration by the Society.

3.4 Calculation principles

3.4.1 Method

a) Torsional vibration calculations are to be carried out using a recognised method.

b) 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.

3.4.2 Scope of the calculations

a) Torsional vibration calculations are to be carried out considering:
- normal firing of all cylinders, and
- misfiring of one cylinder.

b) 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.

c) For installations with controllable pitch propellers, two calculations are to be carried out:
- one for full pitch condition
- one for zero pitch condition.

d) The calculations are to take into account all possible sources of excitation. Electrical sources of excitations, such as static frequency converters, are to be detailed.

e) 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.

3.4.3 Criteria for acceptance of the torsional vibration loads under normal firing conditions

a) Torsional vibration stresses in the various shafts are not to exceed the limits defined in [3.5]. Higher limits calculated by an alternative method may be considered, subject to special examination by the Society.

The limit for continuous running τ_1 may be exceeded only in the case of transient running in restricted speed ranges, which are defined in [3.5.5]. In no case are the torsional vibration stresses to exceed the limit for transient running τ_2.

Propulsion systems are to be capable of running continuously without restrictions at least within the speed range between 0,8 N_n and 1,05 N_n. Transient running may be considered only in restricted speed ranges for speed ratios $\lambda \leq 0,8$.

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 $\lambda \leq 0,95$.

b) Torsional vibration levels in other components are to comply with the provisions of [3.6].

3.4.4 Criteria for acceptance of torsional vibration loads under misfiring conditions *(1/7/2006)*

a) The provisions of [3.4.3] related to normal firing conditions also apply to misfiring conditions except that restricted speed ranges are also acceptable for $\lambda > 0,8$.

The restricted speed ranges in one-cylinder misfiring condition of single propulsion engine ships are to enable safe navigation.

b) 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 occurence of such conditions.

3.5 Permissible limits for torsional vibration stresses in crankshaft, propulsion shafting and other transmission shafting

3.5.1 General

a) 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.

b) These limits apply to the torsional vibration stresses as defined in [3.3.1]. They relate to the shaft minimum section, without taking account of the possible stress concentrations.

3.5.2 Crankshaft

a) Where the crankshaft has been designed in accordance with App 1, 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 [3.2.2], Note 1).

b) Where the crankshaft has not been designed in accordance with App 1, 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
- $\tau_2 = 2,3\ \tau_1$ for transient running.

3.5.3 Intermediate shafts, thrust shafts and propeller shafts *(1/7/2006)*

The torsional vibration stresses in any intermediate, thrust and propeller shafts are not to exceed the following limits:

- $\tau_1 = C_R \cdot C_k \cdot C_D \cdot C_\lambda$ for continuous running
- $\tau_2 = 1,7\ \tau_1 \cdot C_k^{-0,5}$ for steady state conditions within barred speed range.

Note 1: For intermediate, thrust and propeller shafts, the material factor C_R is not to be taken as greater than 42,2.

3.5.4 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
- $\tau_2 = 5,4\ \tau_1$ for transient running.

3.5.5 Restricted speed ranges *(1/7/2006)*

a) Where the stress amplitudes exceed the limiting values of τ_1 for continuous operation, including one cylinder misfiring conditions, restricted speed ranges are to be imposed which are to be passed through rapidly;

b) restricted speed ranges in one-cylinder misfiring conditions of single propulsion engine ships are to enable safe navigation;

c) the barred speed range is to cover all speeds where the acceptance limits (τ_1) are exceeded. For controllable pitch propellers with the possibility of individual pitch and speed control, both full and zero pitch conditions are to be considered.

Additionally, the tachometer tolerance is to be added. At each end of the barred speed range the engine is to be stable in operation;

d) the limits of the restricted speed range related to a critical speed N_c are to be calculated in accordance with the following formula:

$$\frac{16 \cdot N_c}{18 - \lambda} \leq N \leq \frac{(18 - \lambda) \cdot N_c}{16}$$

e) 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;

f) 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.

3.6 Permissible vibration levels in components other than shafts

3.6.1 Gears

a) 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.

Where the torque transmitted at nominal speed is less than that corresponding to the approved rating, higher torsional vibration torques may be accepted, subject to special consideration by the Society.

b) Gear hammering induced by torsional vibration torque reversal is not permitted throughout the service speed range, except during transient running at speed ratios $\lambda \leq 0,3$.

Where calculations show the existence of torsional vibration torque reversals for speed ratios $\lambda > 0,3$, the corresponding speed ranges are to be identified by appropriate investigations during sea trials and considered as restricted speed ranges in accordance with [3.5.5].

3.6.2 Generators

a) In the case of alternating current generators, the torsional vibration amplitude at the rotor is not to exceed $\pm 2,5$ electrical degrees at service rotational speed under full load working conditions.

b) 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 $\lambda \leq 0,95$: $M_A = \pm 6\ M_T$,

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 [3.3.2].

3.6.3 Flexible couplings

a) 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.

b) Flexible couplings fitted in generating sets are also to be capable of withstanding the torques and twist angles arising from transient criticals and short-circuit currents.

3.6.4 Dampers

a) Torsional vibration dampers are to be such that the permissible power loss recommended by the manufacturer is not exceeded throughout the service speed range.

b) Dampers for which a failure may lead to a significant vibration overload of the installation will be the subject of special consideration.

3.7 Torsional vibration measurements

3.7.1 General

a) The Society may require torsional vibration measurements to be carried out under its supervision 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.

b) Where measurements are required, a comprehensive report including the analysis of the results is to be submitted to the Society.

3.7.2 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 Lateral vibrations of main propulsion systems

4.1 General

4.1.1 *(20/12/2005)*

Main propulsion systems are to be free from excessive lateral vibration throughout the working speed range.

Failing this, provision is to be made to limit the vibration amplitudes by modifying the dynamic system or restricted speed ranges are to be imposed in the corresponding regions of speeds.

4.2 Calculations and measurements on board

4.2.1 *(20/12/2005)*

Unless previous experience of similar installations proves it to be unnecessary, the Society, on the basis of the characteristics of the main propulsion system concerned, reserves the right to require lateral vibration calculations to be submitted and/or measurements on board to be taken using an apparatus accepted by the Society.

5 Axial vibrations of main propulsion systems

5.1 General

5.1.1 *(20/12/2005)*

Main propulsion systems are to be free from excessive axial vibrations throughout the working speed range.

Failing this, provision is to be made to limit the vibration amplitudes by modifying the dynamic system, or restricted speed ranges are to be imposed in the corresponding regions of speeds.

5.2 Calculations and measurements on board

5.2.1 *(20/12/2005)*

Unless previous experience of similar installations proves it to be unnecessary, the Society, on the basis of the characteristics of the main propulsion system concerned, reserves the right to require axial vibration calculations to be submitted and/or measurements on board to be taken using an apparatus accepted by the Society.

SECTION 10 PIPING SYSTEMS

1 General

1.1 Application

1.1.1 *(1/1/2025)*

a) General requirements applying to all piping systems are contained in:
- [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
- [21] for their certification, inspection and testing.

b) Specific requirements for ship piping systems and machinery piping systems are given in Articles [6] to [19].

The requirements of this Section do not apply to the following piping systems:

a) Chemical cargo piping systems of ships subject to the IBC Code and shipboard hydrocarbon/chemical process piping system, for which the requirements in Pt E, Ch 8 applies

b) Gas cargo/fuel and process piping systems of ships, subject to the IGC Code and gas fuel piping systems of ships subject to the IGF Code, for which the requirements in Pt E, Ch 9 and App 7 respectively applies

c) Piping systems for other low flashpoint fuels defined in SOLAS II-1/2.29. for which the applicable requirements in the appendices of this chapter applies.

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 *(1/1/2026)*

No.	I/A **(1)**	Document **(2)**
1	A	Drawing showing the arrangement of the sea chests and ship side valves
2	A	Diagram of the bilge and ballast systems (in and outside machinery spaces)
3	A	Specification of the central priming system intended for bilge pumps, when provided
4	A	Diagram of the scuppers and sanitary discharge systems
5	A	Diagram of the air, sounding and overflow systems
6	A	Diagram of cooling systems (sea water and fresh water)
7	A	Diagram of fuel oil system
8	A	Drawings of the fuel oil tanks not forming part of the ship‘s structure
9	A	Diagram of the lubricating oil system
10	A	Diagram of the thermal oil system
11	A	Diagram of the hydraulic systems intended for essential services or located in machinery spaces
12	A	Diagram of steam system, including safety valve exhaust and drain pipes

(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.

No.	I/A **(1)**	Document **(2)**
13	A I	For high temperature steam pipes: • stress calculation note • drawing showing the actual arrangement of the piping in three dimensions
14	A	Diagram of the boiler feed water and condensate system
15	A	Diagram of the compressed air system
16	A	Diagram of the hydraulic and pneumatic remote control systems
17	A	Diagram of the remote level gauging system
18	I	Diagram of the exhaust gas system
19	A	Diagram of drip trays and gutterway draining system
20	A	Diagram of the oxyacetylene welding system
21	A	Drawings and specification of valves and accessories, where required in [2.7]
22	A	Diagram of the onboard carbon capture and storage system, drawings and documents referred to in Pt E, Ch 9, Sec 1, as applicable.
23	I	Risk Assessment of the onboard carbon capture and storage system

(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 *(1/7/2020)*

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	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
7	A	For fuel oil system: the diagram of the fuel oil system is to indicate the location of sampling points or a dedicated diagram of sampling points is to be presented together with the documentation relevant to the fuel system

(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 Chapter 1.

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 *(1/7/2006)*

Flammable oils include fuel oils, lubricating oils, thermal oils and hydraulic oils (having flashpoint lower than 150°C).

1.4 Symbols and units

1.4.1 The following symbols and related units are commonly used in this Section. Additional symbols, related to some formulae indicated in this Section, are listed wherever it is necessary.

p : Design pressure, in MPa

T : Design temperature, in °C

t : Rule required minimum thickness, in mm

D : Pipe external diameter, in mm.

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, heat treatment, welding, pressure testing and the certification of fittings.

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:

- cargo piping for oil tankers, gas tankers and chemical tankers, and
- fluids for refrigerating plants.

Table 3 : Class of piping systems *(1/1/2025)*

Media conveyed by the piping system	CLASS I	CLASS II	CLASS III
Fuel oil **(1)**	p > 1,6 or T > 150	other **(2)**	p ≤ 0,7 and T ≤ 60
Thermal oil	p > 1,6 or T > 300	other **(2)**	p ≤ 0,7 and T ≤ 150
Flammable Hydraulic oil **(5)**	p>1,6 or T>150	other **(2)**	p ≤ 0,7 and T≤60
Lubricating oil	p> 1,6 or T > 150	other **(2)**	p ≤ 0,7 and T ≤ 60
Other flammable media: • heated above flashpoint, or • having flashpoint <60°C (7)	without special safeguards **(3)**	with special safeguards **(3)**	
Oxyacetylene	irrespective of p		
Toxic media	irrespective of p, T		
Corrosive media	without special safeguards **(3)**	with special safeguards **(3)**	
Steam	p > 1,6 or T > 300	other **(2)**	p ≤ 0,7 and T ≤ 170
Air, gases, water, non-flammable hydraulic oil **(4)**, Urea for SCR systems (6)	p > 4 or T > 300	other **(2)**	p ≤ 1,6 and T ≤ 200
Open-ended pipes (drains, overflows, vents, exhaust gas lines, boiler escape pipes)			irrespective of T

(1) Valves under static pressure on fuel oil tanks belong to class II.

(2) Pressure and temperature conditions other than those required for class I and class III.

(3) Safeguards for reducing the possibility of leakage 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.

(4) Valves and fittings fitted on the ship side and collision bulkhead belong to class II.

(5) Steering gear piping belongs to class I irrespective of p and T

(6) When piping materials selected according to ISO 18611-3:2014 for Urea in SCR systems.

(7) Methyl/ethyl alcohol piping are to comply with the requirements in App 15, [7.3.2].

Note 1: p : Design pressure, as defined in [1.3.2], in MPa.

Note 2: T : Design temperature, as defined in [1.3.3], in °C.

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 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 Part D.

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 Part D.

2.1.3 Use of plastics

a) Plastics may be used for piping systems belonging to class III in accordance with App 3. 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 but, in any case, is not to be less than the minimum thickness given in Tab 5 to Tab 8.

$$t = \frac{t_0 + b + c}{1 - \frac{a}{100}}$$

where:

t_0 : Coefficient, in mm, equal to

$$t_0 = \frac{p \cdot D}{2Ke + p}$$

with:

p and 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 percentage:

- equal to 10 for copper and copper alloy pipes, cold drawn seamless steel pipes and steel pipes fabricated according to a welding procedure approved by the Society,
- equal to 12,5 for hot laminated seamless steel pipes,
- subject to special consideration by the Society in other cases.

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 4 : Conditions of use of metallic materials in piping systems *(1/7/2010)*

Material	Allowable classes	Maximum design temperature (°C) **(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	**(4)**
Copper-nickel	III, II, I	300	
Special high temperature resistant bronze	III, II, I	260	

(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 100000 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 grey cast iron is not allowed when the design pressure exceeds 1,3 MPa.

(6) Accessories of aluminium or aluminium alloys intended for flammable oil systems may be accepted subject to the satisfactory result of an endurance flame test to be carried out according to the "Rules for the type approval of flexible hoses and expansion joints" issued by the Society.

Note 1: On board oil tankers and chemical tankers aluminised pipes may be permitted in ballast tanks, in inerted cargo tanks and, provided the pipes are protected from accidental impact, in hazardous areas on open deck.

Material	Allowable classes	Maximum design temperature (°C) **(1)**	Particular conditions of use
Stainless steel	III, II, I	300	Austenitic stainless steel is not recommended for sea water systems
Spheroidal graphite cast iron	III, II	350	• Spheroidal cast iron of the ferritic type according to the material rules of the Society may be accepted for bilge, ballast and cargo oil piping • The use of this material for pipes, valves and fittings for other services, in principle Classes II and III, will be subject to special consideration • Spheroidal cast iron pipes and valves fitted on ship's side should have specified properties to the Society's satisfaction, according to the intention of Regulation 22 of the 1966 Convention on Load Lines • Minimum elongation is not to be less than 12% on a gauge length of $5,65.S^{0,5}$, where S is the actual cross-sectional area of the test piece
Grey cast iron	III II **(5)**	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 • parts of scuppers and sanitary discharge systems located next to the hull below the freeboard deck or for passengers ships below the bulkhead deck • ship side valves and fittings • valves fitted on the collision bulkhead • valves fitted to fuel oil and lubricating oil tanks under static pressure head • class II fuel oil systems • thermal oil systems
Aluminium and aluminium alloys	III, II, I **(6)**	200	Aluminium and aluminium alloys are not to be used on the following systems: • flammable oil systems **(6)** • 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 • scuppers and overboard discharges except for pipes led to the bottoms or to the shell above the freeboard deck or fitted at their upper end with closing means operated from a position above the freeboard deck • 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 100000 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 grey cast iron is not allowed when the design pressure exceeds 1,3 MPa.

(6) Accessories of aluminium or aluminium alloys intended for flammable oil systems may be accepted subject to the satisfactory result of an endurance flame test to be carried out according to the "Rules for the type approval of flexible hoses and expansion joints" issued by the Society.

Note 1: On board oil tankers and chemical tankers aluminised pipes may be permitted in ballast tanks, in inerted cargo tanks and, provided the pipes are protected from accidental impact, in hazardous areas on open deck.

Table 5 : Minimum wall thickness for steel pipes *(1/1/2009)*

External diameter (mm)	Minimum nominal wall thickness (mm)		Minimum reinforced wall thickness (mm) **(2)**	Minimum extra-reinforced wall thickness (mm) **(3)**
	Sea water pipes, bilge and ballast systems **(1)**	Other piping systems **(1)**		
10,2 - 12,0	-	1,6	-	-
13,5 - 19,3	-	1,8	-	-
20,0	-	2,0	-	-

External diameter (mm)	Minimum nominal wall thickness (mm)		Minimum reinforced wall thickness (mm) **(2)**	Minimum extra-reinforced wall thickness (mm) **(3)**
	Sea water pipes, bilge and ballast systems **(1)**	Other piping systems **(1)**		
21,3 - 25,0	3,2	2,0	-	-
26,9 - 33,7	3,2	2,0	-	-
38,0 - 44,5	3,6	2,0	6,3	7,6
48,3	3,6	2,3	6,3	7,6
51,0 - 63,5	4,0	2,3	6,3	7,6
70,0	4,0	2,6	6,3	7,6
76,1 - 82,5	4,5	2,6	6,3	7,6
88,9 - 108,0	4,5	2,9	7,1	7,8
114,3 - 127,0	4,5	3,2	8,0	8,8
133,0 - 139,7	4,5	3,6	8,0	9,5
152,4 - 168,3	4,5	4,0	8,8	11,0
177,8	5,0	4,5	8,8	12,7
193,7	5,4	4,5	8,8	12,7
219,1	5,9	4,5	8,8	12,7
244,5 - 273,0	6,3	5,0	8,8	12,7
298,5 - 368,0	6,3	5,6	8,8	12,7
406,4 - 457,2	6,3	6,3	8,8	12,7

(1) Attention is drawn to the special requirements regarding:

- bilge and ballast systems
- scupper and discharge pipes
- sounding, air and overflow pipes
- ventilation systems
- oxyacetylene welding systems
- cargo lines (see Pt E, Ch 10, Sec 3).

(2) Reinforced wall thickness applies to bilge, ballast, vent, overflow and sounding pipes passing through fuel tank and bilge, vent, overflow, sounding and fuel pipes passing through ballast tanks.

(3) Extra-reinforced wall thickness applies to pipes connected to the shell.

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: Where pipes and any integral pipe joints are protected against corrosion by means coating, lining, etc. at the discretion of the Society, thickness may be reduced by not more than 1 mm.

Note 3: The thickness of threaded pipes is to be measured at the bottom of the thread.

Note 4: The minimum thickness listed in this table is the nominal wall thickness and no allowance is required for negative tolerance or reduction in thickness due to bending.

Note 5: The minimum wall thickness for pipes larger than 450 mm nominal size is to be in accordance with a national or international standard and in any case not less than the minimum wall thickness of the appropriate column indicated for 450 mm pipe size.

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	0,8
12 - 20	1,2	1,0
25 - 44,5	1,5	1,2
50 - 76,1	2,0	1,5

External diameter (mm)	Minimum wall thickness (mm)	
	Copper	Copper alloy
88,9 - 108	2,5	2,0
133 - 159	3,0	2,5
193,7 - 267	3,5	3,0
273 - 457,2	4,0	3,5
470	4,0	3,5
508	4,5	4,0
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 stainless steel pipes *(1/1/2001)*

External diameter (mm)	Minimum wall thickness (mm)
up to 17,2	1,0
up to 48,3	1,6
up to 88,9	2,0
up to 168,3	2,3
up to 219,1	2,6
up to 273,0	2,9
up to 406,4	3,6
over 406,4	4
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 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 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 carbon and carbon-manganese steel pipes,
- in Tab 10 for alloy steel pipes, and
- in Tab 11 for copper and copper alloy pipes,

as a function of the temperature. Intermediate values may be obtained by interpolation.

b) Where, for carbon steel and alloy steel pipes, the value of the permissible stress K is not given in Tab 9 or Tab 10, it is to be taken equal to the lowest of the following values:

$$\frac{R_{m,20}}{2,7} \qquad \frac{R_e}{A} \qquad \frac{S_R}{A} \qquad S$$

where:

$R_{m,20}$: Minimum tensile strength of the material at ambient temperature (20°C), in N/mm²

R_e : Minimum yield strength or 0,2% proof stress at the design temperature, in N/mm²

S_R : Average stress to produce rupture in 100000 h at design temperature, in N/mm²

S : Average stress to produce 1% creep in 100000 h at design temperature, in N/mm²

A : Safety factor to be taken equal to:

- 1,6 when R_e and S_R values result from tests attended by the Society,
- 1,8 otherwise.

c) The permissible stress values adopted for materials other than carbon steel, alloy steel, copper and copper alloy will be specially considered by the Society.

2.2.3 Thickness reduction due to bending

a) Unless otherwise justified, the thickness reduction b due to bending is to be determined by the following formula:

$$b = \frac{Dt_0}{2,5\rho}$$

where:

ρ : Bending radius measured on the centre line of the pipe, in mm

D : as defined in [1.4.1]

t_0 : as defined in [2.2.1].

b) When the bending radius is not given, the thickness reduction is to be taken equal to:

$$\frac{t_0}{10}$$

c) For straight pipes, the thickness reduction is to be taken equal to 0.

2.2.4 Corrosion allowance

The values of corrosion allowance c are given for steel pipes in Tab 12 and for non-ferrous metallic pipes in Tab 13.

Table 9 : Permissible stresses for carbon and carbon-manganese steel pipes

Specified minimum tensile strength (N/mm²)	Design temperature (°C)												
	≤50	100	150	200	250	300	350	400	410	420	430	440	450
320	107	105	99	92	78	62	57	55	55	54	54	54	49
360	120	117	110	103	91	76	69	68	68	68	64	56	49
410	136	131	124	117	106	93	86	84	79	71	64	56	49
460	151	146	139	132	122	111	101	99	98	85	73	62	53
490	160	156	148	141	131	121	111	109	98	85	73	62	53

Table 10 : Permissible stresses for alloy steel pipes

Type of steel	Specified minimum tensile strength (N/mm²)	Design temperature (°C)									
		≤50	100	200	300	350	400	440	450	460	470
1Cr1/2Mo	440	159	150	137	114	106	102	101	101	100	99
2 1/4Cr1Mo annealed	410	76	67	57	50	47	45	44	43	43	42
2 1/4Cr1Mo normalised and tempered below 750°C	490	167	163	153	144	140	136	130	128	127	116
2 1/4Cr1Mo normalised and tempered above 750°C	490	167	163	153	144	140	136	130	122	114	105
1/2Cr 1/2Mo 1/4V	460	166	162	147	120	115	111	106	105	103	102

Type of steel	Specified minimum tensile strength (N/mm²)	Design temperature (°C)									
		480	490	500	510	520	530	540	550	560	570
1Cr1/2Mo	440	98	97	91	76	62	51	42	34	27	22
2 1/4Cr1Mo annealed	410	42	42	41	41	41	40	40	40	37	32
2 1/4Cr1Mo normalised and tempered below 750°C	490	106	96	86	79	67	58	49	43	37	32
2 1/4Cr1Mo normalised and tempered above 750°C	490	96	88	79	72	64	56	49	43	37	32
1/2Cr 1/2Mo 1/4V	460	101	99	97	94	82	72	62	53	45	37

Table 11 : Permissible stresses for copper and copper alloy pipes

Material (annealed)	Specified minimum tensile strength (N/mm²)	Design temperature (°C)										
		≤50	75	100	125	150	175	200	225	250	275	300
Copper	215	41	41	40	40	34	27,5	18,5				
Aluminium brass	325	78	78	78	78	78	51	24,5				
Copper-nickel 95/5 and 90/10	275	68	68	67	65,5	64	62	59	56	52	48	44
Copper-nickel 70/30	365	81	79	77	75	73	71	69	67	65,5	64	62

Table 12 : Corrosion allowance for steel pipes *(1/7/2001)*

Piping system	Corrosion allowance (mm)
Superheated steam	0,3
Saturated steam	0,8
Steam coils in cargo tanks and liquid fuel tanks	2,0
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
Thermal oil	1,0
Fresh water	0,8
Sea water	3,0
Refrigerants referred to in Section 13	0,3
Cargo systems for oil tankers	2,0
Cargo systems for ships carrying liquefied gases	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 may be reduced where pipes and any integral pipe joints are protected against corrosion by means of coating, lining, etc. **Note 3:** When the corrosion resistance of alloy steels is adequately demonstrated, the corrosion allowance may be disregarded.	

Table 13 : Corrosion allowance for non-ferrous metal pipes

Piping material **(1)**	Corrosion allowance (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.

2.2.5 Tees

As well as complying with the provisions of [2.2.1] to [2.2.4] above, the thickness t_T of pipes on which a branch is welded to form a Tee is not to be less than that given by the following formula:

$$t_T = \left(1 + \frac{D_1}{D}\right) \cdot t_0$$

where:

D_1 : External diameter of the branch pipe

D : as defined in [1.4.1]

t_0 : as defined in [2.2.1]

Note 1: This requirement may be dispensed with for Tees provided with a reinforcement or extruded.

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}, in N/mm^2, due to thermal expansion, calculated by the following formula:

$$\sigma_{ID} = (\sigma^2 + 4\tau^2)^{0,5}$$

is to be such as to satisfy the following equation:

$$\sigma_{ID} \leq 0,75K_{20} + 0,25K_T$$

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 *(1/7/2002)*

a) The number of joints in flammable oil piping systems is to be kept to the minimum necessary for mounting and dismantling purposes.

b) Direct connections of pipe lengths may be made by direct welding, flanges, threaded joints or mechanical joints, and are to be to a recognised standard or of a design proven to be suitable for the intended purpose and acceptable to the Society.

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] and [2.4.4] below.

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 App 3.

2.4.2 Welded connections *(1/7/2002)*

a) Welding and non destructive testing of welds are to be carried out in accordance with [3]. Welded joints are to be used in accordance with Tab 15.

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.

Butt welded joints with special provision for a high quality of root side may be used for piping of any Class and any outside diameter.

c) Slip-on sleeve and socket welded joints are to have sleeves, sockets and weldments of adequate dimensions conforming to a standard recognised by the Society.

2.4.3 Flange connections *(1/7/2002)*

a) The dimensions and configuration of flanges and bolts are to be chosen in accordance with a Standard recognised by the Society. This standard is to cover the design pressure and design temperature of the piping system.

b) For non-standard flanges the dimensions of flanges and bolts are subject to special consideration by the Society.

c) Flange material is to be suitable for the nature and temperature of the fluid, as well as for the material of the pipe on which the flange is to be attached.

d) Flanges are to be attached to the pipes by welding or screwing in accordance with one of the designs shown in Fig 1.

Permitted applications are indicated in Tab 14. However the Society may accept flange attachments in accordance with national or international standards that are applicable to the piping system and recognise the boundary fluids, design pressure and temperature conditions, external or cyclic loading and location.

2.4.4 Slip-on threaded joints *(1/1/2025)*

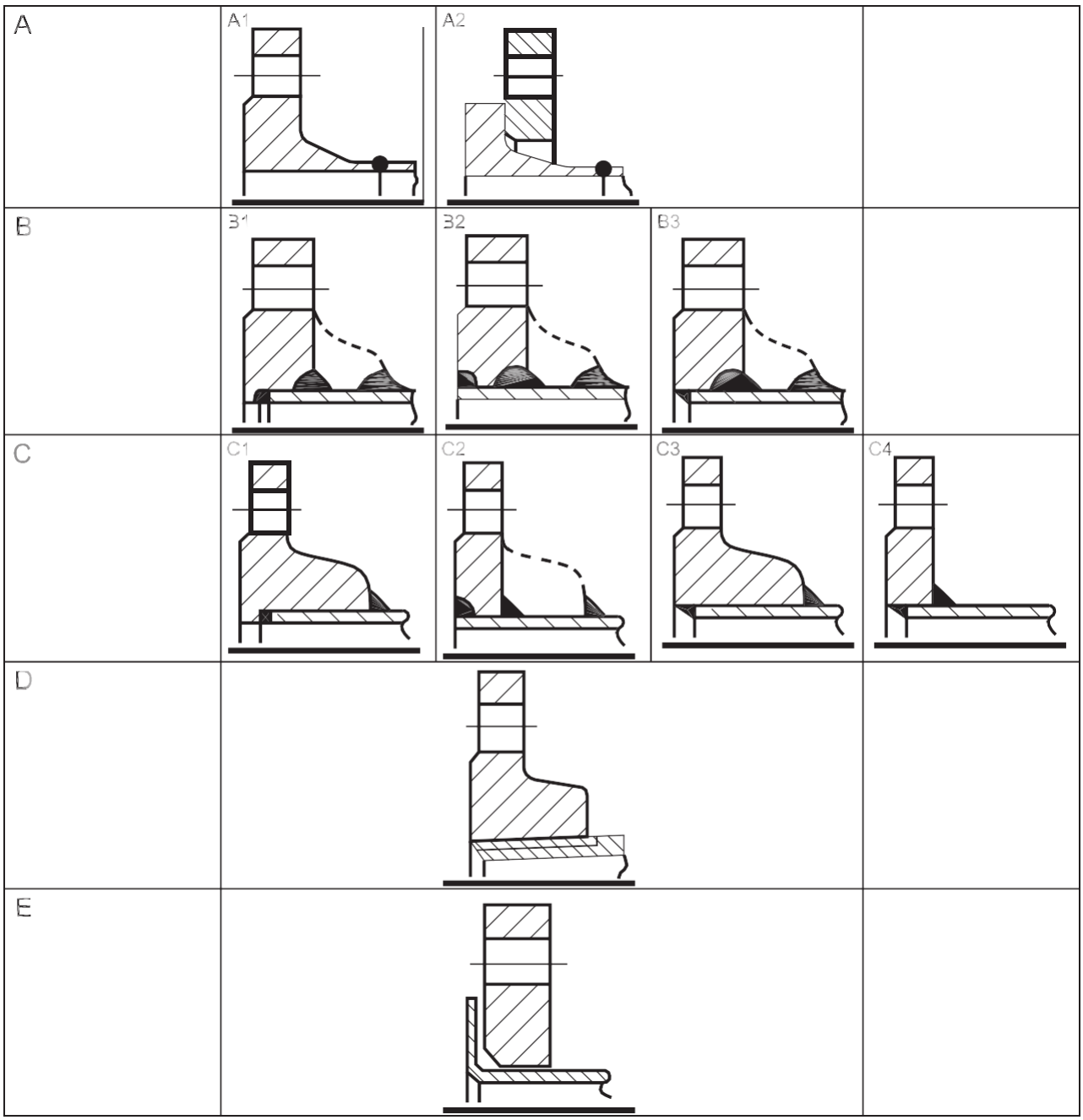
Slip-on threaded joints having pipe threads where pressure-tight joints are made on the threads with parallel or tapered threads, are to comply with requirements of a recognised national and/or international standard (see Note 1).

Slip-on threaded joints are to be used according to Tab 15.

Slip-on threaded joints may be used for connecting small bore instrumentation equipment (e.g., pressure/temperature sensors) to piping systems conveying flammable media if such connections comply with a recognized national and/or international standard (see Note 1). The use of such threaded joints is to be limited to outside diameters of maximum 25mm.

Note 1: Standards such as ASME B31.1 and ASME B31.3 may be referenced for the purpose.

Figure 1 : Types of metallic flange connections *(1/7/2002)*



Note 2: For type D, 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 3: For connections (C1), (C2), (C3) and (C4) the leg length of the fillet weld is to be in general equal to 1,5 times the pipe thickness but in no case is to be less than 6 mm.

Note 4: For connections (B1), (B2), (B3) and (C2) the dimension of the groove penetration in the flange is to be in general equal to the pipe thickness but in no case is to be less than 5 mm.

Table 14 : Types of flange connections required in relation to the class of piping and the type of media conveyed (1) *(1/7/2006)*

Class of piping → **Type of media conveyed ↓**	**Class I**	**Class II**	**Class III**
Toxic or corrosive media, flammable liquid media or liquefied gases	(A1)-(A2)-(B1)-(B2)-(B3) **(2) (3) (4)**	(A1)-(A2)-(B1)-(B2)-(B3)-(C1)- (C2)-(C3) **(2) (4)**	(A1)-(A2)-(B1)-(B2)-(B3) -(C1)- (C2)-(C3) **(2) (4)**
Lubricating and fuel oil	(A1)-(A2)-(B1)-(B2)-(B3)	(A1)-(A2)-(B1)-(B2)-(B3) -(C1)- (C2)-(C3)-(C4) **(5)**	(A1)-(A2)-(B1)-(B2)-(B3) -(C1)- (C2)-(C3)-(C4)
Steam and thermal oil	(A1)-(A2)-(B1)-(B2)-(B3) **(3) (6)**	(A1)-(A2)-(B1)-(B2)-(B3) -(C1)- (C2)-(C3)-(C4)-(D) **(7)**	(A1)-(A2)-(B1)-(B2)-(B3) -(C1)- (C2)-(C3)-(C4)-(D)
Other media, including water, air, gases, refrigerants, non flammable hydraulic oil **(8)**	(A1)-(A2)-(B1)-(B2)-(B3) **(6)**	(A1)-(A2)-(B1)-(B2)-(B3) -(C1)- (C2)-(C3)-(C4)-(D) **(7)**	(A1)-(A2)-(B1)-(B2)-(B3) -(C1)- (C2)-(C3)-(C4)-(D)-(E) **(9)**

(1) The types of flange connections given in the Table are those shown in Fig 1.

(2) Only type (A1) and (A2) flange connections are to be adopted for piping conveying flammable, toxic or corrosive liquid media or liquefied gases having a design pressure **p** (see item [1.3.2]) higher than 1 N/mm^2.

(3) For piping having a nominal diameter equal to or greater than 150 mm, only type (A1) and (A2) flange connections are to be adopted.

(4) For the cargo piping of chemical carriers the provisions of IBC Code Ch. 5, 5.3 apply. For the cargo piping of gas carriers, the provisions of IGC Code Ch. 5, 5.4 apply.

(5) Flange connections of type (C4) are only acceptable for piping having a design pressure **p** less than 1,6 N/mm^2 and design temperature **T** (see item [1.3.3]) less than 150°C.

(6) Only type (A1) and (A2) flange connections are to be adopted for piping having a design temperature **T** higher than 400°C.

(7) Flange connections of types (D) and (C4) are not acceptable for piping having a design temperature **T** exceeding 250°C.

(8) For piping of hydraulic power plants of steering gears, only flange connections of types required for Class I piping are to be used.

(9) Flange connections of type (E) are only acceptable for water piping and open ended lines (e.g. drain, overflow, air vent piping, etc.).

Table 15 : Use of welded and threaded metallic joints in piping systems *(1/7/2002)*

	Permitted classes of piping	Restrictions of use
Butt-welded joint **(1)**	III, II, I	no restrictions
Slip-on sleeve joint **(2)**	III	no restrictions
Sleeve threaded joint (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.
	II, 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.

	Permitted classes of piping	Restrictions of use
Sleeve threaded joint (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) Welded butt-joints without special provisions for root side may be used for Classes II and III, any outside diameter.

(2) In particular cases, slip- on sleeve and socket welded joints 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 in compliance with a recognised national and/or international standard.

2.4.5 Mechanical joints *(1/1/2025)*

Due to the great variations in design and configuration of mechanical joints, no specific recommendation regarding the method for theoretical strength calculations is given in these requirements. The mechanical joints are to be type approved by the Society according to the "Rules for the type approval of mechanical joints for pipes".

These requirements are applicable to pipe unions, compression couplings and slip-on joints as shown in Fig 2. Similar joints complying with these requirements may be acceptable.

The application and pressure ratings of different mechanical joints are to be approved by the Society.

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.

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.

Material of mechanical joints is to be compatible with the piping material and internal and external media.

Mechanical joints are to be tested where applicable, to a burst pressure of 4 times the design pressure.

For design pressures above 20 MPa the required burst pressure will be specially considered by the Society.

Where appropriate, mechanical joints are to be of fire-resistant type as required by Tab 16.

Mechanical joints which in the event of damage could cause fire or flooding are not to be used in piping sections directly connected to ship's side below the bulkhead deck of passenger ships and freeboard deck of cargo ships or tanks containing flammable fluids.

The number of mechanical joints in flammable fluid systems is to be kept to a minimum. In general, flanged joints conforming to recognised standards are to be used.

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.

Slip-on joints are not to be used in pipelines in cargo holds, tanks, and other spaces which are not easily accessible (refer to MSC/Circ.734), except that these joints may be permitted in tanks that contain the same media.

Usage of slip type slip-on joints as the main means of pipe connection is not permitted except for cases where compensation of axial pipe deformation is necessary.

Application of mechanical joints and their acceptable use for each service are indicated in Tab 16; dependence upon the Class of piping and pipe dimensions are indicated in Tab 17.

In particular, Tab 16 indicates systems where the various kinds of joints may be accepted. However, in all cases, acceptance of the joint type is to be subject to approval of the intended application, and subject to conditions of the approval and applicable requirements. Further, relevant statutory requirements are to be taken into consideration. In cases exposure time (t_T) is greater than 30 minutes the dry-wet test conditions are 8 minutes dry and, accordingly, the wet period t_T-8 min.

In particular cases, sizes in excess of those mentioned above may be accepted if in compliance with a national and/or international standard recognised by the Society.

Mechanical joints are to be tested in accordance with a program approved by the Society, which is to include at least the following:

a) leakage test

b) vacuum test (where necessary)

c) vibration (fatigue) test

d) fire endurance test (where necessary)

e) burst pressure test

f) pressure pulsation test (for Class I and II mandatory, for Class III where necessary)

g) assembly test (where necessary)

h) pull out test (where necessary).

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 *(1/1/2020)*

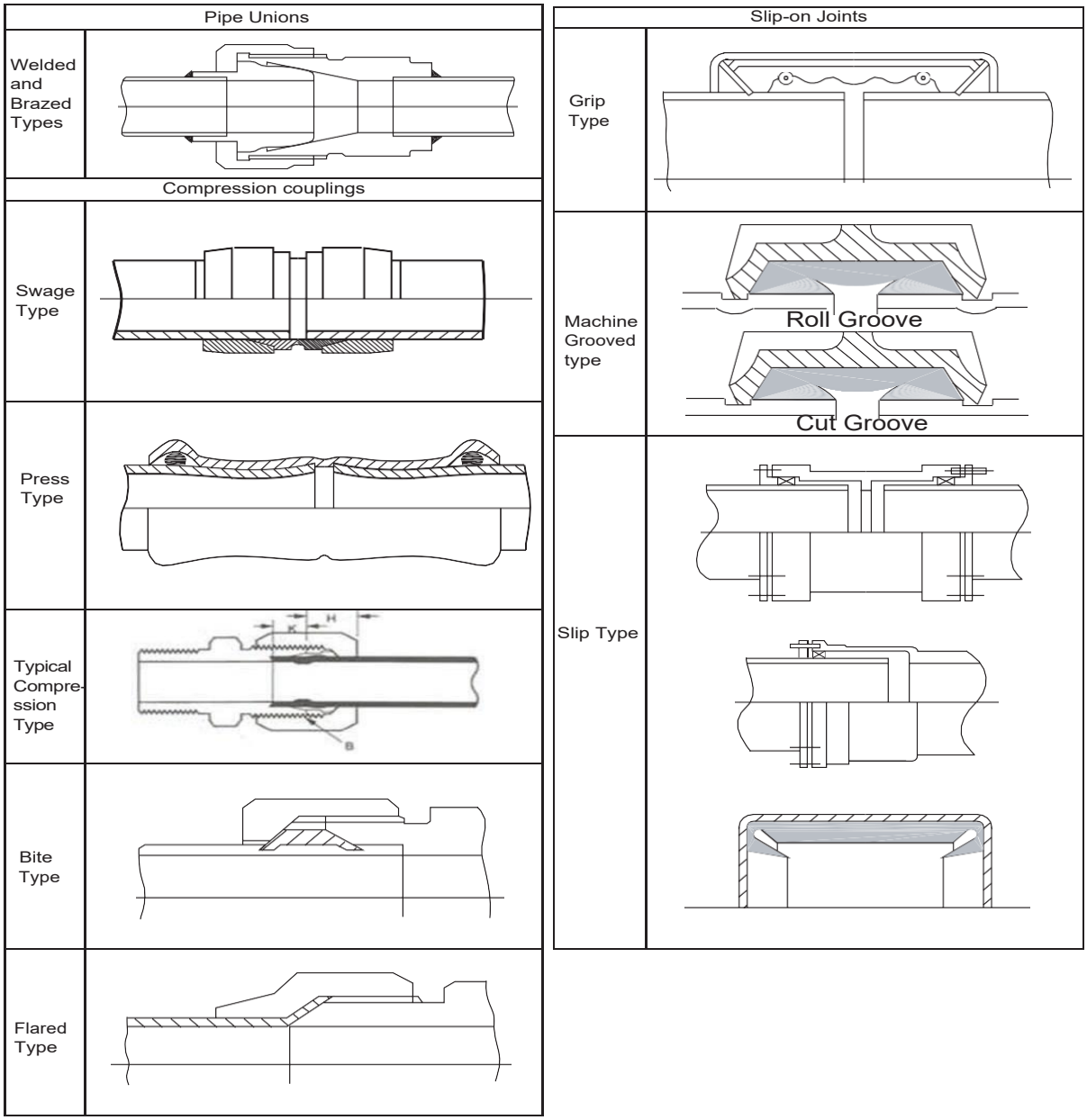


Table 16 : Application of mechanical joints *(1/7/2022)*

Systems		Kind of connections			Classification of pipe system	Fire endurance test condition[7]
		Pipe Unions	Compression Couplings	Slip-on Joints		
Flammable fluids (Flash point ≤ 60°)						
1	Cargo oil lines **(1)**	+	+	+	dry	30 min dry (*)
2	Crude oil washing lines **(1)**	+	+	+	dry	
3	Vent lines **(3)**	+	+	+	dry	
Inert gas						
4	Water seal effluent lines	+	+	+	wet	30 min wet (*)
5	Scrubber effluent lines	+	+	+	wet	30 min wet (*)
6	Main lines **(1) (2)**	+	+	+	dry	30 min dry (*)
7	Distributions lines **(1)**	+	+	+	dry	30 min dry (*)
Flammable fluids (Flash point > 60°)						
8	Cargo oil lines **(1)**	+	+	+	dry	30 min dry (*)
9	Fuel oil lines **(2) (3)**	+	+	+	wet	30 min wet (*)
10	Lubricating oil lines **(2) (3)**	+	+	+	wet	30 min wet (*)
11	Hydraulic oil **(2) (3)**	+	+	+	wet	30 min wet (*)
12	Thermal oil **(2) (3)**	+	+	+	wet	30 min wet (*)
Sea Water						
13	Bilge lines **(4)**	+	+	+	dry/wet	8 min dry + 22 min wet (*)
14	Permanent Water filled fire extinguishing systems, e.g. fire main, sprinkler systems **(3)**	+	+	+	wet	30 min wet (*)
15	Non-permanent water filled fire extinguishing systems, e.g. foam, drencher systems and fire main **(3)**	+	+	+	dry/wet	8 min dry + 22 min wet (*) For foam systems FSS CodeChapter 6 to be observed
16	Ballast system **(4)**	+	+	+	wet	30 min wet (*)
17	Cooling water system **(4)**	+	+	+	wet	30 min wet (*)
18	Tank cleaning services	+	+	+	dry	Fire endurance test not required
19	Non-essential systems	+	+	+	dry dry/wet wet	Fire endurance test not required
Fresh water						
20	Cooling water system **(4)**	+	+	+	wet	30 min wet (*)

Abbreviations:

+ Application is allowed

- Application is not allowed

* Fire endurance test as specified in [5.5.6] of the Rules for the Type Approval of Mechanical Joints for Pipes

Footnotes - Table 16 - Fire resistance capability

If mechanical joints include any components which readily deteriorate in case of fire the following footnotes are to be observed:

(1) Fire endurance test is to be applied when mechanical joints are installed in pump rooms and open decks.

(2) Slip on joints are not accepted inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions (refer to MSC/Circ.734).

(3) Approved fire-resistant types except in cases where such mechanical joints are installed on open decks, as defined in SOLAS II-2/Reg. 9.2.3.3.2.2(10) and not used for fuel oil lines.

(4) Fire endurance test is to be applied when mechanical joints are installed inside machinery spaces of category A.

Footnotes - Table 16 - General

(5) Only above bulkhead deck of passenger ships and freeboard deck of cargo ships.

(6) Slip type slip-on joints as shown in Table 16. May be used for pipes on deck with a design pressure of 10 bar or less.

(7) If a connection has passed the "30 min dry" test, it is considered suitable also for applications for which the "8 min dry+22 min wet" and/or "30 min wet " tests are required. If a connection has passed the "8 min dry+22 min wet" test, it is considered suitable also for applications for which the "30 min wet" test is required.

Systems		Kind of connections				
		Pipe Unions	Compression Couplings	Slip-on Joints	Classification of pipe system	Fire endurance test condition[7]
21	Condensate return **(4)**	+	+	+	wet	30 min wet (*)
22	Non-essential system	+	+	+	dry dry/wet wet	Fire endurance test not required
	Sanitary/Drains/Scuppers					
23	Deck drains (internal) **(5)**	+	+	+	dry	Fire endurance test not required
24	Sanitary drains	+	+	+	dry	
25	Scuppers and discharge (overboard)	+	+	-	dry	
	Sounding/Vent					
26	Water tanks/Dry spaces	+	+	+	dry, wet	Fire endurance test not required
27	Oil tanks (f.p.> 60°C) **(2) (3)**	+	+	+	dry	
	Miscellaneous					
28	Starting/Control air **(4)**	+	+	-	dry	30 min dry (*)
29	Service air (non-essential)	+	+	+	dry	Fire endurance test not required
30	Brine	+	+	+	wet	
31	CO_2 system (outside protected space)	+	+	-	dry	30 min dry (*)
32	CO_2 system (inside protected space)	+	+	-	dry	Mechanical joints are to be constructed of materials with melting point above 925°C. Ref. to FSS Code Chapter 5.
33	Steam	+	+	+ **(6)**	wet	Fire endurance test not required

Abbreviations:

+ Application is allowed

- Application is not allowed

* Fire endurance test as specified in [5.5.6] of the Rules for the Type Approval of Mechanical Joints for Pipes

Footnotes - Table 16 - Fire resistance capability

If mechanical joints include any components which readily deteriorate in case of fire the following footnotes are to be observed:

(1) Fire endurance test is to be applied when mechanical joints are installed in pump rooms and open decks.

(2) Slip on joints are not accepted inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions (refer to MSC/Circ.734).

(3) Approved fire-resistant types except in cases where such mechanical joints are installed on open decks, as defined in SOLAS II-2/Reg. 9.2.3.3.2.2(10) and not used for fuel oil lines.

(4) Fire endurance test is to be applied when mechanical joints are installed inside machinery spaces of category A.

Footnotes - Table 16 - General

(5) Only above bulkhead deck of passenger ships and freeboard deck of cargo ships.

(6) Slip type slip-on joints as shown in Table 16. May be used for pipes on deck with a design pressure of 10 bar or less.

(7) If a connection has passed the "30 min dry" test, it is considered suitable also for applications for which the "8 min dry+22 min wet" and/or "30 min wet " tests are required. If a connection has passed the "8 min dry+22 min wet" test, it is considered suitable also for applications for which the "30 min wet" test is required.

Table 17 : Application of mechanical joints depending upon the class of piping *(1/1/2025)*

Types of joints	Classes of piping systems		
	Class I	Class II	Class III
Pipe Unions			
Welded and brazed type	yes (outside diameter ≤ 60.3mm)	yes (outside diameter ≤ 60.3mm)	yes
Compression Couplings			
Swage type	yes	yes	yes
Bite type Typical compression type Flared type	yes yes yes	yes yes yes	yes yes yes
Press type	not	not	yes
Slip-on joints			
Machine grooved type	yes	yes	yes
Grip type	not	yes	yes
Slip type	not	yes	yes
yes means application is allowed not means 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 Sec 3, [2.4].

b) Safety valves are to be sealed after setting.

2.5.2 Protection of flammable oil systems *(1/7/2002)*

Provisions shall be made to prevent overpressure in any flammable oil tank or in any part of the flammable oil systems, including the filling pipes served by pumps on board.

2.5.3 Protection of pump and compressor discharges *(1/1/2026)*

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.

d) All positive displacement pumps which are capable of developing a pressure exceeding the design pressure of the system should be provided with relief valves. Each relief valve should be so arranged as to discharge back to the suction side of the pump/piping system or to a tank as appropriate, and to effectively limit the pump discharge pressure to the design pressure of the system. If the vessel design requires isolation valves at the relief valve discharge line, these valves should be locked open, otherwise other arrangements should be set to prevent overpressurization. In addition to the arrangement to prevent overpressurization, further arrangements initiating a visual and audible alarm following the relief valve opening can be also considered to enhance safety.

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. See also [1.3.2] and [2.9.1].

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 *(1/7/2022)*

a) The Society may permit the use of flexible hose assemblies (short lengths of hose normally with prefabricated end fittings ready for installation), for permanent connection between a fixed piping system and items of machinery, and expansion joints, both in metallic and non-metallic materials, provided they are approved for the intended service.

Note 1: Flexible hose assemblies for essential services or containing either flammable or toxic media are not to exceed 1,5 m in length.

b) Flexible hoses and expansion joints are to be of a type approved by the Society, designed in accordance with [2.6.2] and tested in accordance with [21.2.1].

c) These requirements may also be applied to temporary connected flexible hoses or hoses of portable equipment, and media not indicated in d).

d) Flexible hose assemblies as defined in a) may be accepted for use in fuel oil, lubricating, hydraulic and thermal oil systems, fresh water and sea water cooling systems, compressed air systems, bilge and ballast systems, and Class III steam systems. Flexible hoses in high pressure fuel oil injection systems are not accepted.

e) Flexible hoses and expansion joints are to be installed in accordance with the requirements stated in [5.9.3].

f) These requirements for flexible hose assemblies are not applicable to hoses intended to be used in fixed fire-extinguishing systems.

g) Specific requirements are given in:
- Part E, Chapter 7 for flexible hoses and expansion joints intended for cargo pipe lines of oil tankers
- Part E, Chapter 8 for flexible hoses and expansion joints intended for cargo pipe lines of chemical tankers
- Part E, Chapter 9 for flexible hoses and expansion joints intended for cargo pipe lines of liquefied gas carriers.

h) 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.

i) The position of flexible hoses and expansion joints is to be clearly shown on the piping drawings submitted to the Society.

2.6.2 Design of flexible hoses and expansion joints *(1/7/2022)*

a) Flexible hoses 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 hoses are to be designed and constructed in accordance with recognised national or international standards acceptable to the Society.

c) Flexible hoses constructed of rubber materials and intended for use in bilge, ballast, compressed air, fuel oil, lubricating, hydraulic and thermal oil systems are to incorporate a single, double or more closely woven integral wire braid or other suitable material reinforcement.

Flexible hoses of plastics materials for the same purposes, such as Teflon or nylon, which are unable to be reinforced by incorporating closely woven integral wire braid are to have suitable material reinforcement as far as practicable.

d) Where rubber or plastic material hoses are to be used in oil supply lines to burners, the hoses are to have external wire braid protection in addition to the reinforcement mentioned above.

e) Flexible hoses for use in steam systems are to be of metallic construction.

f) Flexible hoses are to be complete with approved end fittings in accordance with the Manufacturer's specification. End connections that do not have a flange are to comply with [2.4.5] as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

g) The use of hose clamps and similar types of end attachments is not acceptable for flexible hoses in piping systems for steam, flammable media, starting air systems or for sea water systems where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 0,5 MPa and provided there are double clamps at each end connection.

h) Flexible hoses and expansion joints are to be so designed as to withstand the bursting pressure requested by the "Rules for the type approval of flexible hoses and expansion joints".

i) Flexible hose assemblies and expansion joints intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required in [21.2.1] are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

j) Flexible hose assemblies and expansion joints constructed of non-metallic materials intended for installation in piping systems for flammable media and sea water systems where failure may result in flooding are to be of fire-resistant type, except in cases where such hoses are installed on open decks, as defined in Regulation 9.2.3.3.2.2(10) of SOLAS Chapter II-2 as amended by IMO resolutions up to MSC.421(98) and not used for fuel oil lines. Fire resistance is to be demonstrated by testing according to ISO 15540:2016 and 15541:2016.

k) Flexible hose assemblies are to be selected for the intended location and application taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the Manufacturer's instructions.

2.6.3 Conditions of use of expansion joints in sea water systems and within duct keels and tanks *(1/1/2006)*

a) The use of non-metallic expansion joints on pipes connected to sea inlets and overboard discharges will be given special consideration by the Society. As a rule, the fitting of such joints between the ship side and the valves mentioned in [2.8.3] is not permitted. Furthermore, unless the above-mentioned valves are fitted with remote controls operable from places located above the freeboard deck, the expansion joints are to be 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.

b) Use of expansion joints in water lines for other services, including ballast lines in machinery spaces, in duct keels and inside double bottom water ballast tanks, and bilge lines inside double bottom tanks and deep tanks, will be given special consideration by the Society.

2.7 Valves and accessories

2.7.1 General *(1/7/2002)*

a) Valves and accessories are normally to be built in accordance with a recognised standard.

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.

Failing this, they are to be approved by the Society when they are fitted:

- in a class I piping system, or
- in a class II piping system with a diameter exceeding 100 mm, or
- on the ship side, on the collision bulkhead or on fuel tanks under static pressure.

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
- for survey or repair purposes.

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 *(1/1/2026)*

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.

d) Power failure of the remote control system is not to cause an undesired change of the valve position.

e) Electrical components - such as solenoid valves and remote indication devices (limit switches) - installed on remotely controlled bilge valves that are located below the bulkhead deck or may be subject to submersion are to comply with an IPX8 protection rating. The water pressure testing of the enclosures protected to IPX8 is to be based

on the maximum hydrostatic pressure that may occur at the installed location during flooding, for a period of 36 hours or consistent with the endurance time required by the applicable statutory and classification requirements.

2.8 Sea inlets and overboard discharges

2.8.1 General

Except where expressly stated in Article [8], the requirements of this sub-article do not apply to scuppers and sanitary discharges.

2.8.2 Design of sea inlets and overboard discharges

a) All inlets and discharges in the shell plating are to be fitted with efficient and accessible arrangements for preventing the accidental admission of water into the ship.

b) Sea inlets and overboard discharges are to be fitted with valves complying with [2.7] and [2.8.3].

c) Machinery space main and auxiliary sea inlets and discharges in connection with the operation of machinery are to be fitted with readily accessible valves between the pipes and the shell plating or between the pipes and fabricated boxes attached to the shell plating. The valves may be controlled locally and are to be provided with indicators showing whether they are open or closed.

d) Sea inlets are to be so designed and arranged as to limit turbulence and to avoid the admission of air due to motion of the ship.

e) Sea inlets are to be fitted with gratings complying with [2.8.4].

f) Provisions are to be made for clearing sea inlet gratings.

g) Sea chests are to be suitably protected against corrosion.

2.8.3 Valves

a) Sea inlet and overboard discharge valves are to be secured:
   - directly on the shell plating, or
   - on sea chests built on the shell plating, with scantlings in compliance with Part B, or
   - on extra-reinforced and short distance pieces attached to the shell (see Tab 5).

b) The bodies of the valves and distance pieces are to have a spigot passing through the plating without projecting beyond the external surface of such plating or of the doubling plates and stiffening rings, if any.

c) Valves are to be secured by means of:
   - bolts screwed through the plating with a countersunk head, or
   - studs screwed in heavy pads themselves secured to the hull or chest plating, without penetration of the plating by the stud holes.

d) The use of butterfly valves will be specially considered by the Society. In any event, butterfly valves not fitted with flanges are not to be used for water inlets or overboard discharges unless provisions are made to allow disassembling at sea of the pipes served by these valves without any risk of flooding.

e) The materials of the valve bodies and connecting pieces are to comply with [2.1.2] and Tab 4.

f) Ship side valves serving piping systems made of plastics are to comply with App 3, [3.7.1].

2.8.4 Gratings

a) Gratings are to have a free flow area not less than twice the total section of the pipes connected to the inlet.

b) When gratings are secured by means of screws with a countersunk head, the tapped holes provided for such screws are not to pass through the plating or doubling plates outside distance pieces or chests.

c) Screws used for fixing gratings are not to be located in the corners of openings in the hull or of doubling plates.

d) In the case of large sea inlets, the screws used for fixing the gratings are to be locked and protected from corrosion.

e) When gratings are cleared by use of compressed air or steam devices, the chests, distance pieces and valves of sea inlets and outlets thus arranged are to be so constructed as to withstand the maximum pressure to which they may be subjected when such devices are operating.

2.8.5 Ship side connections for blow-down of boilers

a) Blow-down pipes of boilers are to be provided with cocks or valves placed as near the end of the pipes as possible, while remaining readily accessible and located above the engine room floor.

b) Blow-down valves are to be so designed that it is easy to ascertain whether they are open or shut. Where cocks are used, the control keys are to be such that they cannot be taken off unless the cocks are shut. Where valves are used, the control-wheels are to be permanently fixed to the spindle.

c) A protection ring is to be fitted on the shell plating, outside, at the end of the blow-down pipes. The spigot of the valve referred to in [2.8.3], item b), is to pass through this ring.

2.9 Control and monitoring

2.9.1 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.

2.9.2 Level gauges *(1/7/2008)*

Level gauges used in fuel oil systems, pressure lubricating oil systems and other flammable oil systems are to be of a type approved by the Society and are subject to the following conditions:

- in passenger ships, they 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
- in cargo ships, their failure or overfilling of the tank is not to permit release of fuel into the space. The use of cylindrical gauges is prohibited. The Society may permit the use of oil-level gauges with flat glasses and self-closing valves between the gauges and fuel tanks. Their glasses are to be made of heat-resistant material and efficiently protected against shocks.

The above level gauges are to be maintained in the proper condition to ensure their continued accurate functioning in service.

Note 1: On cargo ships of less than 500 tons gross tonnage and non-propelled ships:

- cylindrical gauges may be used provided they are fitted with self-closing valves at their lower end as well as at their upper end if the latter is below the maximum liquid level.
- in the case of tanks not subject to filling by power pumps, with the exception of fuel oil service tanks, the valves need not be of the self-closing type. Such valves are, however, to be readily accessible and instruction plates are to be fitted adjacent to them specifying that they are to be kept closed.

3 Welding of steel piping

3.1 Application

3.1.1

a) 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 cargo installation piping systems operating at temperatures lower than minus 40°C.

c) The requirements for qualification of welding procedures are given in Part D.

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 [2.4.4], 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. However, for class I pipes with an internal diameter not exceeding 50 mm and for class II pipes, socket welded connections of approved types may be used.

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 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.

e) Tack welds should be made with an electrode suitable for the base metal; tack welds which form part of the finished weld should be made using approved procedures.

When welding materials requiring preheating are employed, the same preheating should be applied during tack welding.

Table 18 : Maximum value of misalignment

d (mm)	t (mm)		
	t ≤ 6	6 < t ≤ 10	10 < t
d < 150	1,0	1,0	1,0
150 ≤ d < 300	1,0	1,5	1,5
d ≥ 300	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 t ≥ 13	100 150
2,25 Cr 1 Mo **(1)**		t < 13 t ≥ 13	150 200
0,5 Cr 0,5 Mo 0,25 V **(1)**		t < 13 t ≥ 13	150 200

(1) For 2,25 Cr 1 Mo and 0,5 Cr 0,5 Mo 0,25 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 the Table, 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 0,25 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 0,25 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 with an external diameter exceeding 75 mm are to be subjected to full radiographic examination or equivalent
- welded joints other than butt-welded joints and which cannot be radiographed 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
- 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 *(1/7/2007)*

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) The acceptance criteria of defects are:

- for class I pipes, those defined in the "Rules for carrying out not-destructive examinations of welding" for the special quality level,
- for class II pipes, those defined in the "Rules for carrying out not-destructive examinations of welding" for the normal quality level.

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.

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 *(1/7/2017)*

The bending radius measured on the centreline 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.

Smaller bending radius may be accepted for specific applications (pipe materials and geometries), based on the results of relevant studies that demonstrate that the strength characteristics of the pipe is not negatively affected by the bending.

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 5% 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 Cr-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 [5.10].

5.2.2 Piping systems with open ends

Attention is to be paid to the requirements for the location of open-ended pipes on board ships having to comply with the provisions of [5.5].

5.2.3 Pipe lines located inside tanks *(1/7/2006)*

a) The passage of pipes through tanks, when permitted, requires special arrangements such as reinforced thickness as per Tab 5 for steel pipes or tunnels, in particular for:
   - bilge pipes
   - ballast 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 welded reinforced flange connections. See also [2.4.3].

5.2.4 Overboard discharges

Overboard discharges are to be so located as to prevent any discharge of water into the lifeboats while they are being lowered.

5.2.5 Piping and electrical apparatus *(1/7/2007)*

The installation of piping near switchboards and other electrical apparatus is to comply with Ch 2, Sec 12, [6.1.7].

5.3 Passage through watertight bulkheads or decks

5.3.1 General *(1/7/2009)*

Item [5.3.2] applies to cargo ships.

Item [5.3.3] applies to cargo and passenger ships.

5.3.2 Penetration of watertight bulkheads and decks *(1/1/2011)*

a) Where penetrations of watertight bulkheads and internal decks are necessary for piping and ventilation, arrangements are to be made to maintain the watertight integrity.

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.

This applies in particular to the following systems:

- bilge system
- ballast system
- scuppers and sanitary discharge systems.

c) Where bolted connections are used for piping passing through watertight bulkheads or decks, the bolts are to be screwed in heavy pads secured to the bulkhead or deck plating without penetration of the plating by the bolt holes. Where welded connections are used, they are to be welded on both sides of the bulkhead or deck plating.

d) Penetrations of watertight bulkheads or decks by plastic pipes are to comply with App 3, [3.6.2].

5.3.3 Passage through the collision bulkhead *(1/1/2026)*

a) For ships constructed before 1 January 2024 except as provided in c), *the collision bulkhead may be pierced below the bulkhead deck of passenger ships and the freeboard deck of cargo ships by not more than one pipe for dealing with fluid in the forepeak tank, provided that the pipe is fitted with a screw-down valve capable of being operated from above the bulkhead deck of passenger ships and the freeboard deck of cargo ships, the valve being located inside the forepeak to the collision bulkhead. The Society may, however, authorise the fitting of this valve on the after side of the collision bulkhead provided that the valve is readily accessible under all service conditions and the space in which it is located is not a cargo space.*

Alternatively, for cargo ships, the pipe may be fitted with a butterfly valve suitably supported by a seat or flanges and capable of being operated from above the freeboard deck.

All valves are to be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

b) For ships constructed on or after 1 January 2024, except as provided in c), the collision bulkhead may be pierced below the bulkhead deck of passenger ships and the freeboard deck of cargo ships by not more than one pipe for dealing with fluid in the forepeak tank, provided that the pipe is fitted with a remotely controlled valve capable of being operated from above the bulkhead deck of passenger ships and the freeboard deck of cargo ships. The valve shall be normally closed. If the remote control system should fail during operation of the valve, the valve shall close automatically or be capable of being closed manually from a position above the bulkhead deck of passenger ships and the freeboard deck of cargo ships. The valve shall be located at the collision bulkhead on either of forward or aft side, provided that the space on the aft side is not a cargo space. The valve shall be steel, bronze other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

The relevant interpretation in IACS UI SC306 applies.

c) If the forepeak is divided to hold two different kinds of liquids the Society may allow the collision bulkhead to be pierced below the bulkhead deck of passenger ships and the freeboard deck of cargo ships by two pipes, each of which is fitted as required in a) or b), provided the Society is satisfied that there is no practical alternative to the fitting of such a second pipe and that, having regard to the additional subdivision provided in the forepeak, the safety of the ship is maintained.

d) The remote operation device of the valve referred to in a) or b) is to include an indicator to show whether the valve is open or shut.

5.4 Independence of lines

5.4.1 As a general rule, bilge and ballast lines are to be entirely independent and distinct from lines conveying liquid cargo, lubricating oil and fuel oil, with the exception of:

- pipes located between collecting boxes and pump suctions
- pipes located between pumps and overboard discharges
- pipes supplying compartments likely to be used alternatively for ballast, fuel oil or liquid or dry cargoes, provided such pipes are fitted with blind flanges or other appropriate change-over devices, in order to avoid any mishandling.

5.5 Prevention of progressive flooding

5.5.1 Principle

a) In order to comply with the subdivision and damage stability requirements of Pt F, Ch 13, Sec 11, provision is to be made to prevent any progressive flooding of a dry compartment served by any open-ended pipe, in the event that such pipe is damaged or broken in any other compartment by collision or grounding.

b) For this purpose, if pipes are situated within assumed flooded compartments, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed to be flooded for each case of damage. However, the Society may permit minor progressive flooding if it is demonstrated that its effects can be easily controlled and the safety of the ship is not impaired. Refer to Pt F, Ch 13, Sec 11.

5.5.2 Extent of damage

For the definition of the assumed transverse extent of damage, reference is to be made to Pt F, Ch 13, Sec 11.

5.5.3 Piping arrangement *(1/7/2007)*

a) The assumed transverse extent of damage is not to contain any pipe with an open end in a compartment located outside this extent.

b) Where the provisions of a) cannot be fulfilled, and after special examination by the Society, pipes may be situated within the assumed transverse extent of damage penetration provided that:

- either a closable valve operable from above the bulkhead deck is fitted at each penetration of a watertight subdivision and secured directly on the bulkhead, or
- a closable valve operable from above the bulkhead deck is fitted at each end of the pipe concerned, the valves and their control system being inboard of the assumed extent of damage, or
- the tanks to which the pipe concerned leads are regarded in the damage stability calculations as being flooded when damage occurs in a compartment through which the pipe passes.

c) Valves required to be operable from above the bulkhead deck are to be fitted with an indicator to show whether the valve is open or shut.

Where the valve is remote controlled by other than mechanical means, and where the remote control system is located, even partly, within the assumed extent of damage penetration, this system is to be such that the valve is automatically closed by loss of power.

d) Air and overflow pipes are to be so arranged as to prevent the possibility of flooding of other tanks in other watertight compartments in the event of any one tank being flooded.

This arrangement is to be such that in the range of positive residual righting levers beyond the angle of equilibrium stage of flooding, the progressive flooding of tanks or watertight compartments other than that flooded does not occur.

5.6 Provision for expansion

5.6.1 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
- the coefficient of thermal expansion of the pipes material
- the deformation of the ship’s hull.

5.6.2 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.

5.7 Supporting of the pipes

5.7.1 General

Unless otherwise specified, the fluid lines referred to in this Section are to consist of pipes connected to the ship's structure by means of collars or similar devices.

5.7.2 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.

5.8 Protection of pipes

5.8.1 Protection against shocks *(1/7/2022)*

Pipes passing through cargo holds and ‘tweendecks are to be protected against shocks by means of strong casings.

Seawater pipes in cargo holds for dry cargoes, including cargo spaces of container ships, ro-ro ships, are to be protected from impact of cargo where they are liable to be damaged.

5.8.2 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) If galvanised steel pipes are used for sea water systems, the water velocity is not to exceed 3 m/s.

d) If copper pipes are used for sea water systems, the water velocity is not to exceed 2 m/s.

e) Arrangements are to be made to avoid galvanic corrosion.

5.8.3 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.

5.8.4 Protection of high temperature pipes and components *(1/7/2006)*

a) All pipes and other components where the temperature may exceed 220°C are to be efficiently insulated, as indicated in Sec 1, [3.7].

b) Particular attention is to be paid to lagging in way of flanges.

5.9 Valves, accessories and fittings

5.9.1 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.

5.9.2 Valves and accessories

a) 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.

b) Control-wheels of low inlet valves are to rise at least 0,45 m above the lowest floor.

5.9.3 Flexible hoses and expansion joints *(1/1/2006)*

a) Flexible hoses are to be so arranged as to be clearly visible and readily accessible at all times.

b) In general, flexible hoses and expansion joints are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery/equipment or systems.

c) Flexible hose assemblies and expansion joints are not to be installed where they may be subjected to torsion deformation (twisting) under normal operating conditions.

d) The adjoining pipes are to be suitably aligned, supported, guided and anchored.

e) The number of flexible hoses and expansion joints is to be kept to a minimum.

f) Where flexible hoses and expansion joints are intended to be used in piping systems conveying flammable fluids that are in close proximity to heated surfaces, the risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other similar protection to the satisfaction of the Society.

g) Expansion joints are to be protected against over-extension and over-compression.

h) The installation of flexible hose assemblies and expansion joints is to be in accordance with the Manufacturer's instructions and use limitations with particular attention to the following, as applicable:
   - orientation
   - end connection support (where necessary)
   - avoidance of hose contact that could cause rubbing and abrasion
   - minimum bend radii.

5.9.4 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.

5.9.5 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.

5.9.6 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.

5.10 Additional arrangements for flammable fluids

5.10.1 General

The requirements in [5.10.3] and [5.10.4] 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.

5.10.2 Prohibition of carriage of flammable oils in forepeak tanks

In cargo ships of more than 400 tons gross tonnage and in passenger ships, fuel oil, lubricating oil and other flammable oils are not to be carried in forepeak tanks or tanks forward of the collision bulkhead.

5.10.3 Prevention of flammable oil leakage ignition *(1/7/2002)*

a) As far as practicable, parts of the fuel oil and lubricating oil systems containing heated oil under pressure exceeding 0,18 MPa are to be placed above the platform or in any other position where defects and leakage can readily be observed.

   The machinery spaces in way of such parts are to be adequately illuminated.

b) No flammable oil tanks are to be situated where spillage or leakage therefrom can constitute a hazard by falling on:
   - hot surfaces, including those of boilers, heaters, steam pipes, exhaust manifolds and silencers
   - electrical equipment
   - air intakes
   - other sources of ignition.

c) Parts of flammable oil systems under pressure exceeding 0,18 MPa such as pumps, filters and heaters are to comply with the provisions of b) above.

d) Flammable oil lines are not to be located immediately above or near units of high temperature including boilers, steam pipelines, exhaust manifolds, silencers or other equipment required to be insulated in Sec 1, [3.7.1]. As far as practicable, flammable oil lines are to be arranged far from hot surfaces, electrical installations or other sources of ignition and to be screened or otherwise suitably protected to avoid oil spray or oil leakage onto the sources of ignition.

   Precautions are to be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.

e) Any relief valve of fuel oil and lubricating oil systems is to discharge to a safe position, such as an appropriate tank. See also item (a) of [9.1.7].

5.10.4 **Provisions for flammable oil leakage containment** *(1/7/2007)*

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:
   - under independent tanks (refer to App 4, [2.3.2])
   - 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 drain pipes are provided for collecting leakages, they are to be led to an appropriate drain tank.

5.10.5 Drain tank

a) The drain tank is not to form part of an overflow system and is to be fitted with an overflow alarm device.

b) In ships required to be fitted with a double bottom, appropriate precautions are to be taken when the drain tank is constructed in the double bottom, in order to avoid flooding of the machinery space where drip trays are located, in the event of accidentally running aground.

5.10.6 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.

5.10.7 Level switches

Level switches fitted to flammable oil tanks are to be contained in a steel or other fire-resisting enclosure.

6 Bilge systems

6.1 Application

6.1.1 *(1/7/2006)*

This Article does not apply to bilge systems of non-propelled ships and fishing vessels. See Part E, Chapter 19 and Part E, Chapter 20, respectively.

6.2 Principle

6.2.1 General

An efficient bilge pumping system shall be provided, capable of pumping from and draining any watertight compartment other than a space permanently appropriated for the carriage of fresh water, water ballast, fuel oil or liquid cargo and for which other efficient means of pumping are to be provided, under all practical conditions. Efficient means shall be provided for draining water from insulated holds.

Bilge pumping system is not intended at coping with water ingress resulting from structural or main sea water piping damage.

6.2.2 Availability of the bilge system

The bilge system is to be able to work while the other essential installations of the ship, especially the fire-fighting installations, are in service.

6.2.3 Bilge and ballast systems

The arrangement of the bilge and ballast pumping system shall be such as to prevent the possibility of water passing from the sea and from water ballast spaces into the cargo and machinery spaces, or from one compartment to another.

Provisions shall be made to prevent any deep tank having bilge and ballast connections being inadvertently flooded from the sea when containing cargo, or being discharged through a bilge pump when containing water ballast.

6.3 Design of bilge systems

6.3.1 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 [6.2.1] through bilge branches, distribution boxes and bilge suctions, except for some small spaces where individual suctions by means of hand pumps may be accepted as stated in [6.6.3] and [6.6.4].

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.

6.3.2 Number and distribution of bilge suctions

a) Draining of watertight spaces is to be possible, when the ship is on an even keel and either is upright or has a list of up to 5°, by means of at least:

- two suctions in machinery spaces, including one branch bilge suction and one direct suction and, in addition, for spaces containing propulsion machinery, one emergency bilge suction
- one suction in other spaces.

See also [6.5.5].

b) Bilge suctions are to be arranged as follows:

- wing suctions are generally to be provided except in the case of short and narrow compartments when a single suction ensures effective draining in the above conditions
- in the case of compartments of unusual form, additional suctions may be required to ensure effective draining under the conditions mentioned in [6.3.2], item a).

c) In all cases, arrangements are to be made such as to allow a free and easy flow of water to bilge suctions.

6.3.3 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].

c) In ships designed for the carriage of flammable or toxic liquids in enclosed cargo spaces, the bilge pumping system is to be designed to prevent the inadvertent pumping of such liquids through machinery space piping or pumps.

6.4 Draining of cargo spaces

6.4.1 General

a) Cargo holds are to be fitted with bilge suctions connected to the bilge main.

b) Drainage arrangements for cargo holds likely to be used alternatively for ballast, fuel oil or liquid or dry cargoes are to comply with [7.1].

6.4.2 Ships without double bottom

a) In ships without double bottom, bilge suctions are to be provided in the holds:

- at the aft end in the centreline where the rise of floor exceeds 5°,
- at the aft end on each side in other cases.

b) Additional suctions may be required if, due to the particular shape of the floor, the water within the compartment cannot be entirely drained by means of the suctions mentioned in a) above.

6.4.3 Ships with double bottom *(1/7/2011)*

a) In ships with double bottom, bilge suctions are to be provided in the holds on each side aft. Where the double bottom plating extends from side to side, the bilge suctions are to be led to wells located at the wings. Where the double bottom plating slopes down to the centreline by more than 5°, only one centreline well with a suction may be accepted.

b) If the inner bottom is of a particular design, shows discontinuity or is provided with longitudinal wells, the number and position of bilge suctions will be given special consideration by the Society.

6.4.4 Ships with holds over 30 m in length

In holds greater than 30 m in length, bilge suctions are to be provided in the fore and aft ends.

6.4.5 Additional suctions

Additional suctions may be required in the forward part of holds in ships which are likely to navigate normally with a trim by the head.

6.4.6 Drainage of cargo spaces, other than ro-ro spaces, intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion *(1/7/2011)*

In cargo spaces, other than ro-ro spaces, intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion, when fixed pressure water-spraying systems are fitted, in view of the serious loss of stability which could arise due to large quantities of water accumulating on the deck or decks during the operation of the fixed pressure water-spraying system, the following arrangements are to be provided:

a) the drainage and pumping arrangements are to be such as to prevent the build-up of free surfaces. In such case, the drainage system is to be sized to remove no less than 125% of the combined capacity of both the water-spraying system pumps and the required number of fire hose nozzles, taking into account the guidelines developed by IMO [see Note 1]. The drainage system valves are to be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells are to be of sufficient holding capacity and are to be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment. If this is not possible, the adverse effect upon stability of the added weight and free surface of water is to be taken into account to the extent deemed necessary by the Society in its approval of the stability information (see Note 2). Such information is to be included in the stability information supplied to the Master. See Pt B, Ch 3, App 2.

b) for closed vehicles spaces, where fixed pressure water-spraying systems are fitted, means are to be provided to prevent the blockage of drainage arrangements, taking into account the guidelines developed by IMO (see Note 1).

Note 1: see resolution MSC.1/Circ. 1320 "Guidelines for the drainage of fire-fighting water from closed vehicle and ro-ro spaces and special category spaces of passenger and cargo ships"

Note 2: see Resolution A.123(V).

6.5 Draining of machinery spaces

6.5.1 General

Where all the propulsion machinery, boilers and main auxiliaries are located in a single watertight space, the bilge suctions are to be distributed and arranged in accordance with the provisions of [6.5.5].

6.5.2 Branch bilge suction

The branch bilge suction is to be connected to the bilge main.

6.5.3 Direct suction

The direct suction is to be led direct to an independent power bilge pump and so arranged that it can be used independently of the main bilge line.

The use of ejectors for pumping through the direct suction will be given special consideration.

6.5.4 Emergency bilge suction

a) The emergency bilge suction is to be led directly from the drainage level of the machinery space to a main circulating (or cooling) pump and fitted with a non-return valve.

b) In ships where, in the opinion of the Society, the main circulating (or cooling) pump is not suitable for this purpose, the emergency bilge suction is to be led from the largest available independent power driven pump to the drainage level of the machinery space. Such a pump is not to be a bilge pump. Its capacity when the emergency suction is operating is to be at least equal to the required capacity of each bilge pump as determined in [6.7.4].

c) The emergency bilge suction is to be located at the lowest possible level in the machinery spaces.

6.5.5 Number and distribution of suctions in propulsion machinery spaces

a) In propulsion machinery spaces, bilge suctions are to include:

- where the bottom of the space, bottom plating or top of the double bottom slope down to the centreline by more than 5°, at least two centreline suctions, i.e. one branch bilge suction and one direct suction, or
- where the bottom of the space is horizontal or slopes down to the sides, at least two suctions, i.e. one branch bilge suction and one direct suction, on each side,
- and one emergency bilge suction.

b) If the tank top is of a particular design or shows discontinuity, additional suctions may be required.

c) Where the propulsion machinery space is located aft, suctions are normally to be provided on each side at the fore end and, except where not practicable due to the shape of the space, on each side at the aft end of the space.

d) In electrically propelled ships, provision is to be made to prevent accumulation of water under electric generators and motors.

6.5.6 Number and distribution of suctions in boiler and auxiliary machinery spaces

In boiler and auxiliary compartments, bilge suctions are to include:

- bilge branch suctions distributed as required in [6.4.2] to [6.4.5] for cargo holds
- one direct suction.

6.6 Draining of dry spaces other than cargo holds and machinery spaces

6.6.1 General

a) Except where otherwise specified, bilge suctions are to be branch bilge suctions, i.e. suctions connected to a bilge main.

b) Draining arrangements of tanks are to comply with the provisions of [7].

6.6.2 Draining of cofferdams

a) All cofferdams are to be provided with suction pipes led to the bilge main.

b) Where cofferdams are divided by longitudinal watertight bulkheads or girders into two or more parts, a single suction pipe led to the aft end of each part is acceptable.

6.6.3 Draining of fore and aft peaks

a) Where the peaks are not used as tanks and bilge suctions are not fitted, drainage of both peaks may be effected by hand pump suction provided that the suction lift is well within the capacity of the pump and in no case exceeds 7,3 m.

b) Except where permitted in [5.3.3], the collision bulkhead is not to be pierced below the freeboard deck.

6.6.4 Draining of spaces above fore and aft peaks

a) Provision is to be made for the drainage of the chain lockers and watertight compartments above the fore peak tank by hand or power pump suctions.

b) Steering gear compartments or other small enclosed spaces situated above the aft peak tank are to be provided with suitable means of drainage, either by hand or power pump bilge suctions. However, in the case of rudder stock glands located below the summer load line, the bilge suctions of the steering gear compartment are to be connected to the main bilge system.

c) If the compartments referred to in b) above are adequately isolated from the adjacent ‘tweendecks, they may be drained by scuppers discharging to the tunnel (or machinery space in the case of ships with machinery aft) and fitted with self-closing cocks situated in well-lighted and visible positions.

Note 1: This arrangement is not applicable to ships required to comply with [5.5], and in particular to passenger ships, unless they are specially approved in relation to subdivision.

6.6.5 Draining of tunnels

a) Tunnels are to be drained by means of suctions connected to the main bilge system. Such suctions are generally to be located in wells at the aft end of the tunnels.

b) Where the top of the double bottom, in the tunnel, slopes down from aft to forward, an additional suction is to be provided at the forward end of this space.

6.6.6 Draining of refrigerated spaces

Provision is to be made for the continuous drainage of condensate in refrigerated and air cooler spaces. To this end, valves capable of blanking off the water draining lines of such spaces are not to be fitted, unless they are operable from an easily accessible place located above the load waterline.

6.7 Bilge pumps

6.7.1 Number and arrangement of pumps

a) For cargo ships, at least two power pumps connected to the main bilge system are to be provided, one of which may be driven by the propulsion machinery.

b) Bilge pumps driven by the propulsion machinery are not allowed on ships exceeding 1000 gross tonnage.

c) Each pump may be replaced by a group of pumps connected to the bilge main, provided their total capacity meets the requirements specified in [6.7.4].

d) Alternative arrangements, such as the use of a hand pump in lieu of a power pump, will be given special consideration by the Society.

6.7.2 Use of ejectors

One of the pumps may be replaced by a hydraulic ejector connected to a high pressure water pump and capable of ensuring the drainage under similar conditions to those obtained with the other pump.

On passenger ships, the pump supplying the ejector is not to be used for other services.

6.7.3 Use of bilge pumps for other duties *(1/1/2007)*

Bilge pumps may be used for other duties, such as fire, general service, sanitary service or ballast provided that:

- such duties are of intermittent nature
- any failure of the piping systems connected to the bilge pumps does not render the bilge system inoperable
- pumps are immediately available for bilge duty when necessary.

6.7.4 Capacity of the pumps *(1/7/2011)*

a) Each power bilge pump is to be capable of pumping water through the required main bilge pipe at a speed of not less than 2 m/s.

b) The capacity of each pump or group of pumps is not to be less than:

$Q = 0{,}00565\ d^2$

where:

Q : Minimum capacity of each pump or group of pumps, in m^3/h

d : Internal diameter, in mm, of the bilge main as defined in [6.8.1].

Note 1: For cargo ships of less than 35 m in length:

- the speed of water to be considered for calculating the capacity may be reduced to 1,22 m/s
- the capacity of each pump or group of pumps is not to be less than $Q = 0{,}00345\ d^2$.

c) If the capacity of one of the pumps or one of the groups of pumps is less than the Rule capacity, the deficiency may be compensated by an excess capacity of the other pump or group of pumps; as a rule, such deficiency is not permitted to exceed 30% of the Rule capacity.

Note 2: This provision does not apply to passenger ships.

d) The capacity of hand pumps is to be based on one movement once a second.

e) Where an ejector is used in lieu of a driven pump, its suction capacity is not to be less than the required capacity of the pump it replaces.

f) When fixed pressure water-spraying systems are fitted in closed vehicle spaces and closed ro-ro spaces, the requirements contained in the guidelines developed by IMO (see Note 3) are to be satisfied.

Note 3: see resolution MSC.1/Circ. 1320 "Guidelines for the drainage of fire-fighting water from closed vehicle and ro-ro spaces and special category spaces of passenger and cargo ships"

6.7.5 Choice of the pumps

a) 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.

b) Circulating or cooling water pumps connected to an emergency bilge suction need not be of the self-priming type.

c) Sanitary, ballast and general service pumps may be accepted as independent power bilge pumps if fitted with the necessary connections to the bilge pumping system.

d) Hand pumps are to have a maximum suction height not exceeding 7,30 m and to be operable from a position located above the load waterline.

6.7.6 Connection of power pumps

a) Bilge pumps and other power pumps serving essential services which have common suction or discharge are to be connected to the pipes in such a way that:

- compartments and piping lines remain segregated in order to prevent possible intercommunication
- the operation of any pump is not affected by the simultaneous operation of other pumps.

b) 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.

6.7.7 Electrical supply of submersible pump motors

a) Where submersible bilge pumps are provided, arrangements are to be made to start their motors from a convenient position above the bulkhead deck.

b) Where an additional local-starting device is provided at the motor of a permanently installed submersible bilge pump, the circuit is to be arranged to provide for the disconnection of all control wires therefrom at a position adjacent to the starter installed on the deck.

6.8 Size of bilge pipes

6.8.1 Bilge main line *(1/7/2011)*

a) The diameter of the bilge main is to be calculated according to the following formula:

$$d = 25 + 1{,}68\ \sqrt{L(B + D)}$$

where:

d : The internal diameter of the bilge main, in mm

L : Length of the ship is the length measured between perpendiculars taken at the extremities of the deepest subdivision load line, in m.

B : Breadth of the ship is the extreme width from outside of frame to outside of frame at or below the deepest subdivision load line, in m.

D : Moulded depth of the ship to the bulkhead deck, in m, provided that, in a ship having an enclosed cargo space on the bulkhead deck which is internally drained and which extends for the full length of the ship, D is measured to the next deck above the bulkhead deck. Where the enclosed cargo spaces cover a lesser length, D is to be taken as the moulded depth to the bulkhead deck plus lh/L where l and h are the aggregate length and height, respectively, of the enclosed cargo spaces, in m.

Note 1: In cargo ships fitted with side ballast tanks forming a double hull on the whole length of the holds, the diameter of the bilge main may be determined by introducing the actual breadth of the holds amidships as B in the above formula. The cross-section of the bilge main is, however, not to be less than twice the cross-section of the largest branch suction to these spaces.

b) Where the bilge pumps are designed to pump from the machinery space only, the internal diameter d, in mm, of the bilge main may be less than that required in (a) but not less than that calculated with the following formula:

$$d = 35 + 3\ \sqrt{L_0(B + D)}$$

where:

L_0 : Length of the engine room, in m

B : Breadth of the ship, in m, as defined in a)

D : Moulded depth of the ship to the bulkhead deck, in m, as defined in a)

In any case, the internal section of the bilge main is not to be less than twice that of the bilge suction pipes determined from [6.8.3].

c) When fixed pressure water-spraying systems are fitted in closed vehicle spaces and closed ro-ro spaces, the requirements contained in the guidelines developed by IMO (see Note 2) are to be satisfied (see Note 3).

Note 2: see resolution MSC.1/Circ. 1320 "Guidelines for the drainage of fire-fighting water from closed vehicle and ro-ro spaces and special category spaces of passenger and cargo ships"

Note 3: the requirement in [6.8.1] c) need not be applied to cargo ships less than 500 GT.

d) In no case is the actual internal diameter to be:

- more than 5 mm smaller than that obtained from the formula given in a) or b), or
- less than 60 mm.

6.8.2 Distribution box branch pipes

The cross-section of any branch pipe connecting the bilge main to a bilge distribution box is not to be less than the sum of the cross-sections required for the two largest branch suctions connected to this box. However, this cross-section need not exceed that of the bilge main.

6.8.3 Branch bilge suction pipes *(1/7/2011)*

a) The internal diameter, in mm, of pipes situated between distribution boxes and suctions in holds and machinery spaces is not to be less than the diameter given by the following formula (a smaller actual diameter may be accepted, as specified in [6.8.1], b):

$$d_1 = 25 + 2{,}16\ \sqrt{L_1(B + D)}$$

where:

B and D : as defined in [6.8.1]

L_1 : Length of the compartment, in m.

d_1 is not to be less than 50 mm and need not exceed 100 mm.

b) For ships other than passenger ships, which have side ballast tanks forming a double hull, the diameter of suction pipes in holds may be determined by introducing as B the actual breadth of the holds.

c) When fixed pressure water-spraying systems are fitted in closed vehicle spaces and closed ro-ro spaces, the requirements contained in the guidelines developed by IMO (see Note 1) are to be satisfied (see Note 2).

Note 1: see resolution MSC.1/Circ. 1320 "Guidelines for the drainage of fire-fighting water from closed vehicle and ro-ro spaces and special category spaces of passenger and cargo ships".

Note 2: the requirement in [6.8.3] c) need not be applied to cargo ships less than 500 GT.

6.8.4 Direct suctions other than emergency suctions

a) Direct suctions are to be suitably arranged and those in a machinery space are to be of a diameter not less than that required for the bilge main.

b) In cargo ships having separate machinery spaces of small dimensions, the size of the direct suctions need not exceed that given in [6.8.3] for branch bilge suctions.

6.8.5 Emergency suctions in machinery spaces

a) The diameter of emergency bilge suction pipes is to be:
- at least two thirds of the diameter of the pump inlet in the case of steamships
- the same as the diameter of the pump inlet in the case of motorships.

b) Where the emergency suction is connected to a pump other than a main circulating or cooling pump, the suction is to be the same diameter as the main inlet of the pump.

6.8.6 Bilge suctions from tunnels

Bilge suction pipes to tunnel wells are not to be less than 65 mm in diameter. In ships up to 60 metres in length, this diameter may be reduced to 50 mm.

6.8.7 Scuppers in aft spaces

Any scupper provided for draining aft spaces and discharging to the tunnel is to have an internal diameter not less than 35 mm.

6.8.8 Bilge for small ships *(1/1/2001)*

For cargo ships of a length L, as defined in [6.8.1], under 20 m and assigned with a restricted navigation notation, as well as for sailing ships with or without auxiliary engine, the bilge system will be specially considered by the Society in each single case.

6.8.9 Bilge main for tankers *(1/1/2001)*

In tankers and other ships where the bilge pumps are designed to pump from the machinery space only, the internal diameter d, in mm, of the bilge main may be less than that required by the formula in [6.8.1] above, but it is to be not less than that obtained from the formula specified in Pt E, Ch 7, Sec 4 .

6.9 Bilge accessories

6.9.1 Drain valves on watertight bulkheads

a) The fitting of drain valves or similar devices is not allowed on the collision bulkhead.

b) On other watertight bulkheads, the fitting of drain valves or similar devices is allowed unless practical alternative draining means exist. Such valves are to be easily accessible at all times and operable from above the freeboard deck. Means indicating whether the valves are open or closed are to be provided.

6.9.2 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 pipe connections to bilge distribution boxes or to the alternative valves, if any
- on direct and emergency suctions in machinery spaces
- on the suctions of pumps which also have connections from the sea or from compartments normally intended to contain liquid
- on flexible bilge hose connections
- on the suctions of water bilge ejectors
- at the open end of bilge pipes passing through deep tanks

- in compliance with the provisions for the prevention of progressive flooding, if applicable.

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.

6.9.3 Mud boxes

In machinery spaces and shaft tunnels, termination pipes of bilge suctions are to be straight and vertical and are to be led to mud boxes so arranged as to be easily inspected and cleaned.

The lower end of the termination pipe is not to be fitted with a strum box.

6.9.4 Strum boxes

a) In compartments other than machinery spaces and shaft tunnels, the open ends of bilge suction pipes are to be fitted with strum boxes or strainers having holes not more than 10 mm in diameter. The total area of such holes is to be not less than twice the required 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.

6.9.5 Bilge wells

a) The wells provided for draining the various compartments are to be made of steel plate and their capacity is not to be less than 0,15 m^3. In small compartments, smaller cylindrical wells may be fitted.

b) Bilge wells are to comply with the relevant provisions of Part B.

6.9.6 Liquid sealed traps

a) The bilge line of refrigerated spaces is to be provided with liquid sealed traps of adequate size arranged for easy cleaning and refilling with brine. These traps are to be fitted with removable grids intended to hold back waste products when defrosting.

b) Where drain pipes from separate refrigerated rooms join a common main, each of these pipes is to be provided with a liquid sealed trap.

c) As a general rule, liquid sealed traps are to be fitted with non-return valves. However, for refrigerated spaces not situated in the ship bottom, non-return valves may be omitted, provided this arrangement does not impair the integrity of the watertight subdivision.

6.10 Materials

6.10.1 *All bilge pipes used in or under coal bunkers or fuel storage tanks or in boiler or machinery spaces, including spaces in which oil-settling tanks or fuel oil pumping units are situated, shall be of steel or other suitable material non-sensitive to heat.*

6.11 Bilge piping arrangement

6.11.1 Passage through double bottom compartments *(1/7/2006)*

Bilge pipes are not to pass through double bottom compartments. If such arrangement is unavoidable, the parts of bilge pipes passing through double bottom compartments are to comply with [5.2.3].

6.11.2 Passage through deep tanks *(1/7/2006)*

The parts of bilge pipes passing through deep tanks intended to contain water ballast, fresh water, liquid cargo or fuel oil are normally to be contained within pipe tunnels. Alternatively, such parts are to comply with [5.2.3]; the number of joints is to be as small as possible. These pipes are to be provided at their ends in the holds with non-return valves.

6.11.3 Provision for expansion *(1/1/2025)*

Where necessary, bilge pipes inside tanks are to be fitted with expansion bends (see Note 1). Sliding joints are not permitted for this purpose.

Note 1: Expansion bends means expansion loops such as an omega bend (' Ω ') in piping system to counteract excessive stresses or displacement caused by thermal expansion or hull deformation which could be fabricated from straight lengths of pipe.

6.11.4 Connections

Connections used for bilge pipes passing through tanks are to be welded joints or reinforced welded flange connections.

6.11.5 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

Hand-wheels of valves controlling emergency bilge suctions are to rise at least 0,45 m above the manoeuvring floor.

7 Ballast systems

7.1 Design of ballast systems

7.1.1 Independence of ballast lines

Ballast lines are to be entirely independent and distinct from other lines except where permitted in [5.4].

7.1.2 Prevention of undesirable communication between spaces or with the sea

Ballast systems in connection with bilge systems are to be so designed as to avoid any risk of undesirable communication between spaces or with the sea. See [6.2.3].

7.1.3 Alternative carriage of ballast water and fuel oil

a) Oily ballast systems serving tanks intended for alternative carriage of fuel oil and water ballast are to be independent of clean ballast systems:
   - serving the other ballast tanks, or
   - connected to tanks also intended to contain feed water.

b) Where tanks are intended to alternatively contain fuel oil and ballast water, the relevant piping systems are to be arranged in accordance with [11.4.4].

7.1.4 Alternative carriage of ballast water or other liquids and dry cargo

Holds and deep tanks designed for the alternative carriage of water ballast, fuel oil or dry cargo are to have their filling and suction lines provided with blind flanges or appropriate change-over devices to prevent any mishandling.

7.1.5 Alternative carriage of ballast water and feed water

Where tanks are intended to alternatively contain ballast water and feed water, the suction line is to have removable elbows for connection to the ballast and feed water systems, so as to avoid any accidental interconnection between the two systems due to manoeuvring error.

The same arrangement is required for tanks intended for ballast and vegetable oils, or for other cargoes which may not come in contact with sea water.

7.2 Ballast pumping arrangement

7.2.1 Filling and suction pipes

a) All tanks including aft and fore peak and double bottom tanks intended for ballast water are to be provided with suitable filling and suction pipes connected to special power driven pumps of adequate capacity.

b) Small tanks used for the carriage of domestic fresh water may be served by hand pumps.

c) Suctions are to be so positioned that the transfer of sea water can be suitably carried out in the normal operating conditions of the ship. In particular, two suctions may be required in long compartments.

7.2.2 Pumps *(1/7/2012)*

At least two power pumps connected to the ballast system are to be provided, one of which may be driven by the propulsion machinery.

Bilge pumps may be used for ballast water transfer provided the provisions of [6.7.3] are fulfilled.

7.2.3 Passage of ballast pipes through tanks *(1/7/2006)*

If not contained in pipe tunnels, the parts of ballast pipes passing through tanks intended to contain fresh water, fuel oil or liquid cargo are to comply with [5.2.3].

7.3 Ballast Water Management Systems

7.3.1 *(1/1/2017)*

When a Ballast water Management (treatment) system is installed on board, the requirements in App 8 are to be complied with.

8 Scuppers and sanitary discharges

8.1 Application

8.1.1

a) This Article applies to:
- scuppers and sanitary discharge systems, and
- discharges from sewage tanks.

b) Discharges in connection with machinery operation are dealt with in [2.8].

Note 1: Arrangements not in compliance with the provisions of this Article may be considered for the following ships:
- ships of less than 24 m in length
- cargo ships of less than 500 tons gross tonnage
- ships to be assigned restricted navigation notations
- non-propelled units.

8.2 Principle

8.2.1 *(1/7/2017)*

a) Scuppers, sufficient in number and suitable in size, are to be provided to permit the drainage of water likely to accumulate in the spaces which are not located in the ship's bottom. The Society may permit the means of drainage to be dispensed with in any particular compartment if it is satisfied that, by reason of size or internal subdivision of such space, the safety of the ship is not impaired.

b) The number of scuppers and sanitary discharge openings in the shell plating is to be reduced to a minimum either by making each discharge serve as many as possible of the sanitary and other pipes, or in any other satisfactory manner.

8.3 Drainage from spaces below the freeboard deck or within enclosed superstructures and deckhouses on the freeboard deck

8.3.1 **Normal arrangement** *(1/7/2017)*

Scuppers and sanitary discharges from spaces below the freeboard deck or from within superstructures and deckhouses on the freeboard deck fitted with doors complying with the provisions of Pt B, Ch 9, Sec 6 are to be led to:

a) a suitable space, or spaces, of appropriate capacity, having a high water level alarm and provided with suitable pumping arrangements for discharge overboard. In addition, it is to be ensured that:
   1) the number, size and arrangement of the scuppers are such as to prevent unreasonable accumulation of free water,
   2) the pumping arrangements take account of the requirements for any fixed pressure water-spraying fire-extinguishing system
   3) water contaminated with petrol or other dangerous substances is not drained to machinery spaces or other spaces where sources of ignition may be present, and
   4) where the enclosed cargo space is protected by a carbon dioxide fire-extinguishing system, the deck scuppers are fitted with means to prevent the escape of the smothering gas.

b) suitable sanitary tanks in the case of sanitary discharges.

8.3.2 **Alternative arrangement** *(1/7/2017)*

The scuppers and sanitary discharges may be led overboard provided that:
- the freeboard deck edge is not immersed when the ship heels 5°, and
- the inboard end of the discharge is located above the load waterline formed by a 5° heel, to port or starboard, at a draft corresponding to the assigned summer freeboard, and,
- the pipes are fitted with efficient means of preventing water from passing inboard in accordance with [8.6] and [8.7].

8.4 Drainage of superstructures or deckhouses not fitted with efficient weathertight doors

8.4.1 *(1/7/2017)*

Scuppers leading from superstructures or deckhouses not fitted with doors complying with the requirements of Pt B, Ch 9, Sec 6 are to be led overboard, and subject to [8.3.2].

8.5 Drainage of cargo spaces, other than ro-ro spaces, intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion

8.5.1 Prevention of build-up of free surfaces *(1/7/2011)*

In cargo spaces, other than ro-ro spaces, intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion and fitted with a fixed pressure water-spraying fire-extinguishing system, the drainage arrangement is to be in compliance with the requirements contained in the guidelines developed by IMO (see Note 1) such as to prevent the build-up of free surfaces.

Note 1: see resolution MSC.1/Circ. 1320 "Guidelines for the drainage of fire-fighting water from closed vehicle and ro-ro spaces and special category spaces of passenger and cargo ships".

8.5.2 Scupper draining

Scuppers from cargo spaces, other than ro-ro spaces, intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion are not to be led to machinery spaces or other places where sources of ignition may be present.

8.6 Arrangement of discharges - General

8.6.1 Arrangement of discharges through the shell more than 450 mm below the freeboard deck or less than 600 mm above the summer load waterline *(1/7/2017)*

Scupper and discharge pipes originating at any level and penetrating the shell either more than 450 millimetres below the freeboard deck or less than 600 millimetres above the summer load waterline are to be provided with a non-return valve at the shell. Unless required by [8.7], this valve may be omitted if the piping is of substantial thickness, as per Tab 22.

8.6.2 Arrangement of discharges through the shell less than 450 mm below the freeboard deck and more than 600 mm above the summer load waterline *(1/7/2017)*

Scupper and discharge pipes penetrating the shell less than 450 millimetres below the freeboard deck and more than 600 millimetres above the summer load waterline are not required to be provided with a non-return valve at the shell, except for the cases indicated in [8.7].

8.7 Arrangement of discharges from enclosed spaces below the freeboard deck or on the freeboard deck

8.7.1 Normal arrangement *(1/7/2017)*

Each separate discharge led though the shell plating from enclosed spaces below the freeboard deck is to be provided with one automatic non-return valve fitted with positive means of closing it from above the freeboard deck or one automatic non-return valve and one sluice valve controlled from above the freeboard deck.

The requirements for non-return valves are applicable only to those discharges which remain open during the normal operation of the ship; For discharges which are to be kept closed at sea (such as gravity drain from topside ballast tanks), a single screw down valve operated from above the freeboard deck is acceptable.

Where a valve with positive means of closing is fitted, the operating position above the freeboard deck shall always be readily accessible and means shall be provided for indicating whether the valve is open or closed.

The position of the inboard end of discharges is related to the timber summer load waterline when a timber freeboard is assigned.

8.7.2 Alternative arrangement when the inboard end of the discharge pipe is above the summer waterline by more than 0,01 L *(1/7/2017)*

Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,01 L, the discharge may have two automatic non-return valves without positive means of closing, provided that the inboard valve:

- is above the deepest subdivision load line, and
- is always accessible for examination under service conditions.

If the inboard non-return valve is not according to the above, a valve with positive means of closing controlled locally is to be fitted in between the shell plating and the inboard valve.

8.7.3 Alternative arrangement when the inboard end of the discharge pipe is above the summer waterline by more than 0,02 L

Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,02 L, a single automatic non-return valve without positive means of closing may be accepted subject to the approval of the Society.

Note 1: This requirement does not apply to ships for which the notation chemical tanker or liquefied gas carrier is requested.

8.7.4 Arrangement of discharges through manned machinery spaces *(1/7/2017)*

Where sanitary discharges and scuppers are lead overboard through the shell in way of manned machinery spaces, the fitting at the shell of a locally operated positive closing valve together with a non-return valve inboard may be accepted. The operating position of the valve will be given special consideration by the Society.

8.8 Summary table of overboard discharge arrangements

8.8.1 *(1/7/2024)*

The various arrangements acceptable for scuppers and sanitary overboard discharges are summarised in Table 22.1 of Regulation 22 of the 1966 Convention on Load Line shown in Fig 3.

8.9 Valves and pipes

8.9.1 Materials

a) All shell fittings and valves are to be of steel, bronze or other ductile material. Valves of ordinary cast iron or similar material are not acceptable. All scupper and discharge pipes are to be of steel or other ductile material. Refer to [2.1].

b) Plastic is not to be used for the portion of discharge line from the shell to the first valve.

8.9.2 Thickness of pipes *(1/7/2017)*

a) The thickness of scupper and discharge pipes led to the bilge or to draining tanks is not to be less than that required in [2.2].

b) The thickness of scupper and discharge pipes led to the shell is not to be less than the minimum thickness given in Tab 22, for the part between the shell plating and the outermost valve.

8.9.3 Operation of the valves

a) Where valves are required to have positive means of closing, such means is to be readily accessible and provided with an indicator showing whether the valve is open or closed.

b) Where plastic pipes are used for sanitary discharges and scuppers, the valve at the shell is to be operated from outside the space in which the valve is located.

Where such plastic pipes are located below the summer waterline (timber summer load waterline), the valve is to be operated from a position above the freeboard deck.

Refer also to App 3.

8.10 Arrangement of scuppers and sanitary discharge piping

8.10.1 Overboard discharges and valve connections

a) Overboard discharges are to have pipe spigots extending through the shell plate and welded to it, and are to be provided at the internal end with a flange for connection to the valve or pipe flange.

b) Valves may also be connected to the hull plating in accordance with the provisions of [2.8.3] c).

Figure 3 : Overboard discharge arrangement *(1/7/2017)*

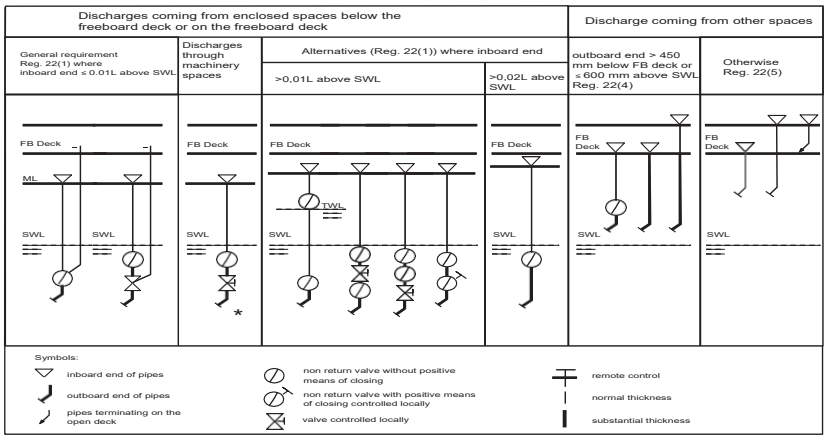


Table 22 : Minimum thickness of scupper and discharge pipes led to the shell

External diameter of the pipe d (mm)	Column 1 substantial thickness (mm)	Column 2 normal thickness (mm)
d ≤ 80,0	7,00	4,50
155	9,25	4,50
180	10,00	5,00
220	12,50	5,80
230 ≤ d	12,50	6,00
Note 1: Intermediate sizes may be determined by interpolation.		

8.10.2 Passage through cargo spaces

Where scupper and sanitary discharge pipes are led through cargo spaces, the pipes and the valves with their controls are to be adequately protected by strong casings or guards.

8.10.3 Passage through tanks

a) As a rule, scupper and sanitary discharge pipes are not to pass through fuel oil tanks.

b) Where scupper and discharge pipes pass unavoidably through fuel oil tanks and are led through the shell within the tanks, the thickness of the piping is not to be less than that given in Tab 22, column 1 (substantial thickness). It need not, however, exceed the thickness of the adjacent Rule shell plating.

c) Scupper and sanitary discharge pipes are normally not to pass through fresh and drinking water tanks.

d) For passage through cargo oil tanks, see Pt E, Ch 7, Sec 4.

8.10.4 Passage through watertight bulkheads or decks

a) The intactness of machinery space bulkheads and of tunnel plating required to be of watertight construction is not to be impaired by the fitting of scuppers discharging to machinery spaces or tunnels from adjacent compartments which are situated below the freeboard deck.

b) Such scuppers may, however, be led into a strongly constructed scupper drain tank situated in the machinery space or tunnel, but close to the above-mentioned adjacent compartments and drained by means of a suction of appropriate size led from the main bilge line through a screw-down non-return valve.

8.10.5 Discharge in refrigerated spaces

No scupper pipe from non-refrigerated spaces is to discharge in refrigerated spaces.

8.10.6 Discharge from galleys and their stores

Discharges from galleys and their stores are to be kept separate from other discharges and be drained overboard or in separate drainage tanks; alternatively, discharges are to be provided with adequate devices against odours and overflow.

8.10.7 Discharge from aft spaces

Where spaces located aft of the aft peak bulkhead not intended to be used as tanks are drained by means of scuppers discharging to the shaft tunnel, the provisions of [6.6.4], item c) are to be complied with.

8.10.8 Scupper tank

a) The scupper tank air pipe is to be led to above the freeboard deck.

b) Provision is to be made to ascertain the level of water in the scupper tank.

9 Air, sounding and overflow pipes

9.1 Air pipes

9.1.1 Principle

Air pipes are to be fitted to all tanks, double bottoms, cofferdams, tunnels and other compartments 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. Their open ends are to be so arranged as to prevent the free entry of sea water in the compartments.

9.1.2 Number and position of air pipes

a) Air pipes are to be so arranged and the upper part of compartments so designed that air or gas likely to accumulate at any point in the compartments can freely evacuate.

b) Air pipes are to be fitted opposite the filling pipes and/or at the highest parts of the compartments, the ship being assumed to be on an even keel.

c) In general, two air pipes are to be fitted for each compartment, except in small compartments, where only one air pipe may be accepted. When the top of the compartment 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.

9.1.3 Location of open ends of air pipes

a) Air pipes of double bottom compartments, tunnels, deep tanks and other compartments which can come into contact with the sea or be flooded in the event of hull damage are to be led to above the bulkhead deck or the freeboard deck.

Note 1: In ships not provided with a double bottom, air pipes of small cofferdams or tanks not containing fuel oil or lubricating oil may discharge within the space concerned.

b) Air pipes of tanks intended to be pumped up are to be led to the open above the bulkhead deck or the freeboard deck.

c) Air pipes other than those of fuel oil tanks may be led to enclosed cargo spaces situated above the freeboard deck, provided that such spaces are fitted with scuppers discharging overboard, which are capable of draining all the water which may enter through the air pipes without giving rise to any water accumulation.

d) Air pipes of tanks other than oil tanks may discharge through the side of the superstructure.

e) The air pipe of the scupper tank is to be led to above freeboard deck.

f) The location of air pipes for flammable oil tanks is also to comply with [9.1.7].

9.1.4 Height of air pipes

a) The height of air pipes extending above the freeboard deck or superstructure deck from the deck to the point where water may have access below is to be at least:

- 760 mm on the freeboard deck, and
- 450 mm on the superstructure deck.

This height is to be measured from the upper face of the deck, including sheathing or any other covering, up to the point where water may penetrate inboard.

b) Where these heights may interfere with the working of the ship, a lower height may be approved, provided the Society is satisfied that this is justified by the closing arrangements and other circumstances. Satisfactory means which are permanently attached are to be provided for closing the openings of the air pipes.

c) The height of air pipes may be required to be increased on ships for the purpose of compliance with buoyancy calculations.

d) The height of air pipes discharging through the side of the superstructure is to be at least 2,3 m above the summer load waterline.

Note 1: For ships to be assigned a restricted service notation, the height of air pipes may be reduced to:

- 450 mm on the freeboard deck,
- 300 mm on the superstructure deck.

9.1.5 Fitting of closing appliances *(1/7/2006)*

a) Satisfactory appliances which are permanently attached are to be provided for closing the openings of air pipes in order to prevent the free entry of water into the spaces concerned.

b) Closing appliances are to be of automatic type in the following cases:
- when fitted on exposed parts of freeboard deck and first superstructure deck,
- where, with the ship at its summer load waterline, the openings are immersed at an angle of heel of 40° or, at the angle of down-flooding if the latter is less than 40°,
- where, as per [9.1.3], item c), air pipes terminate in enclosed spaces,
- where, as per [9.1.4], item b), air pipes have a height lower than that required in [9.1.4], item a),
- and for ships assigned timber freeboard.

See also Pt B, Ch 3, Sec 2, [2.1.2] and Pt F, Ch 13, Sec 11, [2.1.4].

c) Automatic closing appliances are to be of a type approved by the Society. Requirements for type tests are given in [21.2.2].

d) For ships subject to specific buoyancy or stability requirements, or for ships not subject to the 1966 International Convention on Load Lines in force, the fitting of closing appliances to air pipes will be given special consideration.

e) Pressure/vacuum valves installed on cargo tanks, as per Part E, Chapter 7 and Part E, Chapter 8, can be accepted as closing appliances.

9.1.6 Design of closing appliances *(1/7/2022)*

a) When closing appliances are requested to be of an automatic type by these Rules, the International Convention on Load Lines, 1966 or the Protocol of 1988 relating to the International Convention on Load Lines, 1966, as amended by IMO resolutions up to MSC.375(93), they are to comply with the following:
- they are to be capable of preventing the free entry of water into the tanks;
- they are to allow the passage of air or liquid to prevent excessive pressure or vacuum coming on the tank;
- they are to be so designed that they withstand both ambient and working conditions up to an inclination of -40° to +40° without failure or damage;
- they are to be so designed as to allow inspection of the closure and the inside of the casing as well as changing of the seals;
- where they are of the float type, suitable guides are to be provided to ensure unobstructed operation under all working conditions of heel and trim up to an inclination of -40° to +40°;
- efficient ball or float seating arrangements are to be provided for the closures. Bars, a cage or other devices are to be provided to prevent the ball or float from contacting the inner chamber in its normal state and made in such a way that the ball or float is not damaged when subjected to water impact due to a tank being overfilled;
- they are to be self-draining;
- the clear area through an air pipe closing appliance is to be at least equal to the area of the inlet;
- the maximum allowable tolerances for wall thickness of floats is not to exceed ±10% of the nominal thickness;
- their casings are to be of approved metallic materials adequately protected against corrosion;
- closures and seats made of non-metallic materials are to be compatible with the media to be carried in the tank and with sea water at ambient temperatures between -25°C and 85°C;
- the inner and outer chambers of an automatic air pipe head are to be of a minimum thickness of 6 mm. Where side covers are provided and their function is integral to providing functions of the closing device as outlined above, they shall have a minimum wall thickness of 6 mm. If the air pipe head can meet the tightness test in the "Rules for type approval and testing of air pipe closing devices" without the side covers attached, then the side covers are not considered to be integral to the closing device, in which case a wall thickness less than 6 mm can be acceptable for side covers;
- for galvanised steel air pipe heads, the zinc coating is to be applied by the hot method and the thickness is to be 70 to 100 microns;
- for areas of the head susceptible to erosion (e.g. those parts directly subjected to ballast water impact when the tank is being pressed up, for example the inner chamber area above the air pipe, plus an overlap of 10° or more either side), an additional harder coating is to be applied. This is to be an aluminium bearing epoxy, or other equivalent, coating, applied over the zinc.

b) Where closing appliances are not of an automatic type, provision is to be made for relieving vacuum when the tanks are being pumped out. For this purpose, a hole of approximately 10 mm in diameter may be provided in the bend of the air pipe or at any other suitable position in the closing appliance.

c) Wooden plugs and trailing canvas are not permitted in position 1 or position 2, as defined in Pt B, Ch 1, Sec 2.

9.1.7 Special arrangements for air pipes of flammable oil tanks *(1/7/2004)*

a) Air and overflow pipes and relief valves of fuel oil and thermal oil systems are to discharge to a position on the open deck where there is no risk of fire or explosion from the emergence of oils and vapour.

The open ends are to be fitted with flame screens made of corrosion resistant material and readily removable for cleaning and replacement. The clear area of such screens is not to be less than the cross-sectional area of the pipe.

b) Air pipes of lubricating or hydraulic oil storage tanks not subject to flooding in the event of hull damage 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.

c) The location and arrangement of vent pipes for fuel oil service, settling and lubrication oil tanks are to be such that in the event of a broken vent pipe there is no risk of ingress of seawater or rainwater.

d) Air pipes of fuel oil service, settling and lubrication oil tanks likely to be damaged by impact forces are to be adequately reinforced.

e) Where seawater or rainwater may enter fuel oil service, settling and lubrication oil tanks through broken air pipes, arrangements such as water traps with:

- automatic draining, or
- alarm for water accumulation

are to be provided.

9.1.8 Construction of air pipes

a) Where air pipes to ballast and other tanks extend above the freeboard deck or superstructure deck, the exposed parts of the pipes are to be of substantial construction, with a minimum wall thickness of at least:

- 6,0 mm for pipes of 80 mm or smaller external diameter
- 8,5 mm for pipes of 165 mm or greater external diameter,

Intermediate minimum thicknesses may be determined by linear interpolation.

b) Air pipes with height exceeding 900 mm are to be additionally supported.

c) In each compartment 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.

d) The internal diameter of air pipes is not to be less than 50 mm, except for tanks of less than 2 m^3.

9.1.9 Green sea loads *(1/7/2014)*

The requirements in [9.1.9] and in [9.1.10] apply to strength checks of air pipes and their closing devices located within the forward quarter length of the ship, for ships of length L 80 m or greater, where the height of the exposed deck in way of the item is less than 0,1L or 22 m above the summer load waterline, whichever is the lesser. However, these requirements do not apply to the pipes of cargo tank venting systems and inert gas systems in ships with one of the service notations **oil tanker ESP, chemical tanker ESP, FLS tanker** and **tanker**.

The pressures p, in kN/m^2 acting on air pipes and their closing devices may be calculated from:

$$p = 0,5\ \rho\ V^2\ C_d\ C_s\ C_p$$

where:

L : ship length as defined in Pt B, Ch 1, Sec 2, [3.1]

ρ : density of sea water (1,025 t/m^3)

V : velocity of water over the fore deck

= 13,5m/sec for $d \leq 0,5\ d_1$

$$= 13,5\sqrt{2\left(1 - \frac{d}{d_1}\right)}\ \text{m/sec}$$

for $0,5\ d_1 < d < d_1$

d : distance from summer load waterline to exposed deck

d_1 : 0,1L or 22 m whichever is the lesser

C_d : shape coefficient

= 0,5 for pipes, 1,3 for air pipes in general, 0,8 for an air pipe of cylindrical form with its axis in the vertical direction.

C_s : slamming coefficient (3,2)

C_p : protection coefficient:

- (0,7) for pipes located immediately behind a breakwater or forecastle,
- (1,0) elsewhere and immediately behind a bulwark.

Forces acting in the horizontal direction on the pipe and its closing device may be calculated from the pressure specified in this requirement using the largest projected area of each component.

9.1.10 Strength Requirements *(1/1/2004)*

These requirements are additional to those specified in [9.1.6] a), in [21.2.2] and in [9.1.8] a).

a) Bending moments and stresses in air pipes are to be calculated at critical positions: at penetration pieces, at weld or flange connections, at toes of supporting brackets. Bending stresses in the net section are not to exceed 0,8 σ_y, where σ_y is the specified minimum yield stress, or 0,2% proof stress of the steel at room temperature. Irrespective of corrosion protection, a corrosion addition of 2,0 mm is then to be applied to the net section.

b) For standard air pipes of 760 mm height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Tab 23.

Where brackets are required, three or more radial brackets are to be fitted. Brackets are to be of at least 8 mm gross thickness, minimum 100 mm in length and height according to Tab 23, but need not extend over the joint flange for the head. Bracket toes at the deck are to be suitably supported.

c) For other configurations, loads according to [9.1.9] are to be applied, and means of support determined in order to comply with the requirements specified in a). Where fitted, brackets are to be of suitable thickness and length according to their height. Pipe thickness is not to be taken less than as indicated in [9.1.8] a).

d) All component parts and connections of the air pipe are to be capable of withstanding the loads defined in [9.1.9].

Table 23 : 760 mm Air Pipe Thickness and Bracket Standards *(1/1/2004)*

Nominal pipe diameter (mm)	Minimum fitted gross thickness (mm)	Maximum projected area of head (cm^2)	Height **(1)** of brackets (mm)
65	6,0	-	480
80	6,3	-	460
100	7,0	-	380
125	7,8	-	300
150	8,5	-	300
175	8,5	-	300
200	8,5 **(2)**	1900	300 **(2)**
250	8,5 **(2)**	2500	300 **(2)**
300	8,5 **(2)**	3200	300 **(2)**
350	8,5 **(2)**	3800	300 **(2)**
400	8,5 **(2)**	4500	300 **(2)**

(1) Brackets (see [9.1.10]) need not extend over the joint flange for the head.

(2) Brackets are required where the as fitted (gross) thickness is less than 10,5 mm, or where the tabulated projected head area is exceeded.

Note 1: For other air pipe heights, the relevant requirements in [9.1.10] are to be applied.

9.2 Sounding pipes

9.2.1 Principle

a) Sounding devices are to be fitted to tanks intended to contain liquids as well as to all compartments which are not readily accessible at all times.

b) For compartments normally intended to contain liquids, the following systems may be accepted in lieu of sounding pipes:

- a level gauge of an approved type efficiently protected against shocks, or
- a remote level gauging system of an approved type, provided an emergency means of sounding is available in the event of failure affecting such system.

9.2.2 Position of sounding pipes

Sounding pipes are to be located as close as possible to suction pipes.

9.2.3 Termination of sounding pipes

a) As a general rule, sounding pipes are to end above the bulkhead deck or the freeboard deck in easily accessible places and are to be fitted with efficient, permanently attached, metallic closing appliances.

b) In machinery spaces and tunnels, where the provisions of a) cannot be satisfied, short sounding pipes led to readily accessible positions above the floor and fitted with efficient closing appliances may be accepted.

In ships required to be fitted with a double bottom, such closing appliances are to be of the self-closing type.

9.2.4 Special arrangements for sounding pipes of flammable oil tanks

a) Where sounding pipes are used in flammable (except lubricating) oil systems, they are to terminate in the open air, where no risk of ignition of spillage from the sounding pipe might arise. In particular, they are not to terminate in passenger or crew spaces. As a general rule, they are not to terminate in machinery spaces. However, where the Society considers that this requirement is impracticable, it may permit termination in machinery spaces on condition that the following provisions are satisfied:

1) in addition, an oil-level gauge is provided meeting the provisions of [2.9.2]

2) the sounding pipes terminate in locations remote from ignition hazards unless precautions are taken, such as the fitting of effective screens, to prevent the fuel oil in the case of spillage through the terminations of the sounding pipes from coming into contact with a source of ignition

3) the terminations of sounding pipes are fitted with self-closing blanking devices and with a small diameter self-closing control cock located below the blanking device for the purpose of ascertaining before the blanking device is opened that fuel oil is not present. Provision is to be made so as to ensure that any spillage of fuel oil through the control cock involves no ignition hazard.

b) For lubricating oil and fuel oil leakage tanks less than 2 m^3, the oil-level gauge mentioned in a).1 and the control cock mentioned in a).3 need not be provided on condition that the sounding pipes are fitted with appropriate means of closure.

c) Short sounding pipes may be used for tanks other than double bottom tanks without the additional closed level gauge provided an overflow system is fitted.

9.2.5 Closing appliances

a) Self-closing appliances are to be fitted with cylindrical plugs having counterweights such as to ensure automatic closing.

b) Closing appliances not required to be of the self-closing type may consist of a metallic screw cap secured to the pipe by means of a chain or a shut-off valve.

9.2.6 Construction of sounding pipes

a) Sounding pipes are normally to be straight. If it is necessary to provide bends in such pipes, the curvature is to be as small as possible to permit the ready passage of the sounding apparatus.

b) In cargo ships, the sounding arrangement of compartments by means of bent pipes passing through other compartments will be given special consideration by the Society. Such an arrangement is normally accepted only if the compartments passed through are cofferdams or are intended to contain the same liquid as the compartments served by the sounding pipes.

c) Bent portions of sounding pipes are to have reinforced thickness and be suitably supported.

d) The internal diameter of sounding pipes is not to be less than 32 mm. Where sounding pipes pass through refrigerated spaces, or through the insulation of refrigerated spaces in which the temperature may be below 0°C, their internal diameter is to be at least 60 mm.

e) Doubling plates are to be placed under the lower ends of sounding pipes in order to prevent damage to the hull. When sounding pipes with closed lower ends are used, the closing plate is to have reinforced scantlings.

9.3 Overflow pipes

9.3.1 Principle

Overflow pipes are to be fitted to tanks:

- which can be filled by pumping and are designed for a hydrostatic pressure lower than that corresponding to the height of the air pipe, or

- where the cross-sectional area of air pipes is less than that prescribed in [9.1.8], item c).

9.3.2 Design of overflow systems

a) Overflow pipes are to be led:
   - either outside,
   - or, in the case of fuel oil or lubricating oil, 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
   - overfilling of any tank from another assumed flooded due to hull damage.

   For this purpose, overflow pipes are to be led to a high enough point above the deepest load waterline or, alternatively, non-return valves are to fitted where necessary.

c) Arrangements are to be made so that a compartment cannot be flooded from the sea through the overflow in the event of another compartment connected to the same overflow main being bilged. To this end, the openings of overflow pipes discharging overboard are as a rule to be placed above the deepest load waterline and are to be fitted where necessary with non-return valves on the plating, or, alternatively, overflow pipes from tanks are to be led to a point above the deepest load waterline.

d) Where deep tanks which can be used to contain liquid or dry cargo or fuel oil are connected to a common overflow system, arrangements are to be made so that liquid or vapours from other compartments cannot enter such tanks when carrying dry cargo.

e) Where tanks alternately containing fuel oil and ballast water are connected to a common overflow system, arrangements are to be made to prevent the ballast water overflowing into the tanks containing fuel oil and vice-versa.

f) Additional requirements for ships subject to damage stability checks are given in [5.5.3].

9.3.3 Overflow tanks

a) Overflow tanks are to have a capacity sufficient to receive the delivery of the pumps for at least 10 minutes.

b) Overflow tanks are to be fitted with an air pipe complying with [9.1] which may serve as an overflow pipe for the same tank. When the vent pipe reaches a height exceeding the design head of the overflow tank, suitable means are to be provided to limit the actual hydrostatic head on the tank.

   Such means are to discharge to a position which is safe in the opinion of the Society.

c) 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.

9.3.4 Specific requirements for construction of overflow pipes

a) The internal diameter of overflow pipes is not to be less than 50 mm.

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.

9.4 Constructional requirements applying to sounding, air and overflow pipes

9.4.1 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.

9.4.2 Minimum thickness of steel pipes

The minimum thickness of sounding, air and overflow steel pipes is given in Tab 24.

Table 24 : Minimum wall thickness of sounding, air and overflow pipes

External diameter (mm)	Minimum wall thickness (mm) **(1)**
up to 168,3	4,5
177,8	5,0
193,7	5,4
219,1	5,9
above 244,5	6,3
(1) Applies only to structural tanks. For independent tanks, refer to Tab 5.	

9.4.3 Passage of pipes through certain spaces *(1/7/2006)*

a) Air pipes and sounding pipes led through refrigerated cargo holds or spaces are to be suitably insulated.

b) When sounding, air and overflow pipes made of steel are permitted to pass through ballast tanks or fuel oil tanks, they are to comply with [5.2.3].

c) Sounding, air and overflow pipes passing through cargo holds are to be adequately protected.

9.4.4 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.

9.4.5 Name plates

Nameplates are to be fixed at the upper part of air pipes and sounding pipes.

10 Cooling systems

10.1 Application

10.1.1 This article applies to all cooling systems using the following cooling media:

- sea water
- fresh water
- lubricating oil.

Air cooling systems will be given special consideration.

10.2 Principle

10.2.1 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 in Sec 1.

10.2.2 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.

10.3 Design of sea water cooling systems

10.3.1 General

a) Sea water cooling of the propulsion engines, auxiliary engines and other essential equipment is to be capable of being supplied by two different means.

b) Where required, standby pumps are not to be connected to the sea inlet serving the other sea water pumps, unless permitted under [10.7.1], item b).

10.3.2 **Centralised cooling systems** *(1/7/2002)*

a) In the case of centralised cooling systems, i.e. systems serving a group of propulsion engines and/or auxiliary engines, reduction gears, compressors and other essential equipment, the following sea water pumps are to be arranged:
   - one main cooling water pump, which may be driven by the engines, of a capacity sufficient to provide cooling water to all the equipment served
   - one independently driven standby pump of at least the same capacity

b) Where the cooling system is served by a group of identical pumps, the capacity of the standby pump needs only to be equivalent to that of each of these pumps.

c) Ballast pumps or other suitable sea water pumps of appropriate capacity may be used as standby pumps, provided arrangements are made against overpressure in the cooling system.

d) In ships having one or more propulsion engines, each with an output not exceeding 375 kW, the independent standby pump may be replaced by a complete spare pump of appropriate capacity ready to be connected to the cooling circuit.

e) In cases of centralised cooling systems serving only a group of auxiliary engines, the second means of cooling may consist of a connection to a cooling water pump serving the propulsion plant, provided such pump is of sufficient capacity to provide cooling water to both propulsion plant and auxiliary engines.

10.3.3 **Individual cooling of propulsion engines** *(1/7/2002)*

a) Individual cooling systems of propulsion engines are to include at least:
   - one main cooling water pump, which can be driven by the engine
   - one independently driven standby pump

   Where the output of the engine does not exceed 375 kW, the following arrangements may be accepted:
   - one main cooling water pump, which can be driven by the engine
   - one spare pump of appropriate capacity ready to be connected to the cooling circuit

b) Where, in ships having more than one engine per propeller or having several propellers, each engine is served by its own cooling circuit, the second means requested in [10.3.1] is to be provided, consisting of:
   - a connection to an independently driven pump, such as a ballast pump or any other suitable sea water pump of sufficient capacity provided arrangements against overpressure in the cooling system are made. (See [10.7.4], b)),
   - or a complete spare pump identical to those serving the engines and ready to be connected to the cooling circuit.

   This second means may be omitted, however, when safety justifications are provided as regards the propulsion and manoeuvring capabilities of the ship with one cooling circuit disabled.

10.3.4 Individual cooling of auxiliary engines

Where each auxiliary engine is served by its own cooling circuit, no second means of cooling is required.

10.3.5 Cooling of steam plants

a) Steam plants are to be fitted with:
   - a main circulating pump
   - a standby pump capable of ensuring the circulation in the main condenser in the event of failure of the main circulating pump.

b) Where the installation includes more than one propulsive unit, the standby pump is not required, provided a branch pipe is fitted between the discharges of the circulating pumps of each unit.

c) In lieu of the main circulating pump, a sea inlet scoop system may be accepted, provided that an additional means is fitted to ensure the circulation of sea water to the condenser when the ship is manoeuvring. Such means may be:
   - an additional independent pump,
   - or a connection to an available pump of sufficient capacity.

10.3.6 Cooling of other essential equipment

a) The second means of cooling required in [10.3.1] for essential equipment may consist of a connection to a ballast pump or other suitable sea water pump of sufficient capacity, provided arrangements are made against overpressure in the cooling system. (See [10.7.4], item b)).

b) However, where such essential equipment is duplicate, this second means may be omitted when safety justifications are provided as regards the propulsion and manoeuvring capabilities of the ship with the cooling circuit of one set of equipment disabled.

10.4 Design of fresh water cooling systems

10.4.1 General

Fresh water cooling systems are to be designed according to the applicable requirements of [10.3].

10.4.2 Cooling systems

a) Fresh water cooling systems of essential equipment are to include at least:
   - one main cooling water pump, which can be driven by the equipment
   - one independently driven standby pump.

b) The standby pump may be omitted provided an emergency connection to a suitable sea water system is fitted and arranged with a suitable change-over device. Provisions against overpressure in the cooling system are to be made in accordance with [10.7.4], item b).

c) The standby pump may also be omitted in the case of redundancy of the cooled equipment.

10.4.3 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.

10.4.4 Detection of fuel oil or lubricating oil

A device is to be fitted in fresh water cooling systems comprising fuel oil or lubricating oil heat exchangers in order to detect any contamination of the water by fuel oil or lubricating oil.

10.5 Design of oil cooling systems

10.5.1 General

Oil cooling systems are to be designed according to the applicable requirements of [10.3].

10.5.2 Second means of cooling

The second means of cooling requested in [10.3.1] may consist of a satisfactory connection to a lubricating oil pump of sufficient capacity. Arrangements are to be made against overpressure in the cooling system.

10.6 Control and monitoring

10.6.1 General *(1/7/2006)*

In addition to those of this item [10.6], the general requirements given in Chapter 3 apply.

In the case of ships with automation notations, the requirements in Part F, Chapter 3 also apply.

10.6.2 Alarms are to be provided for water cooling systems in accordance with Tab 25, in addition to the requirements stated for diesel engines in Sec 2 and for steam plants in Sec 4.

Note 1: Some departures from Tab 25 may be accepted by the Society in the case of ships with a restricted navigation notation.

10.7 Arrangement of cooling systems

10.7.1 Sea inlets

a) At least two sea inlets complying with [2.8] are to be provided for the cooling system, one for each means of cooling required in [10.3.1].

b) The two sea inlets may be connected by a cross-over supplying both main cooling pump and standby cooling pump.

c) When the second means of cooling is a spare pump, the two sea inlets are to be provided in any event, both serving the main cooling pump.

d) The sea inlets are to be low inlets, so designed as to remain submerged under all normal navigating conditions.

In general, one sea inlet is to be arranged on each side of the ship.

e) One of the sea inlets may be that of the ballast pump or of the general service pump.

Table 25 : 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					

10.7.2 Coolers

a) Coolers are to be fitted with isolating valves at the inlets and outlets.

b) Coolers external to the hull (chest coolers and keel coolers) are to be fitted with isolating valves at the shell.

10.7.3 Filters

a) Where propulsion engines and auxiliary engines for essential services are directly cooled by sea water, both in normal service and in emergency operating conditions, filters are to be fitted on the suction of cooling pumps.

b) These filters are to be so arranged that they can be cleaned without interrupting the cooling water supply.

10.7.4 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 general service pumps, ballast pumps or other pumps 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.

10.7.5 Air venting

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.

11 Fuel oil systems

11.1 Application

11.1.1 Scope

This Article applies to all fuel oil systems supplying any kind of installation.

11.1.2 Requirements applying to fuel oil systems and not contained in this Section *(1/1/2007)*

Additional requirements are given:

- for independent fuel oil tanks, in App 4
- for fuel oil supply equipment forming part of engines, gas turbines, boilers, thermal heaters and incinerators, in the corresponding sections
- for the location and scantling of tanks forming part of the ship's structure, in Part B, Chapter 2 and Part B, Chapter 7.

11.2 Principle

11.2.1 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 Sec 1.

11.2.2 Availability of fuel systems

a) Fuel oil systems are to be so designed that, in the event that any one essential auxiliary of such systems becomes inoperative, the fuel oil supply to boilers and engines can be maintained (see also [11.2.1] a)). Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired.

b) Fuel oil tanks are to be so arranged that, in the event of damage to any one tank, complete loss of the fuel supply to essential services does not occur.

c) Where engines and boilers are operated with heavy fuel oils, provisions are to be made to supply them with fuel oils which do not need to be heated.

11.3 General

11.3.1 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 [5.10] are to be complied with.

11.3.2 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.

11.3.3 Ventilation

The ventilation of machinery spaces is to be sufficient under all normal conditions to prevent accumulation of oil vapour.

11.3.4 Access

Spaces where fuel oil is stored or handled are to be readily accessible.

11.4 Design of fuel oil filling and transfer systems

11.4.1 General

a) A system of pumps and piping for filling and transferring fuel oil is to be provided.

b) Provisions are to be made to allow the transfer of fuel oil from any storage, settling or service tank to another tank.

11.4.2 Filling systems

a) Filling pipes of fuel oil tanks are to terminate on open deck or in filling stations isolated from other spaces and efficiently ventilated. Suitable coamings and drains are to be provided to collect any leakage resulting from filling operations.

b) Arrangements are to be made to avoid overpressure in the filling lines which are served by pumps on board. Where safety valves are provided for this purpose, they are to discharge to the overflow tank referred to in [9.3.3] or to other safe positions deemed satisfactory.

11.4.3 Independence of fuel oil transfer lines

Except where permitted in [11.4.5], the fuel oil transfer piping system is to be completely separate from the other piping systems of the ship.

11.4.4 Simultaneous transfer of fuel oil and ballast water

Where, under the provisions of [7.1.3], tanks are intended to alternately contain fuel oil and ballast water, the piping arrangement is to be such that fuel may be transferred by means of fuel pumps to or from any tank while ballast pumps are simultaneously being used.

11.4.5 Alternative carriage of fuel oil, ballast water or other liquid and dry cargo

Where certain compartments are likely to contain alternatively fuel oil, ballast water and other liquid or dry cargo, the transfer pipes supplying these compartments are to be fitted with blind flanges or other appropriate change-over devices.

11.4.6 Transfer pumps

a) At least two means of transfer are to be provided. One of these means is to be a power pump. The other may consist of:
   - a standby pump,
   - or, alternatively, an emergency connection to another suitable power pump.

Note 1: Where provided, purifiers may be accepted as means of transfer.

b) 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.

11.5 Arrangement of fuel oil tanks and bunkers

11.5.1 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.

b) Fuel oil tanks and bunkers are not to be situated immediately above boilers or in locations where they could be subjected to high temperatures, unless specially agreed by the Society. In general, the distance between fuel oil tanks and boilers is not to be less than 450 mm. Where boilers are situated above double bottom fuel oil tanks, the distance between the double bottom tank top and the lower metallic part of the boilers is not to be less than:
   - 750 mm for water tube boilers,
   - 600 mm for cylindrical boilers.

c) As far as practicable, fuel oil tanks are to be part of the ship's structure and are to be located outside machinery spaces of category A. Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides is to be contiguous to the machinery space boundaries, and is preferably to have a common boundary with the double bottom tanks, and the area of the tank boundary common with the machinery spaces is to be kept to a minimum. Where such tanks are situated within the boundaries of machinery spaces of category A, they are not to contain fuel oil having a flashpoint of less than 60 °C.

Note 1: Machinery spaces of category A are defined in Ch 4, Sec 1.

d) The location of fuel oil tanks is to be in compliance with the requirements of Part B, Chapter 2, particularly as regards the installation of cofferdams, the separation between fuel oil tanks or bunkers and the other spaces of the ship, and the protection of these tanks and bunkers against any abnormal rise in temperature.

e) Attention is drawn to the requirements of Pt E, Ch 7, Sec 4 regarding the segregation of fuel bunkers from the cargo area.

11.5.2 Use of free-standing fuel oil tanks

a) In general the use of free-standing fuel oil tanks is to be avoided except on cargo ships, where their use is permitted in category A machinery spaces.

b) For the design and the installation of independent tanks, refer to App 4.

11.6 Design of fuel oil tanks and bunkers

11.6.1 General *(1/7/2024)*

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.

A sufficient number of main bunker tanks are to be arranged to limit the need to mix newly bunkered fuel with fuel already on-board. For this purpose at least 2 storage fuel oil tanks are to be provided. In this connection special consideration will be given in case of vessels lower than 200 GT and classed for restricted navigation.

11.6.2 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 Part B, Chapter 7.

b) Scantlings of fuel oil tanks and bunkers which are not part of the ship's structure are to comply with App 4. For cases which are not contained in the Tables of that appendix, scantlings will be given special consideration by the Society.

11.6.3 Filling and suction pipes

a) All suction pipes from fuel oil tanks and bunkers, including those in the double bottom, are to be provided with valves.

b) For storage tanks, filling pipes may also be used for suction purposes.

c) Where the filling pipes to fuel oil bunkers and tanks are not led to the upper part of the such bunkers and tanks, they are to be provided with non-return valves at their ends, unless they are fitted with valves arranged in accordance with the requirements stated in [11.6.4].

11.6.4 Remote control of valves *(1/7/2004)*

a) Every fuel oil pipe which, if damaged, would allow oil to escape from a storage, settling or daily service tank having a capacity of 500 l and above situated above the double bottom, is to be fitted with a cock or valve directly on the tank 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.

Note 1: For the location of the remote controls, refer to [11.11.4], item c).

b) Such valves and cocks are also to include local control and on the remote and local controls it is to be possible to verify whether they are open or shut. (See [2.7.3].)

c) In the special case of deep tanks situated in any shaft or pipe tunnel or similar space, valves are to be fitted on the tank but control in the event of fire may be effected by means of an additional valve on the pipe or pipes outside the tunnel or similar space. If such additional valve is fitted in the machinery space it is to be operated from a position outside this space.

11.6.5 Drain pipes *(1/7/2020)*

Where fitted, drain pipes are to be provided with self-closing valves or cocks.

A tank drain cock is not to be considered as a sampling point.

11.6.6 Air and overflow pipes *(1/7/2020)*

Air and overflow pipes are to comply with [9.1] and [9.3].

As far as practicable, the Service tank overflow return line to the settling tank is to be drawn from near the bottom of the service tank to the top of the settling tank to ensure any accumulating sediment in the service tank bottom is minimized.

11.6.7 Sounding pipes and level gauges

a) Safe and efficient means of ascertaining the amount of fuel oil contained in any fuel oil tank are to be provided.

b) Sounding pipes of fuel oil tanks are to comply with the provisions of [9.2].

c) Oil-level gauges complying with [2.9.2] may be used in place of sounding pipes.

d) Gauge cocks for ascertaining the level in the tanks are not to be used.

11.7 Design of fuel oil heating systems

11.7.1 General

a) Where heavy fuel oil is used, a suitable heating system is to be provided for storage tanks, settling tanks and service tanks in order to ensure that the fuel oil has the correct fluidity and the fuel pumps operate efficiently.

b) Where necessary for pumping purposes, storage tanks containing heavy fuel oil are to be provided with heating systems.

c) Where necessary, pumps, filters, pipes and fittings are to be provided with heat tracing systems.

d) Where main or auxiliary engines are supplied with fuel oil which needs to be heated, arrangements are to be made so that the engines can still operate if one oil heating system or the heating power source is out of action. Such arrangements may consist of an alternative supply of the engines in accordance with [11.10.2].

11.7.2 Tank heating systems *(1/7/2004)*

a) Fuel oil in storage tanks is not to be heated to temperatures within 10°C below the flashpoint of the fuel oil. Fuel oil in service tanks, settling tanks and any other tanks in the supply system may be heated above this limit, provided:

- the length of the vent pipes from such tanks and/or a cooling device is sufficient for cooling the vapours to at least 10°C below the flashpoint of the fuel oil and a temperature sensor is fitted in the vent pipe and adjusted to give an alarm if the temperature should exceeds a limit set at 10°C below the flashpoint of the fuel, or the outlet of the vent pipes is located 3 m away from a source of ignition
- the vent pipes are fitted with suitable flame screens

- there are no openings from the vapour space of the fuel tanks into machinery spaces (bolted manholes are acceptable)
- enclosed spaces are not located directly over such fuel tanks, except for well ventilated cofferdams
- electrical equipment is not fitted in the vapour space of the tanks, unless it is certified to be intrinsically safe.

b) The temperature of the heating medium is not to exceed 220°C.

c) Automatic control sensors are to be provided for each heated tank to maintain the temperature of the fuel oil below the limits prescribed in a) above.

d) Heated tanks are to be provided with temperature measuring systems.

11.7.3 Fuel oil heaters

a) Where steam heaters or heaters using other heating media are provided in fuel oil systems, they are to be fitted with at least a high temperature alarm or a low flow alarm in addition to a temperature control, except where temperatures dangerous for the ignition of the fuel oil cannot be reached.

b) Electric heating of fuel oil is to be avoided as far as practicable.

c) However, when electric heaters are fitted, means are to be provided to ensure that heating elements are permanently submerged during operation. In all cases a safety temperature switch is to be fitted in order to avoid a surface temperature of 220°C and above. It is to be:

- independent from the automatic control sensor
- designed to cut off the electrical power supply in the event of excessive temperature
- provided with manual reset.

d) Fuel oil heaters are to be fitted with relief valves leading back to the pump suction concerned or to any other place deemed satisfactory.

11.8 Design of fuel oil treatment systems

11.8.1 General *(1/7/2020)*

a) Heavy fuel oils used in diesel engines are to be purified and filtered according to the engine manufacturer's requirements.

b) Provisions are to be made to avoid inadvertent entry of non-purified heavy fuel into the daily service tanks, in particular through the overflow system.

c) The capacity and arrangements of the fuel oil treatment system are to be suitable for ensuring availability of treated fuel oil for the Maximum Continuous Rating of the propulsion plant and normal operating load at sea of the generator plant.

d) The capacity and arrangements of the fuel oil treatment system are to be determined on the basis of the requirements of the oil fuelled machinery manufacturer and the types of fuel (e.g. heavy fuel oil and marine diesel oil) to be bunkered to the ship.

11.8.2 Drains *(1/7/2020)*

a) Settling tanks and 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.

If settling tanks are not provided, the fuel oil daily service tanks are to be designed and constructed in such a way as to direct water and sludge towards a drainage outlet.

b) Efficient means are to be provided for draining oily water escaping from the drains.

11.8.3 Purifiers *(1/7/2024)*

a) Where fuel oil needs to be purified, at least two purifiers are to be installed on board, each capable of efficiently purifying the amount of fuel oil necessary for the normal operation of the engines.

Note 1: On ships with a restricted navigation notation where fuel oil needs to be purified, one purifier only may be accepted.

b) Subject to special consideration by the Society, the capacity of the standby purifier may be less than that required in a), depending on the arrangements made for the fuel oil service tanks to satisfy the requirement in [11.10.2].

c) The standby purifier may also be used for other services.

d) Each purifier is to be provided with an alarm in case of failures likely to affect the quality of the purified fuel oil.

e) The amount of water reaching the oil fuelled machinery is to be not more than 0.3 % v/v or according to maker's recommendations.

f) Fuel treatment system performance in the removal of catfines and water is recommended to be regularly assessed, by drawing and analyzing samples from before and after the purifier plant and after the service tank to ensure that the catfines and water levels dot not exceed maximum engine entry levels recommended by engine manufacturers.

g) Centrifugal separators are to be certified for a flow rating in accordance with a recognised standard, e.g. EN 17763:2022, Centrifuges - Marine fuel centrifuges - Determination of particle separation performance and certified flow rate (CFR) under defined test conditions, CEN Workshop Agreement (CWA) 15375 (latest revision).

h) Centrifugal separators are to meet the safety requirements of a recognized standard, e.g. EN 12547, Centrifuges - Common safety requirements.

11.9 Fuel oil pumps

11.9.1 General *(1/7/2020)*

Fuel pump capacity is to ensure that fuel flow rate through the fuel system is sufficient to maintain the installed oil fuelled machinery's fuel consumption during normal operation at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant.

Satisfactory fuel pump operation is to be verified according to the Society requirements after installation on board.

11.9.2 Fuel oil pumps arrangement *(1/7/2020)*

The fuel oil pumps used in fuel oil treatment and transfer systems and operating on RMF and DMF are to comply with the requirements in [11.9.3] that are applicable to primary and secondary essential services fuel oil pumps (main and stand-by) which include: separator fuel oil supply pumps; booster pumps; feeder pumps; fuel valve cooling pumps (in systems which use fuel oil for this service); and fuel oil transfer pumps.

11.9.3 Requirements for fuel oil pumps arrangement *(1/7/2024)*

For ships intending to use RMF and/or DMF in non-restricted areas and marine fuels with a minimum viscosity of 2.0 cSt in emission control areas, the fuel oil pumps arrangement is to be in compliance with SOLAS regulation II-I/26.3.4 as interpreted by MSC.1/Circ.1467 (reflecting IACS UI SC255).

11.10 Design of fuel supply systems

11.10.1 General *(1/7/2024)*

a) In ships where heavy fuel oil and marine diesel oil are used, a change-over system from one fuel to the other is to be provided. This system is to be so designed as to avoid:
   - overheating of marine diesel oil
   - inadvertent ingress of heavy fuel oil into marine diesel oil tanks.

b) When necessary, arrangements are to be made for cooling the marine diesel oil from engine return lines.

c) The fuel oil treatment system is to be provided with redundancy so that failure of one system will not render the other system(s) inoperative. Arrangements are to ensure that any single failure in the system will not interrupt the supply of clean fuel to machinery used for propulsion and electrical generating purposes.

11.10.2 Fuel oil service tanks *(1/7/2022)*

a) Two fuel oil service tanks for each type of fuel used on board necessary for propulsion and vital systems, or equivalent arrangements, are to be provided on each new ship, with a capacity of at least 8 h at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant.

b) Where main engines, auxiliary engines and boilers are operated with heavy fuel oil, the following equivalent arrangements may be accepted for fuel oil service tanks:
   - one heavy fuel oil service tank with a capacity of at least 8 h at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant and of the auxiliary boiler
   - one marine diesel oil service tank with a capacity of at least 8 h at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant and of the auxiliary boiler.

c) Where main engine and auxiliary boilers are operated with heavy fuel oil and auxiliary engines are operated with marine diesel oil, the following equivalent arrangements may be accepted for fuel oil service tanks:
   - one heavy fuel oil service tank with a capacity of at least 8 h at maximum continuous rating of the propulsion plant and normal operating load at sea of the auxiliary boiler
   - two marine diesel oil service tanks, each with a capacity of at least the higher of:
     - 8 h at normal operating load at sea of the auxiliary engines and auxiliary boilers

- 4 h at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant and of the auxiliary boiler.

d) The above calculated capacities are to be increased by the volume below the suction pipe due to the requirement in [11.10.4] a).

Note 1: The requirement in [11.10.2] need not be applied to cargo ships of less than 500 tons gross tonnage:

- intended for restricted service or
- having engines declared suitable for prolonged operation on untreated fuel oil.

11.10.3 Fuel oil supply to boilers *(1/7/2011)*

a) In ships where boilers burning oil under pressure are installed to supply steam for propulsion purposes and essential services (such as propulsion machinery, machinery serving essential services or systems essential for propulsion and other essential services, e.g. heavy fuel oil heating system), the fuel oil supply system is to include at least two units, each one comprising:
   - a suction filter
   - an independent pump
   - a heater in the case of heavy fuel oil
   - a discharge filter.

b) Alternative arrangements using double filters are acceptable provided the element of one such filter can be cleaned while the other operates.

c) The fuel oil supply system is to be capable of supplying the fuel oil necessary to generate enough steam for propulsion purposes and essential services with one unit out of action.

d) A quick-closing valve is to be provided on the fuel supply to the burners of each boiler, arranged to be easily operated in case of emergency, either directly or by remote control.

e) The fuel supply to the burners is to be capable of being automatically cut off when required under Sec 3, [5.1.8].

f) Burners are to comply with Section Sec 3, [2.2.5].

g) Where burners are provided with fuel oil flow-back to the pump suctions or other parts under pressure, non-return devices are to be provided to prevent fuel oil from flowing back to the burners when the oil supply is cut off.

h) For the starting-up of boilers, an auxiliary fuel oil unit not requiring power from shore is to be provided.

i) Where fuel oil is supplied to the burners by gravity, a double filter satisfying the provisions of a) is to be provided in the supply line.

j) Fuel oil supply systems are to be entirely separate from feed, bilge, ballast and other piping systems.

11.10.4 Fuel oil supply to internal combustion engines *(1/1/2026)*

a) The suctions of engine fuel pumps are to be arranged at an appropriate distance above the fuel-oil treatment tank drain point in order to prevent accumulated water and sludge being drawn into the fuel oil treatment system (e.g. 5% of the tank volume is below the suction pipe).

b) Suitable filters are to be provided on the fuel oil line to the injection pumps.

   Fuel filters are to reduce the level of contaminants (i.e. metallic particles / sediments etc.) in the fuel to a level commensurate with the downstream equipment manufacturers' requirements.

   Internal combustion engines intended for main propulsion are to be fitted with at least two filters, or similar devices, so arranged that one of the filters can be overhauled while the other is in use.

Note 1: Where the propulsion plant consists of:

- two or more engines, each one with its own filter, or
- one engine with an output not exceeding 375 kW,

the second filter may be replaced by a readily accessible and easily replaceable spare filter.

c) Oil filters fitted in parallel are to be so arranged as to minimise the possibility of a filter under pressure being opened by mistake.

   Filter chambers are to be provided with suitable means for:

   - ventilating when put into operation
   - de-pressurising before being opened.

   Valves or cocks used for this purpose are to be fitted with drain pipes led to a safe location.

d) Oil filters are to be so located that in the event of a leakage the fuel oil cannot be pulverised onto the exhaust manifold.

e) When a fuel oil booster pump is fitted which is essential to the operation of the main engine, a standby pump, connected ready for immediate use, is to be provided.

The standby pump may be replaced by a complete spare pump of appropriate capacity ready to be connected, in the following cases:

- where two or more main engines are fitted, each with its own booster pump
- in ships having main engines each with an output not exceeding 375 kW.

For ships intending to use Heavy Fuel Oil (HFO) or Marine Diesel Oil (MDO) in some areas and marine fuels with a lower viscosity in other areas, either:

- each of the fuel oil pumps (main one and stand-by one) is suitable to supply both types of fuel at the required capacity for normal operation of propulsion machinery, or
- each of the fuel oil pumps (main one and stand-by one) is suitable to supply both types of fuel but one pump alone is not capable of delivering at the required capacity, then both pumps may operate in parallel to achieve the required capacity for normal operation of propulsion machinery but one additional (third) fuel oil pump shall be fitted. The additional pump shall, when operating in parallel with one of the other pumps, be suitable for and capable of delivering fuel at the required capacity for normal operation of the propulsion machinery
- two separate fuel oil pumps (one main and one stand-by) are to be fitted, each capable of and suitable for supplying low viscosity fuels at the required capacity for normal operation of propulsion machinery.

f) Where fuel oils require pre-heating in order to have the appropriate viscosity when being injected in the engine, the following equipment is to be provided in the fuel oil line:

- one viscosity control and monitoring system
- two pre-heaters, one serving as a standby for the other.

g) In case of unrestricted navigation, automatic viscosity controllers are to be maintained as the primary means to control required injection viscosity, with automatic temperature control being only a secondary back up option. In case of restricted navigation, manual temperature control can be accepted.

h) 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.

i) 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
- a non-return valve in the return line from the engines.

j) Components of a diesel engine fuel 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.

k) 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.

l) In multi-engine installations which are supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines, are to be provided. The means of isolation are not to affect the operation of the other engines and are to be operable from a position not rendered inaccessible by a fire on any of the engines.

m) For high pressure fuel oil pipes, refer to Sec 2.

n) For protection from overpressure in the fuel oil return line, refer to [2.5.3] d).

11.10.5 Sampling points *(1/7/2022)*

The fuel oil supply system is to be provided with sampling points.

The sampling points are to be:

- easily and safely accessible
- downstream of the in-use fuel oil service tank
- as close to the fuel oil combustion machinery as safely feasible taking into account the type of fuel oil, flow-rate, temperature, and pressure behind the selected sampling point
- clearly marked for easy identification and described in either the piping diagram or other relevant documents
- located in a position shielded from any heated surface or electrical equipment and the shielding device or construction should be sturdy enough to endure leaks, splashes or spray under design pressure of the fuel oil supply line so as to preclude impingement of fuel oil onto such surface or equipment
- provided with suitable drainage to the drain tank or other safe location
- equipped with closable valve and permanent means of closure like plugs.

A tank drain cock is not to be considered as a sampling point.

11.11 Control and monitoring

11.11.1 General *(1/7/2006)*

In addition to those of this item [11.11], the general requirements given in Chapter 3 apply.

In the case of ships with automation notations, the requirements in Part F, Chapter 3 also apply.

11.11.2 Monitoring

Alarms and safeguards are to be provided for fuel oil systems in accordance with Tab 26.

Note 1: Some departures from Tab 26 may be accepted by the Society in the case of ships with a restricted navigation notation.

Table 26 : 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 overflow tank level	H **(1)**						
Air pipe water trap level on fuel oil tanks	H **(2)**						
Fuel oil temperature after heaters	H **(4)**	local		X **(5)**			
Sludge tank level		local					
Fuel oil settling tank and service tank temperature	H **(3)**	local					
Fuel oil level in daily service tank	L+H **(1)**	local					
Fuel oil daily service tank temperature	H **(3)**	local					

(1) Or sightglasses on the overflow pipe
(2) Or alternative arrangement as per [9.1.7] item c)
(3) Applicable where heating arrangements are provided
(4) Or low flow alarm in addition to temperature control when heated by steam or other media
(5) Cut off of electrical power supply when electrically heated

11.11.3 Automatic controls

Automatic temperature control is to be provided for:

- steam heaters or heaters using other media
- electric heaters.

11.11.4 Remote controls

a) The remote control arrangement of valves fitted on fuel oil tanks is to comply with [11.6.4].

b) The power supply to:
   - fuel oil burning pumps,
   - 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.

c) Remote control of the valve fitted to the emergency generator fuel tank is to be in a separate location from that of other valves fitted to tanks in the engine room.

d) The positions of the remote controls are also to comply with Chapter 3.

11.12 Construction of fuel oil piping systems

11.12.1 Materials *(1/7/2002)*

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 [2.6.2].

b) Where the Society may permit the conveying of oil and combustible liquids through accommodation and service spaces, the pipes conveying oil or combustible liquids are to be of a material approved by the Society having regard to the fire risk.

c) 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.

d) Internal galvanisation of fuel oil pipes and tank or bunker walls is to be avoided.

11.12.2 Pipe thickness *(1/7/2002)*

The thickness of pipes containing fuel oil is to be calculated for a design pressure according to Tab 27.

11.12.3 Pipe connections *(1/7/2002)*

a) Connections and fittings of pipes containing fuel oil are to be suitable for a design pressure according to Tab 27.

b) Connections of pipes conveying heated fuel oil are to be made by means of close-fitting flanges, with joints made of a material impervious to oil heated to 160°C and as thin as possible.

Table 27 : Definition of the design pressure for fuel oil systems *(1/7/2002)*

Working temperature → Working pressure ↓	T ≤ 60°C	T > 60°C
P ≤ 0,7 MPa	0,3 MPa or maximum working pressure, whichever is the greater	0,3 MPa or maximum working pressure, whichever is the greater
P > 0,7 MPa	maximum working pressure	1,4 MPa or maximum working pressure, whichever is the greater

11.13 Arrangement of fuel oil piping systems

11.13.1 Passage of fuel oil pipes through tanks *(1/7/2006)*

a) Fuel pipes are not to pass through tanks containing boiler feed water, fresh water, other flammable oil or liquid cargo, unless they are contained within tunnels.

b) Transfer pipes passing through ballast tanks are to comply with [5.2.3].

11.13.2 Passage of pipes through fuel oil tanks

Boiler feed water, fresh water or liquid cargo pipes are not to pass through fuel oil tanks, unless such pipes are contained within tunnels.

11.13.3 Drains on fuel oil piping *(1/7/2010)*

Where fitted, drain pipes on fuel oil piping are to be provided with self-closing valves or cocks.

12 Lubricating oil systems

12.1 Application

12.1.1 *(1/7/2005)*

This Article applies to lubricating oil systems serving diesel engines, steam and gas turbines, reverse and reduction gears, for lubrication or control purposes.

It also applies to separate oil systems intended for the cooling of engine pistons.

12.2 Principle

12.2.1 General

a) Lubricating oil systems are to be so designed as to ensure reliable lubrication of the engines, turbines and other 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 Sec 1

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.

12.2.2 Availability

a) Lubricating oil systems are to be so designed that, in the event that any one pump is inoperative, the lubrication of the engines and other 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.

b) An emergency lubricating system, such as a gravity system, is to be provided to ensure sufficient lubrication of equipment which may be damaged due to a failure of the pump supply.

12.3 General

12.3.1 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 [5.10] are to be complied with, where applicable.

12.3.2 Filtration

a) In forced lubrication systems, a device is to be fitted which efficiently filters 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.

12.3.3 Purification

Where provided, lubricating oil purifiers are to comply with [11.8.3].

12.3.4 Heaters

Lubricating oil heaters are to comply with [11.7.3].

12.4 Design of engine lubricating oil systems

12.4.1 Lubrication of propulsion engines *(1/7/2005)*

a) Main engines are to be provided with at least two power lubricating pumps, of such a capacity as to maintain normal lubrication with any one pump out of action.

b) In the case of propulsion plants comprising:

- more than one engine, each with its own lubricating pump, one of the pumps mentioned in a) may be a spare pump, provided the arrangements are such as to enable the ship to proceed at a full load speed of not less than 7 knots when one of the engines is out of service, or
- one engine with an output not exceeding 375 kW, one of the pumps mentioned in a) may be a spare pump ready to be connected to the lubricating oil system, provided disassembling and reassembling operations can be carried out on board in a short time.

12.4.2 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. However, when such engines are intended for non-essential services, no additional pump is required.

12.5 Design of steam turbine lubrication systems

12.5.1 General

An alarm device is to be provided giving audible warning in the event of damage or of an appreciable reduction of the oil pressure.

12.5.2 Lubrication of propulsive turbines and turbogenerators

a) Propulsive turbines and turbogenerators are to be provided with:

- one main lubricating pump,
- and one independently driven standby pump of at least the same capacity.

b) Lubricating systems for propulsive turbines and turbogenerators are to be provided with a device which stops the steam supply to the turbines. (See [12.7.2].)

12.5.3 Emergency lubrication of propulsive turbines and turbogenerators

a) Propulsive turbines and turbogenerators are to be provided with an emergency lubricating system arranged for automatic start. (See [12.7.2].)

b) When a gravity system is provided for the purpose of a), it is to ensure an adequate lubrication for not less than six minutes and, in the case of turbogenerators, for a period at least equal to the stopping period after unloading.

c) When the emergency supply is fulfilled by means of an emergency pump, it is to be so arranged that its operation is not affected by a failure of the power supply.

d) Suitable arrangements for cooling the bearings after stopping may also be required.

12.5.4 Lubrication of auxiliary turbines intended for essential services

a) Auxiliary turbines intended for essential services are to be provided with:
   - one main lubricating pump,
   - and one independently driven standby pump of at least the same capacity.

b) The standby pump is to be capable of supplying satisfactory lubrication to the turbines during starting and stopping operations.

12.6 Design of lubricating oil tanks

12.6.1 Remote control of valves *(1/7/2002)*

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 [11.6.4]. Where it is determined that the 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 remote controlled valves need not be installed.

Suction valves from storage tanks need not be arranged with remote controls provided they are kept closed except during transfer operations.

12.6.2 Filling and suction pipes

Filling and suction pipes are to comply with the provisions of [11.6.3].

12.6.3 Air and overflow pipes

Air and overflow pipes are to comply with the provisions of [9.1] and [9.3].

12.6.4 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 [9.2].

c) Oil-level gauges complying with [2.9.2] may be used in place of sounding pipes.

d) Gauge cocks for ascertaining the level in the tanks are not to be used.

12.6.5 Oil collecting tanks for engines

a) In ships required to be fitted with a double bottom, wells for lubricating oil under main engines may be permitted by the Society provided it is satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with Pt B, Ch 4, Sec 4.

b) Where, in ships required to be fitted with a double bottom, oil collecting tanks extend to the outer bottom, a valve is to be fitted on the oil drain pipe, located between the engine sump and the oil drain tank. This valve is to be capable of being closed from a readily accessible position located above the working platform.

   Alternative arrangements will be given special consideration.

c) Oil collecting pipes from the engine sump to the oil collecting tank are to be submerged at their outlet ends.

12.7 Control and monitoring

12.7.1 General *(1/7/2006)*

In addition to those of this item [12.7], the general requirements given in Chapter 3 apply.

In the case of ships with automation notations, the requirements in Part F, Chapter 3 also apply.

12.7.2 Monitoring

In addition to the requirements in Sec 2 for diesel engines, in Sec 4 for steam turbines, in Sec 5 for gas turbines and in Sec 6 for gears, alarms are to be provided for lubricating oil systems in accordance with Tab 28.

Note 1: Some departures from Tab 28 may be accepted by the Society in the case of ships with a restricted navigation notation.

12.8 Construction of lubricating oil piping systems

12.8.1 Materials

Materials used for oil piping system in machinery spaces are to comply with the provisions of [11.12.1].

12.8.2 Sight-flow glasses

The use of sight-flow glasses in lubricating systems is permitted, provided that they are shown by testing to have a suitable degree of fire resistance.

Table 28 : Lubricating 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
Air pipe water trap level of lubricating oil tank **(1)**	H						
Sludge tank level		local					
(1) See [9.1.7]							

13 Thermal oil systems

13.1 Application

13.1.1 This Article applies to all thermal oil systems involving organic liquids heated below their initial boiling temperature at atmospheric pressure by means of:

- oil fired heaters,
- exhaust gas heaters,
- or electric heaters.

13.2 Principle

13.2.1 General

Thermal oil systems are to be so designed as to:

- avoid overheating of the thermal oil and contact with air
- take into account the compatibility of the thermal oil with the heated products in case of contact due to leakage of coils or heater tubes
- prevent oil from coming into contact with sources of ignition.

13.2.2 Availability

Thermal oil systems are to be so designed that, in the event that any one essential auxiliary is inoperative, the thermal oil supply to essential services can be 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.

13.3 General

13.3.1 Limitations on use of thermal oil

a) The oil is to be used in the temperature ranges specified by the producer. The delivery temperature is, however, to be kept 50°C below the oil distillation point.

b) Thermal oil is not to be used for the direct heating of:
   - accommodation,

- fresh drinking water
- liquid cargoes with flashpoints below 60°C, except where permitted in Part E, Chapter 7.

13.3.2 Location of thermal oil system components

Thermal oil heaters are normally to be located in spaces separated from main and auxiliary machinery spaces.

However, thermal oil heaters located in machinery spaces and protected by adequate screening may be accepted, subject to special consideration by the Society.

Note 1: For the purpose of application of Chapter 4, spaces where thermal oil heaters are located are to be considered as machinery spaces of category A.

13.3.3 Provision for quick drainage and alternative arrangements

a) Inlet and outlet valves of oil fired and exhaust fired heaters are to be arranged for remote closing from outside the compartment where they are situated.

   As an alternative, thermal oil systems are to be arranged for quick gravity drainage of the thermal oil contained in the system into a draining tank.

b) The expansion tank is to be arranged for quick gravity drainage into a draining tank.

   However, where the expansion tank is located in a low fire risk space, the quick drainage system may be replaced by a remote controlled closing device for isolating the expansion tank.

   The quick drainage system and the alternative closing device are to be capable of being controlled from inside and outside the space containing the expansion tank.

13.3.4 Ventilation

a) Spaces containing thermal oil heaters are to be suitably mechanically ventilated.

b) Ventilation is to be capable of being stopped from outside these spaces.

13.4 Design of thermal oil heaters and heat exchangers

13.4.1 Thermal oil heaters

Oil fired and exhaust-fired thermal oil heaters are to be designed, equipped and controlled in accordance with the requirements specified in Sec 3.

13.4.2 Heat exchangers

Heat exchangers are to be designed and equipped in accordance with the requirements specified in Sec 3.

13.5 Design of storage, expansion and draining tanks

13.5.1 Storage and draining tanks

a) The capacity of the storage tank is to be sufficient to compensate the losses expected in service.

b) The capacity of the draining tank is to be sufficient to collect the quantity of thermal oil contained in the system, including the expansion tank.

c) Storage and draining tanks may be combined.

13.5.2 Expansion tanks

a) The capacity of the expansion tank is to be sufficient to allow volume variations, due to temperature changes, of all the circulating oil.

b) The expansion tank is to be so designed, installed and connected to the circuit as to ensure that the temperature inside the tank remains below 50°C.

13.5.3 Drain pipes

Where provided, drains pipes of thermal oil tanks are to be fitted with self-closing valves or cocks.

13.5.4 Air pipes

a) Air pipes fitted to the expansion and drainage tanks are to be suitably sized to allow the quick gravity drainage referred to in [13.3.3].

b) The applicable requirements of [9.1] are to be complied with.

13.5.5 Overflow pipes

a) The expansion tank is to be fitted with an overflow pipe led to the drainage tank. This overflow pipe may be combined with the quick draining line provided for in [13.3.3], item b).

b) The applicable requirements of [9.3] are to be complied with.

13.5.6 Sounding pipes and level gauges

a) Sounding pipes are to comply with the provisions of [9.2].

b) Level gauges are to comply with the provisions of [2.9.2].

13.6 Design of circulation and heat exchange systems

13.6.1 Circulating pumps

At least two circulating pumps are to be provided, of such a capacity as to maintain a sufficient flow in the heaters with any one pump out of action.

However, for circulating systems supplying non-essential services, one circulating pump only may be accepted.

13.6.2 Filters

A device which efficiently filters the thermal oil is to be provided in the circuit.

In the case of essential services, the filters provided for this purpose are to be so arranged that they can be easily cleaned without stopping the thermal oil supply.

The fineness of the filter mesh is to comply with the requirements of the thermal oil heating installation manufacturer.

13.7 Control and monitoring

13.7.1 General *(1/7/2006)*

In addition to those of this item [13.7], the general requirements given in Chapter 3 apply.

In the case of ships with automation notations, the requirements in Part F, Chapter 3 also apply.

13.7.2 Monitoring

In addition to the requirements specified in Sec 3, [5.3] for thermal heaters and heat exchangers, alarms and safeguards for thermal oil systems are to be provided in accordance with Sec 3, Tab 21.

Note 1: Some departures from Sec 3, Tab 21 may be accepted by the Society in the case of ships with a restricted navigation notation.

13.7.3 Remote control *(1/7/2003)*

a) Remote control is to be arranged for:
   - shut-off of circulating pumps
   - inlet and outlet valves of heaters (see item a) of [13.3.3])
   - quick drainage of expansion tank, or shut-off of the alternative devices (see item b) of [13.3.3])
   - shut-off of the fuel supply to the oil fired heaters or of the exhaust gas supply to the exhaust gas heaters (see Sec 3, [5.3]).

b) Such control is to be possible from the space containing the thermal oil heaters and from another position located outside such space.

13.8 Construction of thermal oil piping systems

13.8.1 Materials

a) Materials are to comply with the provisions of [11.12.1].

b) Casings of pumps, valves and fittings are to be made of steel or other ductile material.

13.8.2 Pipe connections

a) Pipe connections are to comply with Article [2.4] and to be suitable for the design temperature of the thermal oil system.

b) Screw couplings of a type approved by the Society may be accepted for pipes of an outside diameter not exceeding 15 mm provided they are fitted with cutting rings or equivalent arrangements.

c) The materials of the joints are to be impervious to thermal oil.

13.9 Thermal oil piping arrangements

13.9.1 Passage of thermal oil pipes through certain spaces

a) Thermal oil pipes are not to pass through accommodation or public spaces or control stations.

b) Thermal oil pipes passing through main and auxiliary machinery spaces are to be restricted as far as possible.

13.9.2 Discharge of relief valves

Relief valves are to discharge to the drain tank.

13.9.3 Provision for de-aerating

Provisions are to be made for automatic evacuation of air, steam and gases from the thermal oil system to a safe location.

14 Hydraulic systems

14.1 Application

14.1.1 Hydraulic installations intended for essential services *(1/7/2005)*

Unless otherwise specified, this Article applies to all hydraulic power installations intended for essential services, including:

- actuating systems of thrusters
- actuating systems of steering gear
- actuating systems of lifting appliances
- manoeuvring systems of hatch covers
- manoeuvring systems of stern, bow and side doors and bow visors
- manoeuvring systems of mobile ramps, movable platforms, elevators and telescopic wheelhouses
- starting systems of diesel engines and gas turbines
- remote control of valves.

14.1.2 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 [14.3.2], [14.3.3], [14.4.3] and [14.4.4].

14.1.3 Low pressure or low power hydraulic installations

Hydraulic power installations with a design pressure of less than 2,5 MPa and hydraulic power packs of less than 5 kW will be given special consideration by the Society.

14.1.4 Very high pressure hydraulic installations

Hydraulic power installations with a design pressure exceeding 35 MPa will be given special consideration by the Society.

14.2 Principle

14.2.1 General

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.

14.2.2 Availability

a) 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. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired. Such reduction of capability is not acceptable for steering gear.

b) When a hydraulic power system is simultaneously serving one essential system and other systems, it is to be ensured that:
   - any operation of such other systems, or

- any failure in the whole installation external to the essential system

does not affect the operation of the essential system.

c) Provision b) applies in particular to steering gear.

d) Hydraulic systems serving lifting or hoisting appliances, including platforms, ramps, hatch covers, lifts, 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.

14.3 General

14.3.1 Definitions

a) A power unit is the assembly formed by the hydraulic pump and its driving motor.

b) An actuator is a component which directly converts hydraulic pressure into mechanical action.

14.3.2 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.

14.3.3 Location of hydraulic power units

a) Whenever practicable, hydraulic power units are to be located outside main engine or boiler rooms.

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 mist on heated surfaces which may ignite oil.

14.4 Design of hydraulic systems

14.4.1 Power units

a) Hydraulic power installations are to include at least two power units so designed that the services supplied by the hydraulic power installation can operate simultaneously with one power unit out of service. A reduction of the performance not affecting the safety of the ship may be accepted, except for steering gear.

b) Low power hydraulic installations not supplying essential services may be fitted with a single power unit, provided that alternative means, such as a hand pump, are available on board.

14.4.2 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.

14.4.3 Provision for cooling

Where necessary, appropriate cooling devices are to be provided.

14.4.4 Provision against overpressure

a) Safety valves of sufficient capacity are to be provided at the high pressure side of the installation.

b) Safety valves are to discharge to the low pressure side of the installation or to the service tank.

14.4.5 Provision for venting

Cocks are to be provided in suitable positions to vent the air from the circuit.

14.5 Design of hydraulic tanks and other components

14.5.1 Hydraulic oil service tanks *(1/7/2010)*

a) Service tanks intended for hydraulic power installations supplying essential services are to be provided with at least:
   - a level gauge complying with [2.9.2]
   - a temperature indicator
   - a level switch complying with [14.6.3]. The level switch may be omitted in the case of hydraulic systems capable of being operated only in local position.

b) The free volume in the service tank is to be at least 10% of the tank capacity.

14.5.2 Hydraulic oil storage tanks

a) Hydraulic power installations supplying essential services are to include a storage tank of sufficient capacity to refill the whole installation should the need arise case of necessity.

b) For hydraulic power installations of less than 5 kW, the storage means may consist of sealed drums or tins stored in satisfactory conditions.

14.5.3 Hydraulic accumulators

The hydraulic side of the accumulators which can be isolated is to be provided with a relief valve or another device offering equivalent protection in case of overpressure.

14.6 Control and monitoring

14.6.1 General *(1/7/2006)*

In addition to those of this item [14.6], the general requirements given in Chapter 3 apply.

In the case of ships with automation notations, the requirements in Part F, Chapter 3 also apply.

14.6.2 Indicators

Arrangements are to be made for connecting a pressure gauge where necessary in the piping system.

14.6.3 Monitoring

Alarms and safeguards for hydraulic power installations intended for essential services, except steering gear, for which the provisions of Sec 11 apply, are to be provided in accordance with Tab 29.

Note 1: Some departures from Tab 29 may be accepted by the Society in the case of ships with a restricted navigation notation.

Note 2: Tab 29 does not apply to steering gear.

14.7 Construction of hydraulic oil piping systems

14.7.1 Materials

a) Pipes are to be made of seamless steel. The use of welded steel pipes will be given special consideration by the Society.

b) Casings of pumps, valves and fittings are to be made of steel or other ductile material.

15 Steam systems

15.1 Application

15.1.1 Scope

This Article applies to all steam systems intended for essential and non-essential services.

Steam systems with a design pressure of 10 MPa or more will be given special consideration.

Table 29 : Hydraulic 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
Pump pressure	L						
Service tank level	L **(1)**						
(1) The low level alarm is to be activated before the quantity of lost oil reaches 100 litres or 50 % of the circuit volume , whichever is the less.							

15.2 Principle

15.2.1 General

Steam systems are to be so designed as to:

- avoid overpressure in any part of the steam piping system
- ensure the draining of condensate from the steam line.

15.2.2 Availability *(1/1/2026)*

Steam systems supplying essential services other than cargo services are to be fitted with more than one boiler, so that the steam supplied to essential services can be maintained in case of failure of any single boiler.

15.3 Design of steam lines

15.3.1 General

a) Every steam pipe and every connected fitting through which steam may pass is to be designed, constructed and installed such as to withstand the maximum working stresses to which it may be subjected.

b) When the design temperature of the steam piping system exceeds 400°C, calculations of thermal stresses are to be submitted to the Society as specified in [2.3].

c) Steam connections on boilers and safety valves are to comply with the applicable requirements of Sec 3.

15.3.2 Provision against overpressure

a) If a steam pipe or fitting may receive steam from any source at a higher pressure than that for which it is designed, a suitable reducing valve, relief valve and pressure gauge are to be fitted.

b) When, for auxiliary turbines, the inlet steam pressure exceeds the pressure for which the exhaust casing and associated piping up to the exhaust valves are designed, means to relieve the excess pressure are to be provided.

15.3.3 Provision for dumping

In order to avoid overpressure in steam lines due to excessive steam production, in particular in systems where the steam production cannot be adjusted, provisions are to be made to allow the excess steam to be discharged to the condenser by means of an appropriate dump valve.

15.3.4 Provision for draining

Means are to be provided for draining every steam pipe in which dangerous water hammer action might otherwise occur.

15.3.5 Steam heating pipes

a) When heating coils are fitted in compartments likely to contain either fuel oil or liquid or dry cargoes, arrangements such as blind flanges are to be provided in order to disconnect such coils in the event of carriage of dry or liquid cargoes which are not to be heated.

b) The number of joints on heating coils is to be reduced to the minimum consistent with dismantling requirements.

15.3.6 Steam lines in cargo holds

a) Live and exhaust steam pipes are generally not to pass through cargo holds, unless special provisions are made with the Society's agreement.

b) Where steam pipes pass through cargo holds in pipe tunnels, provision is to be made to ensure the suitable thermal insulation of such tunnels.

c) When a steam smothering system is provided for cargo holds, provision is to be made to prevent any damage of the cargo by steam or condensate leakage.

15.3.7 Steam lines in accommodation spaces

Steam lines are not to pass through accommodation spaces, unless they are intended for heating purposes.

15.3.8 Turbine connections

a) A sentinel valve or equivalent is to be provided at the exhaust end of all turbines. The valve discharge outlets are to be visible and suitably guarded if necessary.

b) Bled steam connections are to be fitted with non-return valves or other approved means to prevent steam and water returning to the turbines.

15.3.9 Strainers

a) Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines or, alternatively, at the inlets to manoeuvring valves.

b) Where required by the manufacturer of the auxiliaries, steam strainers are also to be fitted in the steam lines supplying these auxiliaries.

16 Boiler feed water and condensate systems

16.1 Application

16.1.1 This Article applies to:

- feed water systems of oil fired and exhaust gas boilers
- steam drain and condensate systems.

16.2 Principle

16.2.1 General

Boiler feed water and condensate systems are to be so designed that:

- reserve feed water is available in sufficient quantity to compensate for losses
- feed water is free from contamination by oils or chlorides
- feed water for propulsion systems is suitably de-aerated.

16.2.2 Availability

a) Feed water systems are to be so designed that, in the event of failure of any one component, the steam supply to essential services can be maintained or restored.

b) Condensate systems are to be so designed that, in the event of failure:

- of one condensate pump,
- or of the arrangements to maintain vacuum in the condenser,

the steam supply to essential services can be 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.

16.3 Design of boiler feed water systems

16.3.1 Number of feed water systems

a) Every steam generating system which provides services essential for the safety of the ship, or which could be rendered dangerous by the failure of its feed water supply, is to be provided with not less than two separate feed water systems from and including the feed pumps, noting that a single penetration of the steam drum is acceptable.

b) The requirement stated in a) may be dispensed with for boilers heated exclusively by engine exhaust gases or by steam for which one feed system is considered as sufficient, provided an alternative supply of steam is available on board.

c) Each boiler is to be provided with feed regulators as specified in Sec 3, [5].

16.3.2 Feed pumps

a) The following pumps are to be provided:

- at least one main feed pump of sufficient capacity to supply the boilers under nominal conditions,
- and one standby feed pump.

b) The capacity of the standby pump may be less than that of the main feed pumps provided it is demonstrated that, taking into account the reduction of the propulsion capability, the ship remains safely operable.

c) Main feed pumps may be either independent or driven by the main turbines. The standby feed pump is to be independent.

d) In twin-screw ships in which there is only one independent feed pump, each main turbine is to be fitted with a driven pump. Where all feed pumps are independent, they are to be so arranged as to be capable of dealing with the feed water necessary to supply steam either to both turbines or to one turbine only.

e) Independent feed pumps for main boilers are to be fitted with a delivery control and regulating system.

f) Unless overpressure is prevented by the feed pump characteristics, means are to be provided which will prevent overpressure in any part of the feed water system.

g) The pressure head of feed pumps is to take into account the maximum service pressure in the boiler as well as the pressure losses in the discharge piping. The suction head of feed pumps is to be such as to prevent any risk of cavitation.

h) Feed pumps and pipes are to be provided with valves so arranged that any one pump can be overhauled while the boilers are operating at full load.

16.3.3 Harbour feed pumps

a) Where main turbine driven pumps are provided and there is only one independent pump, a harbour feed pump or an ejector is to be fitted in addition to provide the second means for feeding the boilers which are in use when the main turbine is not working.

b) The harbour feed pump may be used for the general service of the ship, but in no case is this pump to be used to convey liquid fuel, lubricating oil or oily water.

c) The suction pipes of the harbour feed pump from the hotwell, from reserve feed water tanks and from filters are to be fitted with non-return valves.

16.3.4 Feed water tanks

a) All ships fitted with main boilers or auxiliary boilers for essential services are to be provided with reserve feed water tanks of sufficient capacity having regard to the service of the ship.

b) Boilers are 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.

c) Feed water tanks are not to be located adjacent to fuel oil tanks. Fuel oil pipes are not to pass through feed water tanks.

d) For main boilers, one or more evaporators are to be provided, the capacity of which is to compensate for the losses of feed water due to the operation of the machines, in particular where the fuel supplied to the boilers is atomised by means of steam.

16.3.5 Provision for de-aerating feed water

A de-aerator is to be provided to ensure the de-aeration of the feed water intended for main boilers before it enters such boilers.

16.4 Design of condensate systems

16.4.1 Condensers

a) Appropriate arrangements, such as air ejectors, are to be provided to maintain vacuum in the main condenser or restore it to the required value.

b) Cooling of the main condenser is to comply with the provisions of [10.3.5].

16.4.2 Condensate pumps

a) Condensate pumps are to include at least:
   - one main condensate pump of sufficient capacity to transfer the maximum amount of condensate produced under nominal conditions,
   - and one independently driven standby condensate pump.

b) The standby condensate pump may be used for other purposes.

16.4.3 Condensate observation tanks

Any condensate from the steam heating pipes provided for fuel oil tanks and bunkers, cargo tanks and fuel oil or lubricating oil heaters is to be led to an observation tank or some other device of similar efficiency located in a well-lighted and readily accessible position .

16.5 Control and monitoring

16.5.1 General *(1/7/2006)*

In addition to those of this item [16.5], the general requirements given in Chapter 3 apply.

In the case of ships with automation notations, the requirements in Part F, Chapter 3 also apply.

16.5.2 General

The provisions of this sub-article apply only to feed water and condensate systems intended for propulsion.

16.5.3 Monitoring

Alarms and safeguards are to be provided for feed water and condensate systems in accordance with Tab 30.

Note 1: Some departures from Tab 30 may be accepted by the Society in the case of ships with a restricted navigation notation.

Table 30 : Boiler feed and condensate system *(1/7/2001)*

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 flow or equivalent	L						
Condenser pressure	H	local					
	HH			X			
Water level in main condenser (unless justified)	H	local					
Feed water salinity	H	local					
Feed water pump delivery pressure	L	local					
						X	
Feed water tank level	L						

16.5.4 Automatic controls

Automatic level control is to be provided for:

- de-aerators,
- condensers.

16.6 Arrangement of feed water and condensate piping

16.6.1

a) Feed water pipes are not to pass through fuel oil or lubricating oil tanks.

b) Pipes connected to feed water tanks are to be so arranged as to prevent the contamination of feed water by fuel oil, lubricating oil or chlorides.

17 Compressed air systems

17.1 Application

17.1.1 This Article applies to compressed air systems intended for essential services, and in particular to:

- starting of engines,
- control and monitoring.

17.2 Principle

17.2.1 General

a) Compressed air systems are to be so designed that the compressed air delivered to the consumers:
   - is free from oil and water,
   - does not have an excessive temperature.

b) Compressed air systems are to be so designed as to prevent overpressure in any part of the systems.

17.2.2 Availability

a) Compressed air systems are to be so designed that, in the event of failure of one air compressor or one air receiver intended for starting, control purposes or other essential services, the air supply to such services can be maintained.

b) The compressed air system for starting main engines and auxiliary engines for essential services is to be so arranged that it is possible to ensure the initial charge of air receiver(s) without the aid of a power source outside the ship.

17.3 Capacity and availability of compressed air for essential services

17.3.1 Application *(1/7/2025)*

The requirements in this Article apply to the supply of compressed air required by essential services onboard ships other than the supply of compressed air for engine starting.

17.3.2 Requirements *(1/7/2025)*

17.3.2.1 The arrangements for the supply of compressed air to essential services are to ensure that sufficient compressed air to satisfy the total demand of the essential services is available at all times during normal operation, during maintenance, and in the event of a failure of the compressed air system.

17.3.2.2 Where compressed air is supplied from the engine starting air system, either continuously in normal operation, or periodically during maintenance or in the event of a failure of the compressed air system, the required compressed air demand is not to reduce the capacity and availability of the engine starting air required by Sec 2, [5.1.1].

17.4 Design of starting air systems

17.4.1 Initial charge of starting air receivers

a) Where, for the purpose of [17.2.2], an emergency air compressor is fitted, its driving engine is to be capable of being started by hand-operated devices. Independent electrical starting batteries may also be accepted.

b) A hand compressor may be used for the purpose of [17.2.2] only if it is capable of charging within one hour an air receiver of sufficient capacity to provide 3 consecutive starts of a propulsion engine or of an engine capable of supplying the energy required for operating one of the main compressors.

17.4.2 Number and capacity of air compressors *(1/1/2025)*

a) Where main and auxiliary engines are arranged for starting by compressed air, two or more air compressors are to be fitted with a total capacity sufficient to supply within one hour, the receivers being at atmospheric pressure, the quantity of air needed to satisfy the provisions of Sec 2, [5.1.1]. This capacity is to be approximately equally divided between the number of compressors fitted, excluding the emergency compressor fitted in pursuance of [17.4.1].

b) At least one of the compressors is to be driven independent of the engines for which starting air is supplied. The capacity of one of the said independently driven compressors or the combined capacity of independently driven compressors is not to be less than 50% of the total required in a).

17.4.3 Number and capacity of air receivers

a) Where main engines are arranged for starting by compressed air, at least two air receivers are to be fitted of approximately equal capacity and capable of being used independently.

b) The total capacity of air receivers is to be sufficient to provide without replenishment the number of starts required in Sec 2, [5.1.1]. It is also to take into account the air delivery to other consumers, such as control systems, whistle, etc., which are connected to the air receivers.

17.4.4 Air supply for starting the emergency generating set

Starting air systems serving main or auxiliary engines may be used for starting the emergency generator under the conditions specified in Sec 2, [5.1.3].

17.5 Design of control and monitoring air systems

17.5.1 Air supply

a) The control and monitoring air supply to essential services is to be available from two sources of a sufficient capacity to allow normal operation with one source out of service.

b) At least one air vessel fitted with a non-return valve is to be provided for control and monitoring purposes.

c) Pressure reduction units used in control and monitoring air systems intended for essential services are to be duplicated, unless an alternative air supply is provided.

d) Failure of the control air supply is not to cause any sudden change of the controlled equipment which may be detrimental to the safety of the ship.

17.5.2 Pressure control

Arrangements are to be made to maintain the air pressure at a suitable value in order to ensure satisfactory operation of the installation.

17.5.3 Air treatment

In addition to the provisions of [17.9.3], arrangements are to be made to ensure cooling, filtering and drying of the air prior to its introduction in the monitoring and control circuits.

17.6 Design of air compressors

17.6.1 Prevention of excessive temperature of discharged air

Air compressors are to be so designed that the temperature of discharged air cannot exceed 95°C. For this purpose, the air compressors are to provided where necessary with:

- suitable cooling means
- fusible plugs or alarm devices set at a temperature not exceeding 120°.

17.6.2 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.

17.6.3 Crankcase relief valves

Air compressors having a crankcase volume of at least 0,6 m^3 are to be fitted with crankcases explosion relief valves satisfying the provisions of Sec 2, [4.3.4].

17.6.4 Provision for draining

Air compressors are to be fitted with a drain valve.

17.7 Control and monitoring of compressed air systems

17.7.1 General *(1/7/2006)*

In addition to those of this item [17.7], the general requirements given in Chapter 3 apply.

In the case of ships with automation notations, the requirements in Part F, Chapter 3 also apply.

17.7.2 Monitoring

Alarms and safeguards are to be provided for compressed air systems in accordance with Tab 31.

Note 1: Some departures from Tab 31 may be accepted by the Society in the case of ships with a restricted navigation notation.

Table 31 : 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					
Starting air pressure before main shut-off valve	L	local + R **(1)**					
Air vessel pressure	L+H						
(1) Remote indication is required if starting of air compressor are remote controlled, from wheelhouse for example							

17.7.3 Automatic controls

Automatic pressure control is to be provided for maintaining the air pressure in the air receivers within the required limits.

17.8 Materials

17.8.1 Pipes and valve bodies in control and monitoring air systems and in other air systems intended for non-essential services may be made of plastic in accordance with the provisions of App 3.

17.9 Arrangement of compressed air piping systems

17.9.1 Prevention of overpressure

Means are to be provided to prevent overpressure in any part of compressed air systems. Suitable pressure relief arrangements are to be provided for all systems.

17.9.2 Air supply to compressors

a) Provisions are to be made to reduce to a minimum the entry of oil into air pressure systems.

b) Air compressors are to be located in spaces provided with sufficient ventilation.

17.9.3 Air treatment and draining

a) Provisions are 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.

17.9.4 Lines between compressors, receivers and engines

All discharge pipes from starting air compressors are to be lead directly to the starting air receivers, and all starting air pipes from the air receivers to main or auxiliary engines are to be entirely separate from the compressor discharge pipe system.

17.9.5 Protective devices for starting air mains

Non-return valves and other safety devices are to be provided on the starting air mains of each engine in accordance with the provisions of Sec 2, [5.1.1].

18 Exhaust gas systems

18.1 General

18.1.1 Application

This Article applies to:

- exhaust gas pipes from engines and gas turbines
- smoke ducts from boilers and incinerators.

18.1.2 Principle

Exhaust gas systems are to be so designed as to:

- limit the risk of fire
- prevent gases from entering manned spaces
- prevent water from entering engines.

18.2 Design of exhaust systems

18.2.1 General

Exhaust systems are to be so arranged as to minimise the intake of exhaust gases into manned spaces, air conditioning systems and engine intakes.

18.2.2 Limitation of exhaust line surface temperature

a) Exhaust gas pipes 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 Sec 1, [3.7.1].

18.2.3 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 or boiler manufacturers.

18.2.4 Intercommunication of engine exhaust gas lines or boiler smoke ducts

a) Exhaust gas from different engines is not to be led to a common exhaust main, exhaust gas boiler or economiser, unless each exhaust pipe is provided with a suitable isolating device.

b) Smoke ducts from boilers discharging to a common funnel are to be separated to a height sufficient to prevent smoke passing from a boiler which is operating to a boiler out of action.

18.2.5 Exhaust gas pipe terminations

a) Where exhaust pipes are led overboard close to the load waterline, means are to be provided to prevent water from entering the engine or the ship.

b) Where exhaust pipes are water cooled, they are to be so arranged as to be self-draining overboard.

18.2.6 Control and monitoring

A high temperature alarm is to be provided in the exhaust gas manifolds of thermal oil heaters to detect any outbreak of fire.

18.3 Materials

18.3.1 General

Materials of exhaust gas pipes and fittings are to be resistant to exhaust gases and suitable for the maximum temperature expected.

18.3.2 Use of plastics

The use of non-metallic materials may be accepted in water cooled systems in accordance with the provisions of App 3.

18.4 Arrangement of exhaust piping systems

18.4.1 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, and in particular in the connection with engine turboblowers.

b) The devices used for supporting the pipes are to allow their expansion or contraction.

18.4.2 Provision for draining

a) Drains are to be provided where necessary in exhaust systems, and in particular in exhaust ducting below exhaust gas boilers, in order to prevent water flowing into the engine.

b) Where exhaust pipes are water cooled, they are to be so arranged as to be self-draining overboard.

18.4.3 Flexible hoses

The use of flexible hoses in water cooled exhaust systems will be given special consideration by the Society.

18.4.4 Silencers

Engine silencers are to be so arranged as to provide easy access for cleaning and overhaul.

18.5 Exhaust gas treatment systems

18.5.1 *(1/1/2018)*

When exhaust gas treatment systems are installed, they are to be in compliance with the requirements in [20].

19 Oxyacetylene welding systems

19.1 Application

19.1.1 This Article applies to centralised fixed plants for oxyacetylene welding installed on ships. It may also be applied, at the discretion of the Society, to other plants using liquefied gas, such as propane.

19.2 Definitions

19.2.1 **Centralised plants for oxyacetylene welding** *(1/7/2010)*

A centralised plant for oxyacetylene welding is a fixed plant consisting of a gas bottle room or other storage arrangement (see [19.4.1]), distribution stations and distribution piping, where the total number of acetylene and oxygen bottles exceeds 4.

19.2.2 Acetylene

Acetylene (C_2H_2) is assumed to be contained in pressurised gas bottles with pressure equal to 1,5-1,8 MPa at 15°C.

19.2.3 Oxygen

Oxygen (O_2) is assumed to be contained in pressurized gas bottles, with pressure equal to 15-20 MPa at 15°C.

19.2.4 Gas bottle rooms

A gas bottle room is a room containing acetylene and oxygen bottles, where distribution headers, non-return and stop valves, pressure reducing devices and outlets of supply lines to distribution stations are also installed.

19.2.5 Distribution stations

Distribution stations are adequately protected areas or cabinets equipped with stop valves, pressure regulating devices, pressure gauges, non-return valves and oxygen as well as acetylene hose connections for the welding torch.

19.3 Design of oxyacetylene welding systems

19.3.1 General

Except on pontoons and service working ships, no more than two distribution stations are normally permitted.

19.3.2 Acetylene and oxygen bottles

a) The bottles are to be tested by the Society or by a body recognised by the Society.

b) Bottles with a capacity exceeding 50 litres are not permitted.

c) Bottles supplying the plant and spare bottles are to be installed in the gas bottle room. Installation within accommodation spaces, service spaces, control stations and machinery spaces is not permitted.

d) Bottles are to be installed in a vertical position and are to be safely secured. The securing system is to be such as to allow the ready and easy removal of the bottles.

19.3.3 Piping systems *(1/7/2003)*

a) Acetylene and oxygen piping systems are to comply with the following provisions:
- all valves and fittings as well as welding torches and associated supply hoses are to be adapted to this specific service and suitable for the conditions expected in the different parts of the system
- the connections between the various pipe sections are to be carried out by means of butt welding. Other types of connections including threaded connections and flange connections are not permitted.
- only a minimum number of unavoidable connections are permitted provided they are located in a clearly visible position.

b) High pressure lines (i.e. lines between bottles and pressure reducing devices) are to be installed inside the gas bottle room and are to comply with the following provisions:
- acetylene piping is to be of stainless steel and seamless drawn
- oxygen piping is to be of copper or stainless steel and seamless drawn
- acetylene and oxygen piping and associated fittings are to be suitable for a design pressure of 29,5 MPa
- a non-return valve is to be installed on the connection of each acetylene and oxygen bottle to the header
- stop valves are to be provided on the bottles and kept shut when distribution stations are not working.

c) Low pressure lines (i.e. lines between pressure reducing devices and distribution stations) are to comply with the following provisions:
- pipes are to be of seamless steel
- piping is to have a thickness of not less than:
  - 2,5 mm when installed in the open air,
  - 2 mm otherwise.
- supply lines to each distribution station are to include, at the station inlet:
  - a stop valve to be kept shut when the station is not working,
  - devices to protect the supply lines from back flow of gas or flame passage.

d) Safety valves are to be provided on the low pressure side of the pressure reducing devices and led to the open air at least 3 m above the deck in a safe location where no source of ignition is present.

19.4 Arrangement of oxyacetylene welding systems

19.4.1 Gas bottle rooms *(1/7/2010)*

a) The gas bottle room is to be located in an independent space over the highest continuous deck and provided with direct access from outside. The limiting bulkheads and decks are to be made of steel. The limiting bulkheads and decks between the room and other enclosed spaces are to be gas-tight.

b) When the total number of gas bottles, including possible spare bottles which are not connected to the plant, does not exceed 8, acetylene and oxygen bottles may be installed in the same room. Otherwise, acetylene and oxygen bottles are to be separated by a gas-tight bulkhead.

c) The bottle room is to be adequately insulated and fitted with ventilation systems capable of providing at least six air changes per hour based on the gross volume of the room. The ventilation system is to be independent of ventilation systems of other spaces. The space within 3 m from the mechanical ventilation exhaust or 1 m from the natural ventilation exhaust is to be considered a hazardous area. The fan is to be of non-sparking construction. Small storage spaces provided with sufficiently large openings for natural ventilation need not be fitted with mechanical ventilation.

   Electrical equipment installed within the storage room, including the ventilation fan motor, is to be of the certified safe type.

   Where no storage room is provided, the gas cylinders may be placed in an open storage area. In such cases they are to be shaded from heat sources and protected against mechanical, weather and se damage.

d) The gas bottle room is not to be used for other services on board. Flammable oil or gas piping, except that related to the oxyacetylene welding plant, is not to be led through this room.

Note 1: On pontoons and service working ships, gas bottles may be installed on open deck in a safe position to the satisfaction of the Society. In such case, appropriate protection is to be provided:

- for gas bottles, against sunrays and atmospheric agents, by means of watertight covers,
- for the associated valves, piping and fittings, by means of steel covers, metal grids or similar devices.

Such means of protection are to be easily removable to allow bottle removal, when necessary.

When the total number of bottles exceeds 8, acetylene bottles are to be separated from oxygen bottles.

19.4.2 Distribution stations

Distribution stations are to be located in the engine room or in the workshop, in a well-ventilated position and protected against possible mechanical damage.

Note 1: On pontoons and service working ships, distribution stations may be installed in the open air, enclosed in a cabinet with a locked door, or in controlled access areas, to the satisfaction of the Society.

19.4.3 Piping

a) Piping is not to be led through accommodation or service spaces.

b) Piping is to be protected against any possible mechanical damage.

c) In way of deck or bulkhead penetrations, piping is to be suitably enclosed in sleeves so arranged as to prevent any fretting of the pipe with the sleeve.

19.4.4 Signboards

Signboards are to be posted on board the ship in accordance with Tab 32.

Table 32 : Signboards

Location of the signboard	Signboard to be posted
in the gas bottle room	diagram of the oxyacetylene plant
	“no smoking”
in way of: • bottle stop valves • distribution station stop valves	“to be kept shut when distribution stations are not working”
in way of the pressure reducing devices	indication of the maximum allowable pressure at the pressure reducing device outlet
in way of the safety valve discharge outlet	“no smoking”

20 Exhaust gas treatment systems

20.1 Application

20.1.1 *(1/1/2026)*

This Article applies to:

- exhaust gas cleaning systems (scrubbers)
- Selective Catalytic Reduction (SCR) systems
- Onboard Carbon Capture and Storage (OCCS) systems.

20.1.2 Applicability of other Rules *(1/4/2021)*

Exhaust gas treatment systems are regarded as non-essential services, therefore:

- redundancy is not necessary, and
- testing of materials and components is to be in compliance with the requirements for equipment intended non essential services.

  However, equipment intended to ensure the ship safety or essential to ensure personnel safety (such as but not limited to valves connected to the outer shell, sea water piping, pipes conveying hazardous substances, exhaust gas by-pass valves), is anyway to be inspected and tested as requested for equipment intended for essential services.

20.2 Efficiency

20.2.1 *(1/1/2018)*

When the additional class notations "**EGCS-Sox**" or "**EGCS NOx**" are issued, the efficiency of the equipment is to be certified against the requirements of the latest IMO Guidelines published at the Building Contract date.

20.3 Exhaust ducting

20.3.1 *(1/1/2018)*

The parts of the Exhaust gas treatment systems containing exhaust gas are to be in compliance with [18].

When the exhaust gas treatment system may influence the operation of essential machinery, arrangements are to be made to ensure the continuity of the service concerned also in case of possible failures of the exhaust gas treatment system (e.g. exhaust gas bypasses are to be arranged, to enable continued operation of engine intended to drive single essential users in case of filters clogging by particulate matter).

20.3.2 *(1/1/2026)*

Where closing devices are fitted in the exhaust gas main and bypass flow paths, it is to be ensured that there is an open flow path for exhaust gas at all times, even in case of failure of the control or actuation system to the closing devices. The essential services are not to be impaired during the bypass activation.

20.3.3 *(1/1/2026)*

Where an exhaust gas treatment system is fed from multiple exhaust gas inlet streams, the arrangement is to be such that the following safety functions are provided:

- preventing reverse flow of exhaust gas (e.g. isolating valves or equivalent means of isolating the exhaust systems of individual engines from common manifolds are to be provided to prevent reverse flow of exhaust gas into the exhaust manifolds of engines which have been shut down)
- maintaining the backpressure within the allowable limits (such limits are to be provided by machinery manufacturers for all engine or combustion machinery operating configurations).

20.4 Materials

20.4.1 *(1/1/2018)*

Materials used for equipment and piping systems are to be suitable with fluids conveyed, taking into account their chemical reactivity.

Aluminium and galvanized pipes are to be avoided for equipment and piping systems in contact with fluids containing sodium hydroxide or acids.

Copper is to be avoided for equipment and piping systems in contact with fluids containing ammonia.

20.5 Use of hazardous substances

20.5.1 *(1/1/2018)*

When hazardous substances are produced, or loaded and stored on board or anyway used in connection with exhaust gas treatment systems, the arrangements are to take into account the risks involved in such a production, loading, storage and use.

Substances containing products listed in the IMDG Code are to be regarded as hazardous substances, unless documented otherwise.

20.6 Use of reductants in SCR systems

20.6.1 **Use of aqueous ammonia (28% or less concentration of ammonia)** *(1/1/2024)*

Aqueous ammonia is not to be used as a reductant in a SCR except where it can be demonstrated that it is not practicable to use a urea based reductant.

Where an application is made to use aqueous ammonia as the reductant then the arrangements for its loading, carriage and use are to be derived from a risk based analysis.

20.6.2 **Use of anydrous ammonia (99.5% or greater concentration of ammonia by weight)** *(1/1/2024)*

Anydrous ammonia is not to be used as a reductant in a SCR except where it can be demonstrated that it is not practicable to use a urea based reductant and where the Flag Administration agrees to its use.

Where it is not practicable to use a urea reductant then it is also to be demonstrated that it is not practicable to use aqueous ammonia.

Where an application is made to use anhydrous ammonia as the reductant then the arrangements for its loading, carriage and use are to be derived from a risk based analysis.

20.6.3 **Use of urea based ammonia (e.g. 40%/60% urea/water solution)** *(1/1/2024)*

The requirements for SCR reductants tanks with volume below of 500 L will be considered by the Society on a case by case basis.

Where urea based ammonia (e.g. AUS 40 - aqueous urea solution specified in ISO 18611-1:2014) is used, the storage tank is to be arranged so that any leakage will be contained and prevented from making contact with heated surfaces. All pipes or other tank penetrations are to be provided with manual closing valves attached to the tank. Tank and piping arrangements are to be approved.

The storage tank may be located within the engine room.

The storage tank is to be protected from excessively high or low temperatures applicable to the particular concentration of the solution. Depending on the operational area of the ship, this may necessitate the fitting of heating and/or cooling systems. The physical conditions recommended by applicable recognized standards (such as ISO 18611-3:2014) are to be taken into account to ensure that the contents of the aqueous urea tank are maintained to avoid any impairment of the urea solution during storage.

If a urea storage tank is installed in a closed compartment, the area is to be served by an effective mechanical ventilation system of extraction type providing not less than 6 air changes per hour which is independent from the ventilation system of accommodation, service spaces, or control stations. The ventilation system is to be capable of being controlled from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment shall be provided outside the compartment adjacent to each point of entry. These requirements also apply to closed compartments normally entered by persons:

- when they are adjacent to the urea integral tanks and there are possible leak points (e.g. manhole, fittings) from these tanks; or
- when the urea piping systems pass through these compartments, unless the piping system is made of steel or other equivalent material with melting point above 925 degrees C and with fully welded joints.

Alternatively, where a urea storage tank is located within an engine room a separate ventilation system is not required when the general ventilation system for the space is arranged so as to provide an effective movement of air in the vicinity of the storage tank and is to be maintained in operation continuously except when the storage tank is empty and has been thoroughly ventilated.

Each urea storage tank is to be provided with temperature and level monitoring arrangements. High and low level alarms together with high and low temperature alarms are also to be provided.

Where urea based ammonia solution is stored in integral tanks, the following are to be considered during the design and construction:

- These tanks may be designed and constructed as integral part of the hull, (e.g. double bottom, wing tanks).
- These tanks are to be coated with appropriate anti-corrosion coating and cannot be located adjacent to any fuel oil and fresh water tank.
- These tanks are to be designed and constructed as per the structural requirements applicable to hull and primary support members for a deep tank construction.
- These tanks are to be included in the ship's stability calculation.

The reductant piping and venting systems are to be independent of other ship service piping and/or systems. Reductant piping systems are not to be located in accommodation, service spaces, or control stations. The vent pipes of the storage tank are to terminate in a safe location on the weather deck and the tank venting system is to be arranged to prevent entrance of water into the urea tank.

Reductant tanks are to be of steel or other equivalent material with a melting point above 925 degrees C.

Note 1:

Material requirement “to be of steel or other equivalent material” with a melting point above 925 degrees C is not applicable for integral tanks on FRP vessels such as those listed below, provided that the integral tanks are coated and/or insulated with a self-extinguishing material.

- FRP vessels complying with Regulation 17 of SOLAS Chapter II-2 based upon its associated IMO guidelines (MSC.1/Circ.1574), and
- FRP vessels exempted from the application of SOLAS e.g., yachts, fast patrol, navy vessels, etc., generally of less than 500 gross tonnage, subject to yacht codes or flag regulations.

Pipes/piping systems are to be of steel or other equivalent material with melting point above 925 degrees C, except downstream of the tank valve, provided this valve is metal seated and arranged as fail-to-closed or with quick closing from a safe position outside the space in the event of fire; in such case, type approved plastic piping may be accepted even if it has not passed a fire endurance test. Reductant tanks and pipes/piping systems are to be made with a material compatible with reductant or coated with appropriate anti-corrosion coating.

For the protection of crew members, the ship is to have on board suitable personnel protective equipment. Eyewash are to be provided, the location and number of these eyewash stations and safety showers are to be derived from the detailed installation arrangements.

Urea storage tanks are to be arranged so that they can be emptied of urea and ventilated by means of portable or permanent systems.

20.7 Use of aqueous solution of NaOH or $Ca(OH)_2$ in exhaust gas cleaning systems

20.7.1 General *(1/7/2022)*

In this context, the term “chemical treatment fluid” means the aqueous solution of sodium hydroxide (NaOH) or calcium hydroxide ($Ca(OH)_2$) that has corrosive properties or are considered to represent a hazard to personnel (see [20.7.2]).

For exhaust gas cleaning systems using chemicals other than the above, safety measures are to be taken according to the result of a risk assessment to be conducted to analyze the risks, in order to eliminate or mitigate the hazards to personnel brought by the use of such exhaust gas cleaning systems, to an extent equivalent to systems complying with [20.7.2] a) to [20.7.2] p).

20.7.2 Requirements *(1/7/2024)*

a) The storage tank for chemical treatment fluids is to be arranged so that any leakage will be contained and prevented from making contact with heated surfaces. All pipes or other tank penetrations are to be provided with manual closing valves attached to the tank. In cases where such valves are provided below top of tank, they are to be arranged with quick acting shutoff valves which are to be capable of being remotely operated from a position accessible even in the event of chemical treatment fluid leakages. Tank and piping arrangements are to be approved.

b) The storage tank is to be protected from excessively high or low temperatures applicable to the particular concentration chemical treatment fluids. Depending on the operational area of the ship, this may necessitate the fitting of heating and/or cooling systems.

c) If a storage tank for chemical treatment fluids is installed in a closed compartment, the area is to be served by an effective mechanical ventilation system of extraction type providing not less than 6 air changes per hour which is independent from the ventilation system of other spaces. The ventilation system is to be capable of being controlled

from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment is to be provided outside the compartment adjacent to each point of entry.

d) The storage tank may be located within the engine room. In this case, the requirements of [20.7.2] c) are to be complied with, except that a separate ventilation system is not required when the general ventilation system for the space is arranged so as to provide an effective movement of air in the vicinity of the storage tank and is maintained in operation continuously except when the storage tank is empty and has been thoroughly ventilated.

e) Each storage tank for chemical treatment fluids is to be provided with level monitoring arrangements and high/low level alarms. In cases where heating and/or cooling systems are provided, high and/or low temperature alarms or temperature monitoring are also to be provided accordingly.

f) The storage tanks are to have sufficient strength to withstand a pressure corresponding to the maximum height of a fluid column in the overflow pipe, with a minimum of 2,4 m above the top plate taking into consideration the specific density of the treatment fluid.

g) Where chemical treatment fluid is stored in integral tanks, the following are to be considered during the design and construction:

1) These tanks may be designed and constructed as integral part of the hull, (e.g. double bottom, wing tanks).

2) These tanks are to be coated with appropriate anti-corrosion coating and are to be segregated by cofferdams, void spaces, pump rooms, empty tanks or other similar spaces so as to not be located adjacent to accommodation, cargo spaces containing cargoes which react with chemical treatment fluids in a hazardous manner as well as any food stores, oil tanks and fresh water tanks.

3) These tanks are to be designed and constructed as per the structural requirements applicable to hull and primary support members for a deep tank construction.

4) These tanks are to be included in the ship's stability calculation.

h) The requirements specified in [20.7.2] c) also apply to closed compartments normally entered by persons:

1) when they are adjacent to the integral storage tank for chemical treatment fluids and there are possible leak points (e.g. manhole, fittings) from these tanks; or

2) when the treatment fluid piping systems pass through these compartments, unless the piping system is made of steel or other equivalent material with melting point above 925 degrees C and with fully welded joints.

i) The chemical treatment fluid piping and venting systems are to be independent of other ship service piping and/or systems. The chemical treatment fluid piping systems are not to be located in accommodation, service spaces, or control stations. The vent pipes of the storage tank are to terminate in a safe location on the weather deck and the tank venting system is to be arranged to prevent entrance of water into the tank for chemical treatment fluids.

j) Storage tanks and pipes/piping systems and drip trays for chemical treatment fluids which transfer undiluted chemical treatment fluids are to be of steel or other equivalent material with a melting point above 925 degrees C.

k) Storage tanks and pipes/piping systems for chemical treatment fluids are to be made with a material compatible with chemical treatment fluids, or coated with appropriate anticorrosion coating.

Note 1: Several metals are incompatible with the chemical treatment fluids, e.g. NaOH is incompatible with zinc, aluminum, etc.

l) Regardless of design pressure and temperature, piping systems containing chemical treatment fluids only are to comply with the requirements applicable to Class I piping systems. As far as practicable, e.g. except for the flange connections that connect to tank valves, the piping systems are to be joined by welding.

m) The following connections are to be screened and fitted with drip trays to prevent the spread of any spillage where they are installed:

1) Detachable connections between pipes (flanged connections and mechanical joints, etc.);

2) Detachable connections between pipes and equipment such as pumps, strainers, heaters, valves; and

3) Detachable connections between equipment mentioned in the above subparagraph.

The drip trays are to be fitted with drain pipes which lead to appropriate tanks, such as residue tanks, which are fitted with high level alarm, or are to be fitted with alarms for leak detection. In cases where such tank is an integral tank, [20.7.2] g), 1) and [20.7.2] g), 2) are to be applied to the tank.

n) For the protection of crew members, the ship is to have on board suitable personnel protective equipment. The number of personnel protective equipment carried onboard is to be appropriate for the number of personnel engaged in regular handling operations or that may be exposed in the event of a failure; but in no case is there to be less than two sets available onboard.

o) Personnel protective equipment is to consist of protective clothing, boots, gloves and tight-fitting goggles.

Eyewash and safety showers are to be provided, the location and number of these eyewash stations and safety showers are to be derived from the detailed installation arrangements. As a minimum, the following stations are to be provided:

1) In the vicinity of transfer or treatment pump locations. If there are multiple transfer or treatment pump locations on the same deck then one eyewash and safety shower station may be considered for acceptance provided that the station is easily accessible from all such pump locations on the same deck.
2) An eyewash station and safety shower is to be provided in the vicinity of a chemical bunkering station on-deck. If the bunkering connections are located on both port and starboard sides, then consideration is to be given to providing two eyewash stations and safety showers, one for each side.
3) An eyewash station and safety shower is to be provided in the vicinity of any part of the system where a spillage/drainage may occur and in the vicinity of system connections/components that require periodic maintenance.

p) Storage tanks for chemical treatment fluids are to be arranged so that they can be safely emptied of the fluids and ventilated by means of portable or permanent systems.

20.7.3 Requirement for Exhaust Gas Cleaning Systems discharge water pipeline *(1/7/2024)*

a) Overboard discharges from exhaust gas cleaning system (EGCS) are not to be interconnected to other systems.

b) Due consideration is to be given to the location of overboard discharges with respect to vessel propulsion features, such as thrusters, propellers or to prevent any discharge water onto survival craft during abandonment.

c) The piping material for the EGCS discharge water pipeline system is to be selected based on the corrosive nature of the liquid media.

d) Special attention is to be paid to the corrosion resistivity of EGCS overboard discharge piping. Where applicable, adequate arrangements are to be provided to prevent galvanic corrosion due to the use of dissimilar metals.

e) In case distance piece is fitted between the outboard discharge valve and the shell plating, it is to be made of corrosion resistant material steel or be coated with an anti-corrosive material suitable for the operating environment. The thickness of the distance piece is to be at least the minimum values specified in 1) and 2) as below; otherwise Sch.160 thickness specified in piping standards is, as far as practicable, to be used.

1) 12 mm in cases where complete pipe is made of corrosion resistant material steel.
2) 15 mm of mild steel in cases where the inside the pipe is treated with an anticorrosive coating or fitted with a sleeve of corrosion resistant material.

20.7.4 Miscellaneous *(1/7/2022)*

Tanks for residues generated from the exhaust gas cleaning process are to satisfy the following requirements:

a) The tanks are to be independent from other tanks, except in cases where these tanks are also used as the over flow tanks for chemical treatment fluids storage tank.

b) Tank capacities are to be decided in consideration of the number and kinds of installed exhaust gas cleaning systems as well as the maximum number of days between ports where residue can be discharged ashore. In the absence of precise data, a figure of 30 days is to be used.

c) Where residue tanks used in closed loop chemical treatment systems are also used as the overflow tanks for chemical treatment fluids storage tank, the requirements for storage tanks apply.

20.8 Monitoring and Safety Functions for Exhaust Gas Cleaning (SO_x) Systems

20.8.1 General *(1/1/2026)*

Marine air pollution regulations typically require the use of low-sulfur fuel in order to reduce SO_x gaseous emissions. The use of Exhaust Gas Cleaning Systems (EGCS) technology is generally permitted as an alternative means of compliance. EGCS – SO_x Scrubbers can be effective in complying with regulations that require the use of 0,5 percent sulfur fuel globally and 0,1 percent in Emission Control Areas (ECA). The following requirements apply to the arrangements intended for the safeguard of the ship in case of malfunction of the EGCS.

20.8.2 Exhaust Bypass *(1/1/2026)*

The EGCS bypass arrangement is to be provided in order to continue the operation of the engines. The arrangement is to be operated automatically in accordance with Tab 33. The bypass arrangement may be omitted, provided the EGCS is designed for dry operation and the lack of the bypass arrangement does not interfere with the continuous operation of the engine.

In installations with individually controlled bypass and uptake dampers, an interlock is required to prevent both dampers from being closed at the same time. The interlock can comprise a pressure sensor upstream of the dampers, interfaced to the EGCS safety system, opening the bypass damper in case of high back pressure.

20.8.3 Control and Monitoring System *(1/1/2026)*

Automatic control, monitoring (including washwater discharge criteria), alarm, and safety functions are to be provided for the EGCS so that operations remain within preset parameters for all fuel oil combustion unit(s) and SO_x emission abatement system operating conditions.

The control system for the exhaust gas cleaning system may be connected to an integrated control system or may be a standalone system. The system is to be designed such that a single fault of a component will not lead to a potentially dangerous situation for human safety and/or the vessel. An FMEA, or equivalent, demonstrating the safety system design basis is to be submitted to the Society, when the control system is connected to an integrated control system of a vessel.

For vessels with unmanned propulsion machinery space, the alarm and monitoring systems of the EGCS can be integrated in the vessel's centralized monitoring systems.

20.8.4 Safety Shutdown System *(1/1/2026)*

A safety shutdown system is to be provided. The safety system is to be designed as far as is practicable to operate independently of the control and alarm systems mentioned in [20.8.3], such that failures or malfunctions in the control and alarm systems will not prevent the safety system from operating:

a) Upon activation of the safety shutdown system, visual and audible alarms are to be indicated at both the local and remote control positions. Visual alarms are to include a means of indicating the parameters causing shutdown.

b) In addition to the automatic shutdown system, manual emergency shutdown arrangements are to be provided at both the local and remote the control positions.

c) In the event where shutdown by the safety shutdown system is activated, the restart should not occur automatically, unless after the system is manually reset.

d) Safety shutdown is to be automatically activated for the conditions in Tab 33.

20.8.5 Monitored Parameters *(1/1/2026)*

Table 33 : Parameters for indication, alarm and safety functions *(1/1/2026)*

	Gr 1		Gr 2
Monitored Parameters	Indication at control position(s)	Alarm Activation	Automatic EGC Shutdown with alarm and EGC Bypass **(1)**
Exhaust gas temperature after EGC unit	X	High	X (High-High)
Pressure before the EGC unit and/or Differential pressure across EGC unit **(2)**	X	High	X (High-High)
Water level in wet EGC unit		High	X (High-High)
EGC exhaust fan/blower motors **(3)**	Running	Stop	
EGC exhaust bypass, isolation, mixing valves, where provided	Position **(4)**		
Operation of EGC washwater pumps or washwater system supply pressure	Running X	Stop Low	
Chemical treatment fluid storage tank temperature		Low/High **(5)**	
Chemical treatment fluid storage tank level		Low/High **(5)**	

	Gr 1		Gr 2
Chemical treatment fluid leakage detection in system drip tray or drain / residue tank		X **(6)**	

Gr 1 Common sensor for indication and alarm

Gr 2 Sensor for shut down and bypass

(1) Automatic stopping of all EGCS pumps. Automatic bypass of the EGC unit is required when the EGC unit is not suitable for operation in the dry condition

(2) As applicable in accordance with the specific EGC system design and installation

(3) If applied

(4) See [20.8.2]

(5) See [20.7.2] e)

(6) if necessary, see [20.7.2] m)

20.9 Onboard Carbon Capture and Storage systems (OCCS)

20.9.1 Definitions *(1/1/2026)*

a) OCCS - Onboard Carbon Capture and Storage System

b) CO2 Storage tanks - Tanks where captured CO2 is stored either in a packaged form (e.g. portable tank) or in bulk (e.g. IMO Type C storage tanks, as defined in IGC Code, integral ship tanks)

c) CO2 Machinery handling spaces - Spaces where captured CO2 is handled, such as but not limited to the spaces where the CO2 compressors, heat exchangers, and equipment and pumps for stripping, drying, liquefaction and transfer are located

d) CO2 tank room/hold space - Enclosed space where a CO2 storage tank is fitted

e) Chemical Carbon solvent - Amine-based chemical solvent such as Ethanolamine solutions (MEA-Monoethanolamine, DEA-Diethanolamine, TEA-Triethanolamine) are currently the common and most widely used solvent for Carbon emissions abatement systems. Additionally, sodium hydroxide (NaOH) or calcium hydroxide (Ca(OH)2) may also be used as chemical carbon solvent where reaction with CO2 produces a solution containing sodium carbonate and sodium bicarbonate depending on the reaction conditions. All the chemical carbon solvents are hereinafter referred to as solvents

f) post-combustion carbon emission abatement plant - a system which is intended to deal with the carbon composites generated during combustion of a carbon containing fuel in a fuel consumer. It is opposite of pre-combustion carbon emission abatement plant, which is a system intended to deal with the carbon in the fuel, prior to its combustion in a fuel consumer

g) full flow carbon capture plants - carbon capture plants where the full amount of exhaust gases from an engine or group of engines is passing through the carbon capture plant

h) side streams carbon capture plants - plants where the flow of exhaust gases is divided in two streams, one of which is passing through the carbon capture plant.

20.9.2 Risk Assessment *(1/1/2026)*

When an Onboard Carbon Capture and Storage system is intended to be installed onboard, a risk assessment is to be conducted and the relevant recommendations are to be considered in the design construction, testing and operation of the OCCS as applicable.

The risk assessment is to address at least the following systems:

a) supply, storage, handling, venting and unloading system (if installed) of solvents

b) compression, liquefaction, storage and unloading system of OCCS (if installed)

c) location and layout of OCCS equipment and CO2 storage tanks on board

d) supply, storage, and handling of the refrigerant for the carbon dioxide liquefaction system

e) gas detection system for the vapours of the solvents and of other solutions as result of the CO2 capture process chemical reaction

f) bilge and draining system dedicated to rooms where OCCS equipment are installed

g) ventilation system dedicated to rooms where OCCS equipment are installed.

The risk assessment is to address at least the following failure scenarios:

a) leakage of chemical carbon solvent into the ship and on open deck

b) leakage of CO2 into the ship and on open deck

c) leakage of refrigerant for carbon dioxide liquefaction system into the ship and on open deck

d) failure and malfunction of components of carbon capture and storage system which may impair the performance of the ship essential services (e.g. propulsion, life saving appliances, fire fighting systems, main power generation and distribution…).

The hazards to be considered are to include the following:

a) toxicity and flammability of the solvent and other chemical solutions used in the CO2 capture process

b) the asphyxiation capability of CO2

c) toxicity and flammability properties of the refrigerant.

The flashpoint of the chemical carbon solvent should be above 60°C. In case that the chemical treatment fluid has a flashpoint below 60°C or is toxic, the requirements are to be decided on a case-by-case basis and as part of the risk assessment.

20.9.3 General Arrangement *(1/1/2026)*

The equipment handling CO2, such as compressors, heat exchangers, equipment receivers and pumps for stripping, drying, liquefaction and transfer are not to be located within machinery spaces of Category A, unless the arrangement is supported by the risk assessment, in which case such space is also to be regarded as a CO2 machinery handling space.

CO2 machinery handling spaces are not regarded as cargo pump-rooms.

Where the solvent is stored in integral tanks, they are to be segregated, except on those surfaces bound by shell plating, by cofferdams, void spaces, pump-rooms, empty tanks or other similar spaces so as to not be located adjacent to accommodation spaces, control stations, electrical equipment rooms, cargo spaces containing cargoes which react with chemical treatment fluids in a hazardous manner, and any food stores, oil tanks or fresh water tanks. Where a cofferdam is impracticable, alternative arrangements can be considered and are subject to risk assessment.

The solvent storage tanks are not to be located forward of the collision bulkhead.

Arrangements for solvent storage and transfer are to be made to allow the replacement and refilling of the solvent, in accordance with the transfer facility and in line with the operating manual of the plant.

Arrangements for captured CO2 and relevant solutions transfer are to be made to allow safe offloading/discharge in accordance with the transfer facility and in line with the operating manual of the plant.

For the arrangement of the tanks containing the captured CO2 and relevant solutions from CO2 capture process, see [20.9.5].

20.9.4 Piping arrangement *(1/1/2026)*

Means of measuring the exhaust gas differential pressure across the carbon capture plant are to be provided.

In carbon capture plants intended to capture carbon from a limited flow side stream of exhaust gases, the piping for the exhaust gas mainstream is to be suitable for the maximum exhaust gas flow from the combustion machinery to which it is connected.

Acceptance of a common carbon emissions abatement plant (post-combustion) fed by multiple consumers using gas as fuel or other low-flashpoint fuels, is subject to the risk assessment required in [20.9.2] due to the hazard connected to unburned gas or low-flashpoint fuel entering any other machinery.

20.9.5 CO2 storage tank arrangement *(1/1/2026)*

The storage tanks containing captured CO2 and relevant solutions from CO2 capture process are to be located outside of accommodation spaces, control stations and machinery spaces of Category A, and are not to be located forward of the collision bulkhead.

The hold spaces of CO2 storage tanks containing pure CO2 below open deck are to be separated from machinery and boiler spaces, accommodation spaces, service spaces, control stations, chain lockers, domestic water tanks and from stores by a gastight bulkhead of all-welded construction forming an A-0 class division. Alternative arrangements can be accepted for storage tanks containing CO2 dissolved in solutions considered not to have toxicity and polluting risks as evaluated during the risk assessment.

CO2 storage tanks containing pure CO2 are to be located at a distance inboard of not less than B/15 or 2 m, whichever is less, measured from the moulded line of the bottom shell plating at centreline and nowhere less than "d", where "d" = 0,8 m, from the moulded line of outer shell to ensure an appropriate protective distance from external damage, except when fitted on open deck. Alternative arrangement can be accepted for storage tanks containing CO2 dissolved in solutions considered not having toxicity risks and polluting risk as evaluated during the risk assessment

Where the CO2 storage tanks are arranged on the open deck, the impacts on the navigation bridge visibility and the safety access for crew members are to be considered. In addition, the tank location is to consider the potential hazards

related to external mechanical damage. This includes areas for storing or handling machinery, the risk of accidental mechanical damage (such as dropped objects), and environmental conditions.

For CO2 storage tanks containing pure CO2 fitted in enclosed or semi-enclosed tank hold spaces, suitable drainage arrangements for the hold spaces that are not connected with the machinery space of Category A are to be provided. Means of detecting any leakage are to be provided.

Spaces surrounding CO2 storage tanks containing liquefied pure CO2 carried at low temperature are to be filled with suitable dry air and be maintained in this condition with dry air provided by suitable air-drying equipment. If CO2 is carried at ambient temperature or the design of the tank ensures no risk of moisture condensation, the requirement for dry air is not applicable.

The materials used in construction of the CO2 storage tank hold spaces are to be protected from potential leakages or are to have a design temperature corresponding to the temperature they can be subject to in a leakage scenario.

20.9.6 Chemical carbon solvent arrangements *(1/1/2026)*

OCCS systems using the aqueous solution of sodium hydroxide (NaOH) or calcium hydroxide (Ca(OH)2) as chemical carbon solvents are to comply with the requirements contained in [20.7].

20.9.7 Piping design, construction and testing *(1/1/2026)*

Piping intended for conveying pure CO2 or CO2 dissolved in solution is to be joined by welding and regarded as a Class II piping system, but vapour lines at pressure greater than 4 MPa or liquid lines are to be regarded as a Class I piping system. Open ended (not pressurized) vent piping may be regarded as a Class III piping system.

Piping systems containing chemical carbon solvents (such as amine-based solutions) only are to comply with the requirements applicable to Class I, Class II or Class III piping systems, depending on design pressure, temperature, flashpoint, toxicity and corrosiveness of the chemical carbon solvent. Toxic and corrosive solvents are those which are listed in the IMO "International Maritime Dangerous Goods Code (IMDG Code)", as amended and as described in the Material Safety Data Sheet (MSDS) provided by the product supplier. Open ended and vent piping may be regarded as a Class III piping system.

Pipes/piping systems containing chemical carbon solvent are to be of steel or other equivalent material with melting point above 925 degrees C, except downstream of the tank valve, provided this valve is metal seated and arranged as fail-to-closed or with quick closing from a safe position outside the space in the event of fire; in such case, type approved plastic piping may be accepted even if it has not passed a fire endurance test. The solvent pipes/piping systems are to be made with a material compatible with the solvent or coated with appropriate anti-corrosion coating.

The design, construction and testing of liquefied and gaseous CO2 piping systems (including exhaust lines of safety valves or similar piping) are to comply with the requirements in Pt E, Ch 9, Sec 5, as far as reasonable and practicable.

20.9.8 CO2 Tank design, construction and testing *(1/1/2026)*

Fully pressurized and refrigerated storage tanks for pure CO2 are to be independent tanks, as defined in the IGC Code and the additional and special CO2 requirements in IGC Code, para. 17.21 "Carbon dioxide" are to be complied with, as far as reasonable and practicable. The storage tanks for CO2 dissolved solutions where the toxicity and corrosive hazards are considered negligible in the risk assessment, can be built as ship integral or independent tanks.

Independent CO2 storage tanks are to comply with the requirements in Pt E, Ch 9, Sec 4, Sec 6, Sec 8, Sec 13 and Sec 15, as far as reasonable and practicable.

CO2 process pressure vessels are to comply with the requirements in Pt E, Ch 9, Sec 5 and Sec 6, as far as reasonable and practicable.

20.9.9 CO2 storage tank pressure/temperature control *(1/1/2026)*

With the exception of tanks designed to withstand full gauge vapour pressure of the CO2 under conditions of the upper ambient design temperatures, tank pressure and temperature are to be maintained at all times within their design range by one, or a combination of, the following methods:

- pressure accumulation
- reliquefaction of vapours
- liquid cooling.

Venting of the captured CO2 from the storage tank is only allowed when necessary for the purpose of securing the safety of the ship or saving life at sea, or when resulting from damage to the ship or its equipment.

20.9.10 Ventilation *(1/1/2026)*

The ventilation system for the CO2 machinery handling spaces (enclosed spaces) is to be separated from other ventilation systems and is to be of the extraction type. The ventilation capacity is to be minimum as follows:

- 6 air changes per hour in spaces with only desorption & stripping equipment

- 6 air changes per hour in CO2 handling spaces but with ability to automatically increase upon detection of leakage to 30 air changes per hour.

The suction points for exhaust are to be fitted at the floor level of the room/space.

The ventilation of the CO2 tank hold/space is to have a capacity of 30 air changes per hour; in normal conditions the ventilation may be reduced to 6 changes per hour, subject to availability of a leakage detection system capable of increasing the ventilation in case of leakages.

Spaces where chemical storage tanks are located are to have a mechanical ventilation of extraction type with at least 6 air changes/hour independent from the ventilation system of other spaces. The ventilation system is to be capable of being controlled from outside the compartment.

21 Certification, inspection and testing of piping systems

21.1 Application

21.1.1 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.

On board testing is dealt with in Sec 16.

21.2 Type tests

21.2.1 Type tests of flexible hoses and expansion joints *(1/1/2006)*

a) Type approval tests are to be carried out on flexible hoses or expansion joints of each type and of sizes to be agreed with the Society, in accordance with Tab 34 (see also the "Rules for the type approval of flexible hoses and expansion joints").

b) The flexible hoses or expansion joints subjected to the tests are to be fitted with their connections.

Table 34 : Type tests to be performed for flexible hoses and expansion joints *(1/7/2001)*

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 **(2)**	X	X
pressure impulse test	X **(6)**	NR
flexibility test	X **(3)**	NR
elastic deformation test	NR	X
cyclic expansion test **(4)**	NR	X
resistance of the material **(5)**	X	X

(1) only for flexible hoses and expansion joints used in flammable oil systems and, when required, in sea water systems.
(2) the Society reserves the right to require the vibration test in case of installation of the components on sources of high vibrations.
(3) only for flexible hoses conveying low temperature fluids.
(4) the Society reserves the right to require the cyclic expansion test for piping systems subjected to expansion cycles
(5) internal to the conveyed fluid to be demonstrated by suitable documentation and / or tests.
(6) only for flexible hoses.
Note 1: X = required, NR = not required.

21.2.2 Type tests of air pipe closing devices *(1/1/2002)*

Type approval tests are to be carried out on each type and size of air pipe closing device, in accordance with Tab 35 and the "Rules for type approval and testing of air pipe closing devices".

Table 35 : Type tests to be performed for air pipe closing appliances

Test to be performed	Type of air closing appliance	
	Float type	Other types
tightness test **(1)**	X	X
flow characteristic determination **(2)**	X	X
impact test of floats	X	
pressure loading test of floats	X **(3)**	

(1) the tightness test is to be carried out during immerging/emerging in water, in the normal position and at an inclination of 40 degrees.
(2) pressure drop is to be measured versus flow rate using water.
(3) only for non-metallic floats.
Note 1: X = required

21.3 Testing of materials

21.3.1 General

a) Detailed specifications for material tests are given in Part D.

b) Requirements for the inspection of welded joints are given in Part D.

c) The requirements of this Article do not apply to piping systems subjected to low temperatures, such as cargo piping of liquefied gas carriers.

21.3.2 Tests for materials *(1/7/2012)*

a) Where required in Tab 36, 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
- impact test as prescribed in the relevant section of Part D
- 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 App 3.

21.4 Hydrostatic testing of piping systems and their components

21.4.1 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.

21.4.2 Hydrostatic pressure tests of piping

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.

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.

f) While satisfying the condition stated in b), the test pressure of pipes located on the discharge side of centrifugal pumps driven by steam turbines is not to be less than the maximum pressure liable to be developed by such pumps with closed discharge at the operating speed of their overspeed device.

g) When the hydrostatic test of piping is carried out on board, these tests may be carried out in conjunction with the tests required in [21.4.7]

21.4.3 Hydrostatic tests of valves, fittings and heat exchangers *(1/7/2002)*

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) Valves intended to be fitted on the ship side below the load waterline are to be subjected to hydrostatic tests under a pressure not less than 0,5 MPa.

c) 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 Sec 3.

d) 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.

e) For coolers of internal combustion engines, see Sec 2.

21.4.4 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, witha 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.

21.4.5 Hydrostatic tests of pumps and compressors

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 pressure p_H 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_H : test pressure, in MPa
- p : design pressure, as defined in [1.3.2], in MPa.

p_H is not to be less than 0,4 MPa.

b) While satisfying the condition stated in a), the test pressure for centrifugal pumps driven by steam turbines is not to be less than 1,05 times the maximum pressure likely to be recorded with closed discharge at the operating speed of the overspeed device.

c) Intermediate coolers of compressors are to undergo a hydrostatic test under a pressure at least equal to the pressure p_H defined in 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.

d) 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.

e) For air compressors and pumps driven by diesel engines, see Sec 2.

***21.4.6* Hydrostatic test of flexible hoses and expansion joints** *(1/7/2004)*

a) Each flexible hose or expansion joint, together with its connections, is to undergo a hydrostatic test under a pressure at least equal to 1,5 times the maximum service pressure.

b) During the test, the flexible hose or expansion joint is to be repeatedly deformed from its geometrical axis.

***21.4.7* Pressure tests of piping after assembly on board** *(1/1/2025)*

After assembly on board, the following tightness tests are to be carried out in the presence of the Surveyor.

In general, all the piping systems covered by these requirements are to be checked for leakage under operational conditions and, if necessary, using special techniques other than hydrostatic testing. In particular, heating coils in tanks and liquid fuel lines are to be tested to not less than 1,5 times the design pressure but in no case less than 0,4 MPa.

Pneumatic leak testing may be carried out on water sensitive systems, in lieu of hydrostatic testing. In certain circumstances, a combined hydrostatic – pneumatic strength test may also be applied, where the system is partially filled with water and the free space above is pressurized with a test gas (typically air or nitrogen). When pneumatic tests cannot be avoided, the safety precautions in IACS Rec. 140, Part F, are to be observed.

21.5 Testing of piping system components during manufacturing

21.5.1 Pumps

a) Bilge and fire pumps are to undergo a performance test.

b) Rotors of centrifugal feed pumps for main boilers are to undergo a balancing test.

***21.5.2* Centrifugal separators** *(1/7/2020)*

Centrifugal separators used for fuel oil and lubricating oil are to undergo a running test, normally with a fuel water mixture.

Each separator is to be tested to ensure that it is capable to prepare fuel with an amount of water not exceeding 0,3 % v/v.

21.6 Inspection and testing of piping systems

21.6.1 The inspections and tests required for piping systems and their components are summarised in Tab 36.

Table 36 : Inspection and testing at works for piping systems and their components *(1/7/2019)*

No.	Item	Tests for materials **(1)**		Inspections and tests for the product **(1)**			Reference to the Rules
		Tests required	Type of material certificate **(2)**	During manufacturing (NDT)	After completion **(3)**	Type of product certificate **(2)**	
1	Valves, pipes and fittings						
	a) class I, d ≥ 50 mm or class II, d ≥ 100 mm	X	C	X **(4)**	X	C	[21.3.2] [3.6.2] [3.6.3] [21.4.3]; Pt D, Ch 2, Sec 2, [1.8]
	b) class I, d < 50 mm or class II, d < 100 mm	X	W	X **(4)**	X	C	[21.3.2] [3.6.2] [3.6.3] [21.4.3]; Pt D, Ch 2, Sec 2, [1.8]
	c) class III where "d" is the nominal diameter	X	W		X	W	[21.3.2]
2	Flexible hoses and expansion joints	X **(5)**	W		X	C	[21.3.2] [21.4.6]
3	Pumps and compressors						
	a) all	X	W		X	C	[21.4.5]
	b) bilge and fire pumps	X	W		X	C	[21.5.1]
	c) feed pumps for main boilers:						
	• casing and bolts	X	C				Part D
	• main parts			X		C	Part D
	• rotor				X		[21.5.1]
	d) forced circulation pumps for main boiler:						
	• casing and bolts	X	C			C	Part D

(1) X = test is required

(2) C = class certificate
W = works' certificate

(3) Visual examination and hydrostatic pressure test as required.

(4) NDT on welding in case of welded construction.

(5) If metallic.

(6) 100% radiographic examination or equivalent on butt-welded joints of pipes with an external diameter exceeding 75 mm. Magnetic particle or liquid penetrant tests on other types of welded joints.

(7) 10% radiographic examination or equivalent on butt-welded joints of pipes with an external diameter exceeding 100 mm. Magnetic particle or liquid penetrant tests on other types of welded joints.

(8) C certificate for the piping systems mentioned in [21.4.2] a).

No.	Item	Tests for materials **(1)**		Inspections and tests for the product **(1)**			Reference to the Rules
		Tests required	Type of material certificate **(2)**	During manufacturing (NDT)	After completion **(3)**	Type of product certificate **(2)**	
4	Centrifugal separators				X	C	[21.5.2]
5	Prefabricated pipe lines						
	a) class I			X **(4) (6)**	X	C	[3.6.2] [3.6.3] [21.4.2]
	b) class II			X **(4) (7)**	X	C	[3.6.2] [3.6.3] [21.4.2]
	c) class III				X	W **(8)**	[21.4.2]

(1) X = test is required
(2) C = class certificate
W = works' certificate
(3) Visual examination and hydrostatic pressure test as required.
(4) NDT on welding in case of welded construction.
(5) If metallic.
(6) 100% radiographic examination or equivalent on butt-welded joints of pipes with an external diameter exceeding 75 mm. Magnetic particle or liquid penetrant tests on other types of welded joints.
(7) 10% radiographic examination or equivalent on butt-welded joints of pipes with an external diameter exceeding 100 mm. Magnetic particle or liquid penetrant tests on other types of welded joints.
(8) C certificate for the piping systems mentioned in [21.4.2] a).

SECTION 11 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 of all mechanically propelled ships, and to the steering mechanism of thrusters used as means of propulsion.

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:

- Sec 16, as regards sea trials
- Pt B, Ch 10, Sec 1, as regards the rudder and the rudder stock
- Pt E, Ch 7, Sec 4, [7], when fitted to oil tankers, chemical tankers or gas carriers.

1.2 Documentation to be submitted

1.2.1 Documents to be submitted for all steering gear

Before starting construction, all plans and specifications listed in Tab 1 are to be submitted to the Society for approval.

Table 1 : Documents to be submitted for steering gear

No.	I / A **(2)**	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	For hydraulic steering gear, the schematic layout of the hydraulic piping of power actuating systems, including the hydraulic fluid refilling system, with indication of: • the design pressure • the maximum working pressure expected in service • the diameter, thickness, material specification and connection details of the pipes • the hydraulic fluid tank capacity • the flashpoint of the hydraulic fluid
6	I	For hydraulic pumps of power units, the assembly longitudinal and transverse sectional drawings and the characteristic curves
7	A	Assembly drawings of the rudder actuators and constructional drawings of their components, with, for hydraulic actuators, indication of: • the design torque • the maximum working pressure • the relief valve setting pressure
8	I	Constructional drawings of the relief valves for protection of the hydraulic actuators, with indication of: • the setting pressure • the relieving capacity
9	A	Diagrams of the electric power circuits
10	A	Functional diagram of control, monitoring and safety systems including the remote control from the navigating bridge, with indication of the location of control, monitoring and safety devices
11	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

No.	I / A **(2)**	Document **(1)**
12	I/A	For azimuth thrusters used as steering means, the specification and drawings of the steering mechanism and, where applicable, documents 2 to 6 and 8 to 11 above

(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) A = to be submitted for approval in four copies
I = to be submitted for information in duplicate.

1.2.2 Additional documents

The following additional documents are to be submitted:

- analysis in relation to the risk of single failure, where required by [3.5.2]
- analysis in relation to the risk of hydraulic locking, where required by [3.5.5]
- failure analysis in relation to the availability of the hydraulic power supply, where required by [4.5.3], item b)
- fatigue analysis and/or fracture mechanics analysis, where required by Pt E, Ch 7, Sec 4, [7.3.3].

1.3 Definitions

1.3.1 Main steering gear

Main steering gear is the machinery, rudder actuators, steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudder stock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.

1.3.2 Steering gear power unit

Steering gear power unit is:

- *in the case of electric steering gear, an electric motor and its associated electrical equipment*
- *in the case of electrohydraulic steering gear, an electric motor and its associated electrical equipment and connected pump*
- *in the case of other hydraulic steering gear, a driving engine and connected pump.*

1.3.3 Auxiliary steering gear

Auxiliary steering gear is the equipment other than any part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

1.3.4 Power actuating system

Power actuating system is the hydraulic 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.

1.3.5 Rudder actuator

Rudder actuator is the component which directly converts hydraulic pressure into mechanical action to move the rudder.

1.3.6 Steering gear control system *(1/7/2023)*

Steering gear control system is the equipment by which orders are transmitted from the navigation bridge to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

Steering gear control system is also understood to cover “the equipment required to control the steering gear power actuating system”.

1.3.7 Maximum ahead service speed

Maximum ahead service speed is the greatest speed which the ship is designed to maintain in service at sea at the deepest seagoing draught.

1.3.8 Maximum astern speed

Maximum astern speed is the speed which it is estimated the ship can attain at the designed maximum astern power at the deepest seagoing draught.

1.3.9 Maximum working pressure

Maximum working pressure is the maximum expected pressure in the system when the steering gear is operated to comply with the provisions of [3.3.1], item b), or [4.3.1], item b).

1.3.10 Hydraulic locking *(1/7/2023)*

Hydraulic locking means all situations where two hydraulic systems (usually identical) oppose each other in such a way that it may lead to loss of steering. It can either be caused by pressure in the two hydraulic systems working against each other or by hydraulic "by-pass" meaning that the systems puncture each other and cause pressure drop on both sides or make it impossible to build up pressure.

1.4 Symbols

1.4.1 The following symbols are used for strength criteria of steering gear components:

V : Maximum service speed, in knots, with the ship on summer load waterline. When the speed is less than 10 knots, V is to be replaced by the value (V+20)/3

d_s : Rule diameter of the rudder stock in way of the tiller, in mm, as defined in Pt B, Ch 10, Sec 1

d_{se} : Actual diameter of the upper part of the rudder stock in way of the tiller, in mm

(in the case of a tapered coupling, this diameter is measured at the base of the assembly)

T_R : Rule design torque of the rudder stock given, in kN.m, by the following formula:

$$T_R = 13{,}5 \cdot d_s^3 \cdot 10^{-6}$$

T_E : For hand emergency operation, design torque due to forces induced by the rudder, in kN.m, given by the following formula:

$$T_E = 0{,}62 \cdot \left(\frac{V_E + 2}{V + 2}\right)^2 \cdot T_R$$

where:

- $V_E = 7$, where $V \leq 14$
- $V_E = 0{,}5\ V$, where $V > 14$

T_G : For main hydraulic or electrohydraulic steering gear, torque induced by the main steering gear on the rudder stock when the pressure is equal to the setting pressure of the relief valves protecting the rudder actuators

Note 1: for hand-operated main steering gear, the following value is to be used:

$T_G = 1{,}25.T_R$

T_A : For auxiliary hydraulic or electrohydraulic steering geas, torque induced by the auxiliary steering gear on the rudder stock when the pressure is equal to the setting pressure of the relief valves protecting the rudder actuators

Note 2: for hand-operated auxiliary steering gear, the following value is to be used:

$T_A = 1{,}25.T_E$

T'_G : For steering gear which can activate the rudder with a reduced number of actuators, the value of T_G in such conditions

σ : Normal stress due to the bending moments and the tensile and compressive forces, in N/mm^2

τ : Tangential stress due to the torsional moment and the shear forces, in N/mm^2

σ_a : Permissible stress, in N/mm^2

σ_c : Combined stress, determined by the following formula:

$$\sigma_c = \sqrt{\sigma^2 + 3\tau^2}$$

R : Value of the minimum specified tensile strength of the material at ambient temperature, in N/mm^2

R_e : Value of the minimum specified yield strength of the material at ambient temperature, in N/mm^2

R'_e : Design yield strength, in N/mm^2, determined by the following formulae:

- $R'_e = R_e$, where $R \geq 1{,}4\ R_e$
- $R'_e = 0{,}417\ (R_e + R)$ where $R < 1{,}4\ R_e$

2 Design and construction - Requirements applicable to all ships

2.1 Mechanical components

2.1.1 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) Any non-duplicated essential component is, where appropriate, to utilise anti-friction bearings, such as ball bearings, roller bearings or sleeve bearings, which are to be permanently lubricated or provided with lubrication fittings.

c) The construction is to be such as to minimise local concentration of stress.

d) 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.

2.1.2 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 Part D. 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.

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.

2.1.3 Scantling of components

The scantling of steering gear components is to be determined considering the design torque M_T and the permissible value σ_a of the combined stress, as given in:

- Tab 2 for components which are protected against overloads induced by the rudder
- Tab 3 for components which are not protected against overloads induced by the rudder.

Table 2 : Scantling of components protected against overloads induced by the rudder

Conditions of use of the components	M_T	σ_a
Normal operation	T_G	• if $T_G \leq 1,25\ T_R$: $\sigma_a = 1,25\ \sigma_0$ • if $1,25\ T_R < T_G < 1,50\ T_R$: $\sigma_a = \sigma_0\ T_G/T_R$ • if $T_G \geq 1,50\ T_R$: $\sigma_a = 1,50\ \sigma_0$ where $\sigma_0 = 0,55\ R'_e$
Normal operation, with a reduced number of actuators	T'_G	• if $T'_G \leq 1,25\ T_R$: $\sigma_a = 1,25\ \sigma_0$ • if $1,25\ T_R < T'_G < 1,50\ T_R$: $\sigma_a = \sigma_0\ T_G/T_R$ • if $T'_G \geq 1,50\ T_R$: $\sigma_a = 1,50\ \sigma_0$ where $\sigma_0 = 0,55\ R'_e$
Emergency operation achieved by hydraulic or electrohydraulic steering gear	lower of T_R and $0,8\ T_A$	$0,69\ R'_e$
Emergency operation, with a reduced number of actuators	lower of T_R and $0,8\ T'_G$	$0,69\ R'_e$
Emergency operation achieved by hand	T_E	$0,69\ R'_e$

Table 3 : Scantling of components not protected against overloads induced by the rudder

Conditions of use of the components	M_T	σ_a
Normal operation	T_R	$0,55\ R'_e$
Normal operation, with a reduced number of actuators	lower of T_R and $0,8\ T'_G$	$0,55\ R'_e$

Conditions of use of the components	M_T	σ_a
Emergency operation achieved by hydraulic or electrohydraulic steering gear	lower of T_R and 0,8 T_A	0,69 R'_e
Emergency operation, with a reduced number of actuators	lower of T_R and 0,8 T'_G	0,69 R'_e
Emergency operation achieved by hand	T_E	0,69 R'_e

2.1.4 Tillers, quadrants and rotors

a) The scantling of the tiller is to be determined as follows:

- the depth H_0 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 section modulus of the tiller arm in way of the end fixed to the boss is not to be less than the value Z_b, in cm^3, calculated from the following formula:

$$Z_b = \frac{0,147 \cdot d^3_s}{1000} \cdot \frac{L'}{L} \cdot \frac{R_e}{R_e}$$

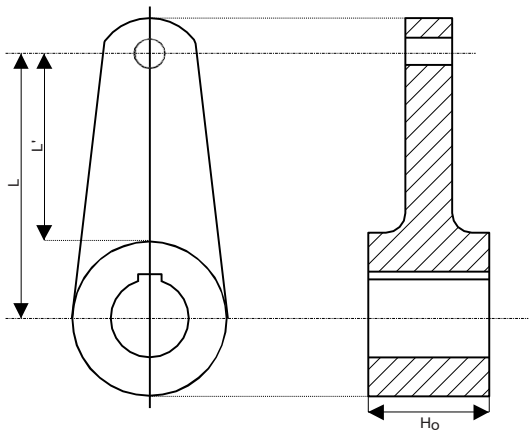
where:

L : Distance from the centreline of the rudder stock to the point of application of the load on the tiller (see Fig 1)

L' : Distance between the point of application of the above load and the root section of the tiller arm under consideration (see Fig 1)

- the width and thickness of the tiller arm in way of the point of application of the load are not to be less than one half of those required by the above formula
- in the case of double arm tillers, the section modulus of each arm is not to be less than one half of the section modulus required by the above formula.

Figure 1 : Tiller arm



b) The scantling of the quadrants is to be determined as specified in a) for the tillers. When quadrants having two or three arms are provided, the section modulus of each arm is not to be less than one half or one third, respectively, of the section modulus required for the tiller.

Arms of loose quadrants not keyed to the rudder stock may be of reduced dimensions to the satisfaction of the Society, and the depth of the boss may be reduced by 10 per cent.

c) Keys are to satisfy the following provisions:

- 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 or rotor without being less than 235 N/mm^2
- 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 (or rotor) are to be rounded and the keyway root fillets are to be provided with small radii of not less than 5 per cent of the key thickness.

d) Bolted tillers and quadrants are to satisfy the following provisions:

- the diameter of the bolts is not to be less than the value d_b, in mm, calculated from the following formula:

$$d_b = 153 \sqrt{\frac{T_R}{n(b + 0{,}5d_{se})} \cdot \frac{235}{R_{eb}}}$$

where:

n : Number of bolts located on the same side in respect of the stock axis (n is not to be less than 2)

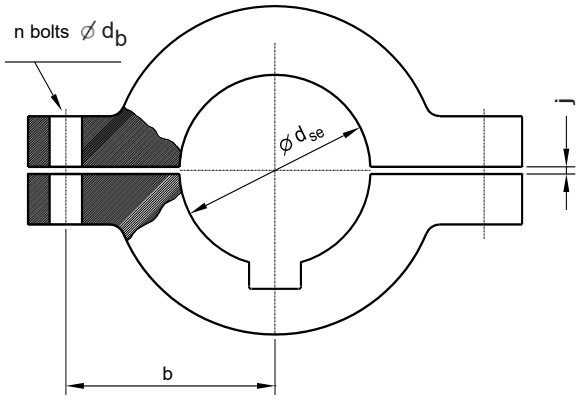
b : Distance between bolts and stock axis, in mm (see Fig 2)

R_{eb} : Yield stress, in N/mm^2, of the bolt material

- the thickness of the coupling flanges is not to be less than the diameter of the bolts
- in order to ensure the efficient tightening of the coupling around the stock, the two parts of the tiller are to bored together with a shim having a thickness not less than the value j, in mm, calculated from the following formula:

$$j = 0{,}0015 \cdot d_s$$

Figure 2 : Bolted tillers



e) Shrink-fit connections of tiller (or rotor) to stock are to satisfy the following provisions:

- the safety factor against slippage is not to be less than:
  - 1 for keyed connections
  - 2 for keyless connections
- the friction coefficient is to be taken equal to:
  - 0,15 for steel and 0,13 for spheroidal graphite cast iron, in the case of hydraulic fit
  - 0,17 in the case of dry shrink fitting
- the combined stress according to the von Mises criterion, due to the maximum pressure induced by the shrink fitting and calculated in way of the most stressed points of the shrunk parts, is not to exceed 80 per cent of the yield stress of the material considered

Note 1: Alternative stress values based on FEM calculations may also be considered by the Society.

- the entrance edge of the tiller bore and that of the rudder stock cone are to be rounded or bevelled.

2.1.5 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 and is to satisfy the following provisions:

a) $\sigma_c \leq \sigma_a$

where:

σ_c : Combined stress as per [1.4.1]

σ_a : Permissible stress as per [2.1.3]

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 : $= \alpha + (\beta^2 - \alpha)^{0,5}$

with:

$\alpha = 0,0072 (l_s/d_s)^2.R'_e/235$,

$\beta = 0,48 + 0,5\ \alpha + 0,1\ \alpha^{0,5}$,

l_s = Length, in mm, of the maximum unsupported reach of the cylinder rod.

2.2 Hydraulic system

2.2.1 General

a) The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure to be expected under the operational conditions specified in [3] and [4], taking into account any pressure which may exist in the low pressure side of the system.

At the discretion of the Society, high cycle and cumulative fatigue analysis may be required for the design of piping and components, taking into account pulsating pressures due to dynamic loads.

b) The power piping for hydraulic steering gear is to be arranged so that transfer between units can be readily effected.

c) Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

The hydraulic piping system, including joints, valves, flanges and other fittings, is to comply with the requirements of Sec 10 for class I piping systems, and in particular with the requirements of Sec 10, [14], unless otherwise stated.

2.2.2 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% and a tensile strength not greater than 650 N/mm^2.

Grey cast iron may be accepted for valve bodies and redundant parts with low stress level, excluding cylinders, subject to special consideration.

2.2.3 Isolating valves

Shut-off valves, non-return valves or other appropriate devices are to be provided:

- to comply with the availability requirements of [3.5] or [4.5]
- to keep the rudder steady in position in case of emergency.

In particular, for all ships with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

2.2.4 Flexible hoses *(1/7/2006)*

a) Flexible hoses may be installed between two points where flexibility is required but are not to be subjected to torsional deflexion (twisting) under normal operation. In general, the hose is to be limited to the length necessary to provide for flexibility and for proper operation of machinery.

b) Hoses are to be high pressure hydraulic hoses according to recognised standards and suitable for the fluids, pressures, temperatures and ambient conditions in question.

c) They are to be of a type approved by the Society according to Sec 10, [2.6].

2.2.5 Relief valves

a) Relief valves shall be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The setting of the relief valves shall not exceed the design pressure. The valves shall be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

b) The setting pressure of the relief valves is not to be less than 1,25 times the maximum working pressure.

c) The minimum discharge capacity of the relief valve(s) is not to be less than the total capacity of the pumps which can deliver through it (them), increased by 10%. Under such conditions, the rise in pressure is not to exceed 10% of

the setting pressure. In this respect, due consideration is to be given to the foreseen extreme ambient conditions in relation to oil viscosity.

2.2.6 Hydraulic oil reservoirs *(1/7/2012)*

Hydraulic power-operated steering gear shall be provided with the following:

- *a low level alarm for each hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. Audible and visual alarms shall be given on the navigation bridge and in the machinery space where they can be readily observed* (for ships intended for operation with unattended machinery spaces the alarm is to be provided at a suitable main machinery control position).
- *a fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir, where the main steering gear is required to be power operated. The storage tank shall be permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering gear compartment and shall be provided with a contents gauge.*

Note 1: For cargo ships of less than 500 tons gross tonnage and for fishing vessels, the storage means may consist of a readily accessible drum, of sufficient capacity to refill one power actuating system if necessary.

2.2.7 Hydraulic pumps

a) Hydraulic pumps are to be type tested in accordance with the provisions of [8.1.1].

b) Special care is to be given to the alignment of the pump and the driving motor.

2.2.8 Filters

a) Hydraulic power-operated steering gear shall be provided with arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system.

b) Filters of appropriate mesh fineness are to be provided in the piping system, in particular to ensure the protection of the pumps.

2.2.9 Accumulators

Accumulators, if fitted, are to be designed in accordance with Sec 10, [14.5.3].

2.2.10 Rudder actuators

a) Rudder actuators, other than non-duplicated rudder actuators fitted to tankers, chemical carriers and gas carriers of 10000 gross tonnage and above, are to be designed in accordance with the relevant requirements of Sec 3 for class I 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 4.

c) Oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal upon metal or equivalent type.

d) 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.

e) 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 [7.3.1].

Table 4 : Value of coefficients A and B

Coefficient	Steel	Cast steel	Nodular cast iron
A	3,5	4	5
B	1,7	2	3

2.3 Electrical systems

2.3.1 General design

The electrical systems of the main steering gear and the auxiliary steering gear are to be so arranged that the failure of one will not render the other inoperative.

2.3.2 Power circuit supply

a) Electric or electrohydraulic steering gear comprising one or more power units is to be served by at least two exclusive circuits fed directly from the main switchboard; however, one of the circuits may be supplied through the emergency switchboard.

b) Auxiliary electric or electrohydraulic steering gear, associated with main electric or electrohydraulic steering gear, may be connected to one of the circuits supplying the main steering gear.

c) The circuits supplying electric or electrohydraulic steering gear are to have adequate rating for supplying all motors which can be simultaneously connected to them and may be required to operate simultaneously.

d) When, in a ship of less than 1600 tons gross tonnage, auxiliary steering gear which is required by [3.3.2], item c) to be operated by power is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard.

e) Where the rudder stock is required to be over 230 millimetres in diameter in way of the tiller, excluding strengthening for navigation in ice, an alternative power supply either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment is to be provided, sufficient at least to supply the steering gear power unit such that the latter is able to perform the duties of auxiliary steering gear.

This power source is to be activated automatically, within 45 seconds, in the event of failure of the main source(s) of electrical power.

The independent source is to be used only for this purpose.

The alternative power source is also to supply the steering gear control system, the remote control of the power unit and the rudder angle indicator.

f) In every ship of 10 000 tons gross tonnage and upwards, the alternative power supply is to have a capacity for at least 30 minutes of continuous operation and in any other ship for at least 10 minutes.

2.3.3 Motors and associated control gear

a) To determine the required characteristics of the electric motors for power units, the breakaway torque and maximum working torque of the steering gear under all operating conditions are to be considered. The ratio of pull-out torque to rated torque is to be at least 1,6.

b) Motors for steering gear power units may be rated for intermittent power demand.

The rating is to be determined on the basis of the steering gear characteristics of the ship in question; the rating is always to be at least:

- S3 - 40% for motors of electric steering gear power units
- S6 - 25% for motors of electrohydraulic steering gear power units and for convertors.

c) Each electric motor of a main or auxiliary steering gear power unit is to be provided with its own separate motor starter gear, located within the steering gear compartment.

2.3.4 Supply of motor control circuits and steering gear control systems

a) Each control for starting and stopping of motors for power units is to be served by its own control circuits supplied from its respective power circuits.

b) Any electrical main and auxiliary steering gear control system operable from the navigating bridge is to be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment, or directly from switchboard busbars supplying that steering gear power circuit at a point on the switchboard adjacent to the supply to the steering gear power circuit. The power supply systems are to be protected selectively.

c) The remote control of the power unit and the steering gear control systems is to be supplied also by the alternative power source when required by [2.3.2], item e).

2.3.5 Circuit protection

a) Short-circuit protection is to be provided for each control circuit and each power circuit of electric or electrohydraulic main and auxiliary steering gear.

b) No protection other than short-circuit protection is to be provided for steering gear control system supply circuits.

c) Protection against excess current (e.g. by thermal relays), including starting current, if provided for power circuits, is to be for not less than twice the full load current of the motor or circuit so protected, and is to be arranged to permit the passage of the appropriate starting currents.

d) Where fuses are fitted, their current ratings are to be two step higher than the rated current of the motors. However, in the case of intermittent service motors, the fuse rating is not to exceed 160% of the rated motor current.

e) The instantaneous short-circuit trip of circuit breakers is to be set to a value not greater than 15 times the rated current of the drive motor.

f) The protection of control circuits is to correspond to at least twice the maximum rated current of the circuit, though not, if possible, below 6 A.

2.3.6 Starting and stopping of motors for steering gear power units

a) Motors for power units are to be capable of being started and stopped from a position on the navigation bridge and from a point within the steering gear compartment.

b) Means are to be provided at the position of motor starters for isolating any remote control starting and stopping devices (e.g. by removal of the fuse-links or switching off the automatic circuit breakers).

c) Main and auxiliary steering gear power units are to be arranged to restart automatically when power is restored after a power failure.

2.3.7 Separation

a) Duplicated electric power circuits are to be separated as far as practicable.

b) Cables for duplicated electric power circuits with their associated components are to be separated as far as practicable. They are to follow different routes separated both vertically and horizontally, as far as practicable, throughout their entire length.

c) Duplicated steering gear control systems with their associated components are to be separated as far as practicable.

d) Cables for duplicated steering gear control systems with their associated components are to be separated as far as practicable. They are to follow different routes separated both vertically and horizontally, as far as practicable, throughout their entire length.

e) Wires, terminals and the components for duplicated steering gear control systems installed in units, control boxes, switchboards or bridge consoles are to be separated as far as practicable.

Where physical separation is not practicable, separation may be achieved by means of a fire-retardant plate.

f) All electrical components of the steering gear control systems are to be duplicated. This does not require duplication of the steering wheel or steering lever.

g) If a joint steering mode selector switch (uniaxial switch) is employed for both steering gear control systems, the connections for the control systems are to be divided accordingly and separated from each other by an isolating plate or air gap.

h) In the case of double follow-up control, the amplifier is to be designed and fed so as to be electrically and mechanically separated. In the case of non-follow-up control and follow-up control, it is to be ensured that the follow-up amplifier is protected selectively.

i) Control circuits for additional control systems, e.g. steering lever or autopilot, are to be designed for all-pole disconnection.

j) The feedback units and limit switches, if any, for the steering gear control systems are to be separated electrically and mechanically connected to the rudder stock or actuator separately.

k) Actuators controlling the power systems of the steering gear, e.g. magnetic valves, are to be duplicated and separated.

2.4 Alarms and indications

2.4.1 Power units *(1/7/2012)*

a) In the event of a power failure to any one of the steering gear power units, an audible and visual alarm shall be given on the navigating bridge and at a suitable main machinery control position.

b) Means for indicating that the motors of electric and electrohydraulic steering gear are running shall be installed on the navigating bridge and at a suitable main machinery control position.

c) Where a three-phase supply is used, an alarm shall be provided that will indicate failure of any one of the supply phases.

d) An overload alarm shall be provided for each motor of electric or electrohydraulic steering gear power units.

e) The alarms required in c) and d) *shall be both audible and visual and situated in a conspicuous position in the main machinery space or control room from which the main machinery is normally controlled* and on the navigation bridge.

2.4.2 Hydraulic system

a) Hydraulic oil reservoirs are to be provided with the alarms required in [2.2.6].

b) Where hydraulic locking, caused by a single failure, may lead to loss of steering, an audible and visual alarm, which identifies the failed system, is to be provided on the navigating bridge.

Note 1: This alarm is to be activated when, for example:

- the position of the variable displacement pump control system does not correspond with the given order, or
- an incorrect position in the 3-way valve, or similar, in the constant delivery pump system is detected.

2.4.3 Control system *(1/7/2017)*

a) In the event of a failure of electrical power supply to the steering gear control systems, an audible and visual alarm shall be given on the navigating bridge and at a suitable main machinery control position.

b) The most probable failures that may cause reduced or erroneous system performance (e.g. uncontrolled movements of rudder) are to be identified and automatically detected. All failure identified are to initiate audible and individual visual alarm on the navigation bridge.

At least the following failure scenarios are to be considered:

- Earth fault on AC and DC circuits
- Loop failures in closed loop systems, both command and feedback loops (normally short circuit, broken connections and earth faults)
- Data communication errors
- Programmable system failures (Hardware and software failures)
- Deviation between rudder order and feedback.

Note 1: Deviation alarm are to initiate if the rudder's actual position does not reach the set point within acceptable time limits for the closed loop control systems (e.g. follow-up control and autopilot). Deviation alarm may be caused by mechanical, hydraulic or electrical failures.

c) An indication (or an alarm) is to be given on the navigating bridge in the event that the steering gear remote control system is not available (e.g. the steering gear control is from the local control position).

2.4.4 Rudder angle indication

The angular position of the rudder is to be:

a) indicated on the navigating bridge, if the main steering gear is power operated. The rudder angle indication is to be independent of the steering gear control system and be supplied through the emergency switchboard, or by an alternative and independent source of electrical power such as that referred to in [2.3.2], item e);

b) recognisable in the steering gear compartment.

2.4.5 *(1/7/2023)*

The failures (as defined but not limited to those in [2.4.3] a) and b)) likely to cause uncontrolled movements of rudder are to be clearly identified and in the event of detection of such failure, the rudder is to stop in the current position without manual intervention or, subject to the discretion of the Society, is to return to the midship/neutral position. For mechanical failures such as sticking valves and failure of static components (pipes, cylinders), the system response without manual intervention is not mandatory, and the operator can follow instructions on the signboard in case of such failures, in accordance with [7.5.1].

2.4.6 Summary table

Displays and alarms are to be provided in the locations indicated in Tab 5.

Table 5 : Location of displays and alarms *(1/7/2017)*

Item	Display	Alarms (audible and visible)	Location		
			Navigation Bridge	Engine Control Room	Steering gear compartment
Power failure of each power unit		X	X	X	
Indication that electric motor of each power unit is running	X		X	X	
Overload of electric motor of each power unit		X	X	X **(1)**	
Phase failure of electric motor of each power unit		X	X	X **(1)**	
(1) or in the machinery space, for ships with attended machinery spaces.					

Item	Display	Alarms (audible and visible)	Location		
			Navigation Bridge	Engine Control Room	Steering gear compartment
Low level of each hydraulic fluid reservoir		X	X	X **(1)**	
Power failure of each control system		X	X	X	
Hydraulic lock		X	X		
Rudder angle indicator	X		X		X
Remote control system not available	X		X		
Failures listed in [2.4.3] b)		X	X		
(1) or in the machinery space, for ships with attended machinery spaces.					

3 Design and construction - Requirements for cargo ships of 500 tons gross tonnage or more and for passenger ships

3.1 Application

3.1.1 The provisions of this Article apply in addition to those of Article [2].

3.2 General

3.2.1 *Unless expressly provided otherwise, every ship shall be provided with main steering gear and auxiliary steering gear to the satisfaction of the Society.*

3.3 Strength, performance and power operation of the steering gear

3.3.1 **Main steering gear** *(1/7/2022)*

The main steering gear and rudder stock shall be:

a) of adequate strength and capable of steering the ship at maximum ahead service speed which shall be demonstrated,

b) capable of putting the rudder over from 35° on one side to 35° on the other side with the ship at its deepest seagoing draught and running ahead at maximum ahead service speed and, under the same conditions, from 35° on either side to 30° on the other side in not more than 28s; where it is impractical to demonstrate compliance with this requirement during sea trials with the ship at its deepest seagoing draught and running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch, ships regardless of date of construction may demonstrate compliance with this requirement by one of the following methods:

1) during sea trials the ship is at even keel and the rudder fully submerged whilst running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch; or

2) where full rudder immersion during sea trials cannot be achieved, an appropriate ahead speed shall be calculated using the submerged rudder blade area in the proposed sea trial loading condition. The calculated ahead speed shall result in a force and torque applied to the main steering gear which is at least as great as if it was being tested with the ship at its deepest seagoing draught and running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch; or

3) the rudder force and torque at the sea trial loading condition have been reliably predicted and extrapolated to the full load condition. The speed of the ship shall correspond to the number of maximum continuous revolutions of the main engine and maximum design pitch of the propeller;

c) operated by power where necessary to meet the requirements of b) *and in any case when the Society requires a rudder stock of over 120 mm diameter in way of the tiller, excluding strengthening for navigation in ice, and*

d) so designed that they will not be damaged at maximum astern speed; however, this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

3.3.2 Auxiliary steering gear *(1/7/2022)*

The auxiliary steering gear and rudder stock shall be:

a) of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency,

b) capable of putting the rudder over from 15° on one side to 15° on the other side in not more than 60s with the ship at its deepest seagoing draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater; where it is impractical to demonstrate compliance with this requirement during sea trials with the ship at its deepest seagoing draught and running ahead at one half of the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch or 7 knots, whichever is greater, ships regardless of date of construction, including those constructed before 1 January 2009, may demonstrate compliance with this requirement by one of the following methods:

1) during sea trials the ship is at even keel and the rudder fully submerged whilst running ahead at one half of the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch or 7 knots, whichever is greater; or

2) where full rudder immersion during sea trials cannot be achieved, an appropriate ahead speed shall be calculated using the submerged rudder blade area in the proposed sea trial loading condition. The calculated ahead speed shall result in a force and torque applied to the auxiliary steering gear which is at least as great as if it was being tested with the ship at its deepest seagoing draught and running ahead at one half of the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch or 7 knots, whichever is greater; or

3) the rudder force and torque at the sea trial loading condition have been reliably predicted and extrapolated to the full load condition; and

c) operated by power where necessary to meet the requirements of b) *and in any case when the Society requires a rudder stock of over 230 mm diameter in way of the tiller, excluding strengthening for navigation in ice.*

3.4 Control of the steering gear

3.4.1 Main and auxiliary steering gear control

Steering gear control shall be provided:

a) for the main steering gear, both on the navigation bridge and in the steering gear compartment,

b) where the main steering gear is arranged in accordance with [3.5.2], by two independent control systems, both operable from the navigation bridge and the steering gear compartment. This does not require duplication of the steering wheel or steering lever. Where the control system consists in a hydraulic telemotor, a second independent system need not be fitted, except in a tanker, chemical tanker or gas carrier of 10 000 gross tonnage and upwards,

c) for the auxiliary steering gear, in the steering gear compartment and, if power operated, it shall also be operable from the navigation bridge and to be independent of the control system for the main steering gear.

3.4.2 Control systems operable from the navigating bridge

Any main and auxiliary steering gear control system operable from the navigating bridge shall comply with the following:

- *if electrical, it shall be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment, or directly from switchboard busbars supplying that steering gear power circuit at a point on the switchboard adjacent to the supply to the steering gear power circuit,*
- *means shall be provided in the steering gear compartment for disconnecting any control system operable from the navigation bridge from the steering gear it serves,*
- *the system shall be capable of being brought into operation from a position on the navigating bridge,*
- *in the event of failure of electrical power supply to the control system, an audible and visual alarm shall be given on the navigation bridge, and*
- *short-circuit protection only shall be provided for steering gear control supply circuits.*

3.5 Availability

3.5.1 Arrangement of main and auxiliary steering gear

The main steering gear and the auxiliary steering gear shall be so arranged that the failure of one will not render the other inoperative.

3.5.2 Omission of the auxiliary steering gear

Where the main steering gear comprises two or more identical power units, auxiliary steering gear need not be fitted, provided that:

a) in a passenger ship, the main steering gear is capable of operating the rudder as required by paragraph [3.3.1] *while any one of the power units is out of operation,*

b) in a cargo ship, the main steering gear is capable of operating the rudder as required by paragraph [3.3.1] *while operating with all power units,*

c) the main steering gear is so arranged that after a single failure in its piping system or in one of the power units, the defect can be isolated so that steering capability can be maintained or speedily regained.

Steering gear other than of the hydraulic type is to achieve standards equivalent to the requirements of this paragraph to the satisfaction of the Society.

3.5.3 Hydraulic power supply

The hydraulic system intended for main and auxiliary steering gear is to be independent of all other hydraulic systems of the ship.

3.5.4 Non-duplicated components

Special consideration is to be given to the suitability of any essential component which is not duplicated.

3.5.5 Hydraulic locking

Where the steering gear is so arranged that more than one system (either power or control) can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

4 Design and construction - Requirements for cargo ships of less than 500 tons gross tonnage and for fishing vessels

4.1 Application

4.1.1 The provisions of this Article apply in addition to those of Article [2].

4.2 General

4.2.1 *(1/7/2009)*

Unless expressly provided otherwise, every ship is to be provided with main steering gear and auxiliary steering gear to the satisfaction of the Society.

The Society may accept an arrangement whereby the two steering gears units share common mechanical components (tiller, quadrant, rudder actuators) provided that any defect can be isolated so that steering capability can be maintained or speedily regained.

4.3 Strength, performance and power operation of the steering gear

4.3.1 Main steering gear

The main steering gear and rudder stock are to be:

a) of adequate strength and capable of steering the ship at maximum ahead service speed, which is to be demonstrated,

b) capable of putting the rudder over from 35° on one side to 35° on the other side with the ship at its deepest seagoing draught and running ahead at maximum ahead service speed and, under the same conditions, from 35° on either side to 30° on the other side in not more than 28s,

c) operated by power where necessary to fulfil the requirements of b), and

d) so designed that they will not be damaged at maximum astern speed; however, this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

4.3.2 Auxiliary steering gear

The auxiliary steering gear is to be:

a) of adequate strength and sufficient to steer the ship at navigable speed and capable of being brought speedily into action in an emergency,

b) capable of putting the rudder over from 15° on one side to 15° on the other side in not more than 60s with the ship at its deepest seagoing draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater, and

c) operated by power where necessary to meet the requirements of b).

4.3.3 Hand operation

Hand operation of steering gear is permitted when it requires an effort less than 160 N.

4.4 Control of the steering gear

4.4.1 Control of the main steering gear

a) Control of the main steering gear is to be provided on the navigation bridge.

b) Where the main steering gear is arranged in accordance with [4.5.2], two independent control systems are to be provided, both operable from the navigation bridge. This does not require duplication of the steering wheel or steering lever.

4.4.2 Control of the auxiliary steering gear

a) Control of the auxiliary steering gear is to be provided on the navigation bridge, in the steering gear compartment or in another suitable position.

b) If the auxiliary steering gear is power operated, its control system is also to be independent of that of the main steering gear.

4.5 Availability

4.5.1 Arrangement of main and auxiliary means for actuating the rudder

The main steering gear and the auxiliary means for actuating the rudder are to be arranged so that a single failure in one will not render the other inoperative.

4.5.2 Omission of the auxiliary steering gear *(1/7/2009)*

Where the main steering gear comprises two or more identical power units, auxiliary steering gear need not be fitted, provided that the main steering gear is capable of operating the rudder:

a) as required in [4.3.1], item b), while operating with all power units

b) as required in [4.3.2], item b), while any one of the power units is out of operation.

The main steering gear is to be so arranged that, after a single failure in its piping system or in one of the power units, the defect can be isolated so that steering capability can be maintained or speedily regained.

The Society may accept the fitting of steering gear of proven service reliability even where it does not comply with the requirements laid down here as far as the hydraulic system is concerned.

4.5.3 Hydraulic power supply

Hydraulic power installations supplying steering gear may also supply other equipment at the same time provided that the operation of the steering gear is not affected:

a) by the operation of this equipment, or

b) by any failure of this equipment or of its hydraulic supply piping.

5 Design and construction - Requirements for ships equipped with several rudders

5.1 Principle

5.1.1 General

In addition to the provisions of Articles [2], [3] and [4], as applicable, ships equipped with two or more aft rudders are to comply with the provisions of this Article.

5.1.2 Availability

Where the ship is fitted with two or more rudders, each having its own actuation system, the latter need not be duplicated.

5.1.3 Equivalent rudder stock diameter

Where the rudders are served by a common actuating system, the diameter of the rudder stock referred to in [3.3.1], item c) and in [3.3.2] item c) is to be replaced by the equivalent diameter d obtained from the following formula:

$$d = \sqrt[3]{\sum_j d_j^{\,3}}$$

with:

d_j : Rule diameter of the upper part of the rudder stock of each rudder in way of the tiller, excluding strengthening for navigation in ice.

5.2 Synchronisation

5.2.1 General

A system for synchronising the movement of the rudders is to be fitted, either:

- by a mechanical coupling, or
- by other systems giving automatic synchronising adjustment.

5.2.2 Non-mechanical synchronisation

Where the synchronisation of the rudder motion is not achieved by a mechanical coupling, the following provisions are to be met:

a) the angular position of each rudder is to be indicated on the navigation bridge,

b) the rudder angle indicators are to be independent from each other and, in particular, from the synchronising system,

c) in case of failure of the synchronising system, means are to be provided for disconnecting this system so that steering capability can be maintained or rapidly regained. See also Pt E, Ch 7, Sec 4, [7.2.1].

6 Design and construction - Requirements for ships equipped with non-traditional propulsion and steering systems, such as thrusters

6.1 Principle

6.1.1 General *(1/1/2012)*

Ships equipped with non-traditional propulsion and steering systems, such as thrusters, are to comply with the provisions of this Section, as far as applicable, and with the content of this Article [6].

For ships fitted with propulsion and steering systems other than traditional arrangements, the main and auxiliary steering gear referred to in [3] and [4] may consist of thrusters of the following types:

- azimuth thrusters
- water-jets
- cycloidal propellers

complying with the provisions of Sec 12, as far as applicable.

6.1.2 Actuation system *(1/1/2012)*

Thrusters and other non-traditional propulsion and steering systems used as steering means are to be fitted with a main actuation system and an auxiliary actuation system.

When the ship is fitted with multiple non-traditional propulsion and steering systems, such as but not limited to those in [6.1.1], the above requirement is considered satisfied if each of the non-traditional propulsion and steering systems is equipped with its own dedicated steering gear in compliance with [6.2.3].

6.1.3 Control system

Where the steering means of the ship consists of two or more thrusters, their control system is to include a device ensuring an automatic synchronisation of the thruster rotation, unless each thruster is so designed as to withstand any additional forces resulting from the thrust exerted by the other thrusters.

6.1.4 Definition *(1/1/2012)*

"Declared steering angle limits" are the operational limits in terms of maximum steering angle, or equivalent according to the Manufacturer's guidelines for safe operation, also taking into account the vessel speed or propeller torque/speed or other limitation; the declared steering angle limits are to be declared by the directional control system Manufacturer; ship's manoeuvrability tests are to be carried out with steering angles not exceeding the declared angle limits.

6.2 Use of azimuth thrusters

6.2.1 Azimuth thrusters used as sole steering means *(1/1/2012)*

Where the ship is fitted with one azimuth thruster used as the sole steering means, this thruster is to comply with [3.3.1] or [4.3.1], as applicable, except that:

a) the main actuation system is required to be capable of rotating the ship's directional control system from one side to the other at the declared steering angle limits at an average rotational speed of at least 2,4°/s with the ship running ahead at maximum ahead service speed and to be operated by power where the expected steering torque exceeds 1,5 kN·m

b) the auxiliary actuation system is required to be capable of rotating the ship's directional control system from one side to the other at the declared steering angle limits at an average rotational speed of at least 0,5°/s with the ship running ahead at one half of the maximum ahead service speed, and to be operated by power in any ship having more than 2500 kW propulsion power per thruster unit or where the expected steering torque exceeds 3 kN·m.

6.2.2 Azimuth thrusters used as auxiliary steering gear *(1/1/2012)*

Where the auxiliary steering gear referred to in [3.2.1] or [4.2.1] consists of one or more azimuth thrusters, at least one such thruster is to capable of:

- steering the ship at maximum ahead service speed
- being brought speedily into action in case of emergency
- an average rotational speed of at least 2,4°/s.

The auxiliary actuation system referred to in [6.1.2] need not be fitted.

6.2.3 Omission of the auxiliary actuation system *(1/1/2012)*

Where the steering means of the ship consists of two independent azimuth thrusters or more, the auxiliary actuation system referred to in [6.1.2] need not be fitted provided that:

- "the thrusters are so designed that the ship can be steered with any one thruster out of operation and each of the steering systems is arranged so that after a single failure in its piping or in one of the power units, ship steering capability (but not individual steering system operation) can be maintained or speedily regained (e.g. by the possibility of positioning the thruster in a neutral steering position in an emergency, if needed), and
- for passenger ships, each of the thrusters is fitted with two or more identical power units, capable of satisfying the requirements in [6.2.1] a) while any one of the power units is out of operation, or
- for cargo ships, each of the thrusters is fitted one or more identical power units, capable of satisfying the requirements in [6.2.1] a) while operating with all power units.

6.3 Use of water-jets

6.3.1 *(1/1/2012)*

The use of water-jets as steering means is subject to the requirements given in [6.2] as far as applicable; other arrangements will be given special consideration by the Society.

7 Arrangement and installation

7.1 Steering gear room arrangement

7.1.1 *The steering gear compartment shall be:*

a) readily accessible and, as far as practicable, separated from machinery spaces, and

b) provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements shall include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

7.2 Rudder actuator installation

7.2.1

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 [2.1.3] and [7.3.1]. 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.

7.3 Overload protections

7.3.1 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.

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 greater value of the torques T_R or T_G.

Where $T_G \geq 1{,}5T_R$, the rudder stops are to be fitted between the rudder actuator and the rudder stock, unless the rudder stock as well as all the components transmitting mechanical forces between the rudder actuator and the rudder blade are suitably strengthened.

7.3.2 Rudder angle limiters

a) Power-operated steering gear is to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronised with the gear itself and not with the steering gear control.

b) Special consideration will be given to power-operated steering gear where the rudder may be oriented to more than 35°.

7.3.3 Relief valves

Relief valves are to be fitted in accordance with [2.2.5].

7.3.4 Buffers

Buffers are to be provided on all ships fitted with mechanical steering gear. They may be omitted on hydraulic gear equipped with relief valves or with calibrated bypasses.

7.4 Means of communication

7.4.1 *A means of communication is to be provided between the navigation bridge and the steering gear compartment.*

If electrical, it is to be fed through the emergency switchboard or to be sound powered.

7.5 Operating instructions

7.5.1 For steering gear comprising two identical power units intended for simultaneous operation, both normally provided with their own (partly or mutually) separate control systems, the following standard notice is either to be placed on a signboard fitted at a suitable place on the steering control post on the bridge or incorporated into the operation manual:

CAUTION

IN SOME CIRCUMSTANCES WHEN 2 POWER UNITS ARE RUNNING SIMULTANEOUSLY, THE RUDDER MAY NOT RESPOND TO THE HELM. IF THIS HAPPENS STOP EACH PUMP IN TURN UNTIL CONTROL IS REGAINED.

8 Certification, inspection and testing

8.1 Type tests of hydraulic pumps

8.1.1 Each type of power unit pump is to be subjected in the workshop to a type test of not less than 100 hours' duration.

The test arrangements are to be such that the pump may run both:

- in idling conditions, and
- at maximum delivery capacity at maximum working pressure.

During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another is to occur at least as quickly as on board.

During the test, no abnormal heating, excessive vibration or other irregularities are permitted.

After the test, the pump is to be disassembled and inspected.

Note 1: Type tests may be waived for a power unit which has been proven to be reliable in marine service.

8.2 Testing of materials

8.2.1 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
   - rotors and rotor housings for rotary vane steering gear
   - hydraulic pump casings
   - and hydraulic accumulators, if any,

   are to be duly tested, including examination for internal defects, in accordance with the requirements of Part D.

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.

8.2.2 Hydraulic piping, valves and accessories

Tests for materials of hydraulic piping, valves and accessories are to comply with the provisions of Sec 10, [21.3].

8.3 Inspection and tests during manufacturing

8.3.1 Components subject to pressure or transmitting mechanical forces

a) The mechanical components referred to in [8.2.1] are to be subjected to appropriate non-destructive tests. For hydraulic cylinder shells, pump casings and accumulators, refer to 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 Part D.

8.3.2 Hydraulic piping, valves and accessories

Hydraulic piping, valves and accessories are to be inspected and tested during manufacturing in accordance with Sec 10, [21], for a class I piping system.

8.4 Inspection and tests after completion

8.4.1 Hydrostatic tests

a) Hydraulic cylinder shells and accumulators are to be subjected to hydrostatic tests according to the relevant provisions of Sec 3.

b) Hydraulic piping, valves and accessories and hydraulic pumps are to be subjected to hydrostatic tests according to the relevant provisions of Sec 10, [21.4].

8.4.2 Shipboard tests

After installation on board the ship, the steering gear is to be subjected to the tests detailed in Sec 16, [3.11].

8.4.3 Sea trials

For the requirements of sea trials, refer to Sec 16.

SECTION 12 THRUSTERS

1 General

1.1 Application

1.1.1 *(1/7/2002)*

The requirements of this Section apply to the following types of thrusters:

- Transverse thrusters intended for manoeuvring developing power equal to 500 kW or more
- Thrusters intended for propulsion, steering and dynamic positioning developing power equal to 220 kW or more; for power less than 220 kW the requirements apply only to the propeller and relevant shaft.

For azimuth thrusters intended for dynamic positioning, the additional requirements in Pt F, Ch 13, Sec 6 are to be complied with.

For ships with an ice class notation, the additional requirements in Part F, Chapter 9 are to be complied with, except for transverse thrusters not intended for dynamic positioning.

1.1.2 *(1/7/2002)*

Thrusters developing power less than that indicated in [1.1.1] are to be built in accordance with sound marine practice and tested as required in [3.2] to the satisfaction of the Surveyor.

1.2 Definitions

1.2.1 Transverse thruster

A transverse thruster is an athwartship thruster developing a thrust in a transverse direction for manoeuvring purposes.

1.2.2 Azimuth thruster

An azimuth thruster is a thruster which has the capability to develop thrust in any direction through 360°.

1.2.3 Water-jet

A water-jet is equipment constituted by a tubular casing (or duct) enclosing an impeller. The shape of the casing is such as to enable the impeller to produce a water-jet of such intensity as to give a positive thrust. Water-jets may have means for deviating the jet of water in order to provide a steering function.

1.2.4 Continuous duty thruster

A continuous duty thruster is a thruster which is designed for continuous operation, such as a propulsion thruster.

1.2.5 Intermittent duty thruster

An intermittent duty thruster is a thruster designed for operation at full power for a period not exceeding 1 hour, followed by operation at reduced rating for a limited period of time not exceeding a certain percentage of the hours in a day and a certain (lesser) percentage of the hours in a year. In general, athwartship thrusters are intermittent duty thrusters.

1.3 Thrusters intended for propulsion

1.3.1 In general, at least two azimuth thrusters are to be fitted in ships where these are the sole means of propulsion. Single azimuth thruster installations will be specially considered by the Society on a case by case basis.

Single water-jet installations are permitted.

1.4 Documentation to be submitted

1.4.1 **Plans to be submitted for athwartship thrusters and azimuth thrusters** *(1/7/2002)*

For thrusters:

- intended for propulsion, steering and dynamic positioning
- intended for manoeuvring developing power equal to 500 kW or more,

the plans listed in Tab 1 are to be submitted. Plans as per item 6 of Tab 1 are also to be submitted for thrusters developing power less than 500 kW.

1.4.2 Plans to be submitted for water-jets

The plans listed in Tab 2 are to be submitted.

1.4.3 Additional data to be submitted

The data and documents listed in Tab 3 are to be submitted by the manufacturer together with the plans.

2 Design and Construction

2.1 Materials

2.1.1 Propellers *(1/7/2002)*

For requirements relative to material intended for propellers, see Sec 8.

2.1.2 Other thruster components

For the requirements relative to materials intended for other parts of the thrusters, such as gears, shaft, couplings, etc., refer to the applicable parts of the Rules.

Table 1 : Plans to be submitted for athwartship thrusters and azimuth thrusters *(1/7/2002)*

No.	A/I **(1)**	ITEM
General requirements for all thrusters		
1	I	General arrangement of the thruster
2	A	Propeller, including the applicable details mentioned in Sec 8
3	A	Bearing details
4	A	Propeller and intermediate shafts
5	A	Gears, including the calculations according to Sec 6 for cylindrical gears or standards recognised by the Society for bevel gears
Specific requirements for transverse thrusters		
6	A	Structure of the tunnel showing the materials and their thickness
7	A	Structural equipment or other connecting devices which transmit the thrust from the propeller to the tunnel
8	A	Sealing devices (propeller shaft gland and thruster-tunnel connection)
9	A	For the adjustable pitch propellers: pitch control device and corresponding monitoring system
Specific requirements for rotating and azimuth thrusters		
10	A	Structural items (nozzle, bracing, etc.)
11	A	Structural connection to hull
12	A	Rotating mechanism of the thruster
13	A	Thruster control system
14	A	Piping systems connected to thruster
(1) A = to be submitted for approval in four copies I = to be submitted for information in duplicate		

Table 2 : Plans to be submitted for water-jets

No.	A/I **(1)**	ITEM
1	I	General arrangement of the water-jet
2	A	Casing (duct) (location and shape) showing the materials and the thicknesses as well as the forces acting on the hull
3	A	Details of the shafts, flanges, keys
4	I	Sealing gland

No.	A/I **(1)**	ITEM
5	A	Bearings
6	A	Impeller
7	A	Steering and reversing buckets and their control devices as well as the corresponding hydraulic diagrams
(1) A = to be submitted for approval in four copies I = to be submitted for information in duplicate		

Table 3 : Data and documents to be submitted for athwartship thrusters, azimuth thrusters and water-jets

No.	A/I **(1)**	ITEM
1	I	Rated power and revolutions
2	I	Rated thrust
3	A	Material specifications of the major parts, including their physical, chemical and mechanical properties
4	A	Where parts of thrusters are of welded construction, all particulars on the design of welded joints, welding procedures, heat treatments and non-destructive examinations after welding
5	I	Where applicable, background information on previous operating experience in similar applications
(1) A = to be submitted for approval in four copies I = to be submitted for information in duplicate		

2.2 Transverse thrusters and azimuth thrusters

2.2.1 Prime movers

a) Diesel engines intended for driving thrusters are to comply with the applicable requirements of Sec 2.

b) Electric motors intended for driving thrusters and their feeding systems are to comply with the requirements of Chapter 2. In particular:

- Provisions are to be made to prevent starting of the motors whenever there are insufficient generators in operation.
- Intermittent duty thrusters will be the subject of special consideration by the Society.

2.2.2 Propellers *(1/7/2002)*

a) For propellers of thrusters intended for propulsion, steering and dynamic positioning, the requirements of Sec 8 apply.

b) For propellers of thrusters intended for manoeuvring only, the requirements of Sec 8 also apply, although the increase in thickness of 10% required in Sec 8, [2.5] does not need to be applied.

2.2.3 Shafts *(1/7/2002)*

a) For propeller shafts of thrusters, the requirements of Sec 7 apply to the portion of propellershaft between the inner edge of the aftermost shaft bearing and the inner face of the propeller boss or the face of the integral propeller shaft flange for the connection to the propeller boss.

b) For other shafts of thrusters, the requirement of Sec 6, [3.4.2] apply.

2.2.4 Gears *(1/7/2002)*

a) Gears of thrusters intended for propulsion steering and dynamic positioning are to be in accordance with the applicable requirements of Sec 6 for cylindrical gears or standards recognised by the Society for bevel gears, applying the safety factors for propulsion gears.

b) Gears of thrusters intended for manoeuvring only are to be in accordance with the applicable requirements of Sec 6, for cylindrical gears or Standards recognised by the Society for bevel gears, applying the safety factors for auxiliary gears.

2.2.5 Nozzles and connections to hull for azimuth thrusters

a) For the requirements relative to the nozzle structure, see Part B, Chapter 10.

b) The scantlings of the nozzle connection to the hull and the welding type and size will be specially considered by the Society, which reserves the right to require detailed stress analysis in the case of certain high power installations.

c) For steerable thrusters, the equivalent rudder stock diameter is to be calculated in accordance with the requirements of Part B, Chapter 10.

2.2.6 Transverse thruster tunnel

a) The thickness of the tunnel is not to be less than the adjacent part of the hull.

b) Special consideration will be given by the Society to tunnels connected to the hull by connecting devices other than welding.

2.2.7 Bearings

Bearing are to be identifiable and are to have a life adequate for the intended purpose. However, their life cannot be less than:

- 40 000 hours for continuous duty thrusters. For ships with restricted service, a lesser value may be considered by the Society.
- 5 000 hours for intermittent duty thrusters.

Table 4 : Azimuth thrusters

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				
			Thruster			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Steering oil pressure	L						
Oil tank level	L						

2.3 Water-jets

2.3.1 Shafts *(1/7/2002)*

The diameter of the shaft supporting the impeller, measured at bottom of keyway or at spline inner diameter, is not to be less than the diameter d_2, in mm, obtained by the following formula:

$$d_2 = 100fh \cdot \left(\frac{P}{N}\right)^{1/3}$$

where:

P : Power, in kW

N : Rotational speed, in rpm

f : Calculated as follows:

$$f = \left(\frac{560}{R_m + 160}\right)^{1/3}$$

where R_m is the ultimate tensile strength of the shaft material, in N/mm^2

h : 1 when the shaft is only transmitting torque loads, and when the weight and thrust of the propeller are totally supported by devices located in the fixed part of the thruster

1,22 otherwise.

The shafts are to be protected against corrosion by means of either a continuous liner or an oil-gland of an approved type, or by the nature of the material of the shaft.

2.3.2 Casings and impellers

Casings and impellers are subject of special consideration by the Society.

2.3.3 Steering performance

Steering performance and emergency steering availability are to be at least equivalent to the requirements in Sec 11, [6.2] and Sec 11, [6.3].

2.4 Alarm, monitoring and control systems

2.4.1 General *(1/7/2006)*

In addition to those of this item, the general requirements given in Chapter 3 apply.

In the case of ships with automation notations, the requirements in Part F, Chapter 3 also apply.

2.4.2 Steering thruster controls

a) Controls for steering are to be provided from the navigating bridge, the machinery control station and locally.

b) Means are to be provided to stop any running thruster at each of the control stations.

c) A thruster angle indicator is to be provided at each steering control station. The angle indicator is to be independent of the control system.

2.4.3 Alarm and monitoring equipment

Tab 4 summarises the minimum alarm and monitoring requirements for propulsion and steering thrusters. See also Sec 11, [6].

3 Testing and certification

3.1 Material tests

3.1.1 Propulsion and steering thrusters *(1/7/2002)*

All materials intended for parts transmitting torque and for propeller/impeller blades are to be tested in accordance with the applicable requirements of Sec 6, [5.2] or Sec 7, [4.1] or Sec 8, [4.1] in the presence of a Surveyor.

3.1.2 Transverse thrusters

Material testing for parts of athwartship thrusters does not need to be witnessed by a Surveyor, provided full test reports are made available to him.

3.2 Testing and inspection

3.2.1 Thrusters *(1/7/2002)*

Thrusters are to be inspected as per the applicable requirements given in the Rules for the specific components.

3.2.2 Prime movers

Prime movers are to be tested in accordance with the requirements applicable to the type of mover used.

3.3 Certification

3.3.1 Certification of thrusters

Thrusters are to be individually tested and certified by the Society.

3.3.2 Mass produced thrusters

Mass produced thrusters may be accepted within the framework of the type approval program of the Society.

SECTION 13 REFRIGERATING INSTALLATIONS

1 General

1.1 Application

1.1.1 Refrigerating installations on all ships

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 one or more of the following additional notations: **REFCARGO**, **REFCONT**, **REFSTORE, AIRCONT**, **PRECOOLING**, **QUICKFREEZE** is (are) requested, the requirements of Part F, Chapter 8 are 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 C 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 Sec 3.

b) Vessels intended to contain ammonia or toxic substances are to be considered as class 1 pressure vessels as indicated in Sec 3, [1.4].

c) The materials used for pressure vessels are to be appropriate to the fluid that they contain. Where ammonia is the refrigerant, copper, bronze, brass and other copper alloys are not to be used.

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) Refrigerant pipes are generally to be regarded as pressure pipes.

b) Refrigerant, brine and sea water pipes are to satisfy the requirements of Sec 10, as applicable.

c) Refrigerant pipes are to be considered as belonging to the following classes:
- class I: where they are intended for ammonia or toxic substances
- class II: for other refrigerants
- class III: for brine.

d) 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.

e) The materials used for the pipes are to be appropriate to the fluids that they convey. Copper, brass, bronze and other copper alloys are not to be used for pipes likely to convey ammonia. Methods proposed for joining such pipes are to be submitted to the Society for consideration.

f) Notch toughness of the steels used is to be suitable for the application concerned.

g) 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.

h) 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:

- Methyl chloride
- R11 - Trichloromonofluoromethane ($C Cl_3 F$)
- Ethane
- Ethylene
- Other substances with lower explosion limit in air of less than 3,5%.

2.2.2 Statutory requirements *(1/7/2020)*

Particular attention is to be paid to any limitation on the use of refrigerants imposed by MARPOL Annex VI Regulation 12 and by the Administration of the State whose flag the ship is flying.

2.2.3 Toxic or flammable refrigerants

The arrangement of refrigerating machinery spaces of plants using toxic or flammable refrigerants will be the subject of special consideration by the Society.

For specific requirements on spaces intended for plants using ammonia as a refrigerant, see [2.3].

2.3 Special requirements for ammonia (R717)

2.3.1 Refrigerating machinery compartment

a) The refrigerating machinery compartment and the compartments where ammonia bottles are stored are to be separated by gastight bulkheads from the accommodation spaces, the engine room (including the shaft tunnel) and other machinery spaces intended for essential services. This requirement does not apply to plants using less than 25 kg of ammonia.

b) The space is to be arranged with a ventilation system, distinct from that of other spaces, having a capacity of at least 30 changes per hour. Provision is to be made for starting and stopping the ventilation fans from outside the refrigerated space.

c) A fire-extinguishing water spray system is to be provided for any ammonia machinery space, in particular in way of the access doors. The actuating device is to be fitted closed to the entrance outside the protected space.

d) At least two access doors are to be provided. One of these doors is to be used for emergency and is to lead directly to an open space. The doors are to open outwards and are to be self-closing.

e) Where the access to a refrigerating machinery space is through an accommodation or machinery space, the ventilation of the former is to be such as to keep it under negative pressure with respect to the adjacent space, or, alternatively, the access is to be provided with an air lock.

f) An independent bilge system is to be provided for the refrigerating machinery space.

g) At least two sets of breathing apparatus and protective clothing are to be available outside and in the vicinity of the ammonia machinery space.

h) All electrical equipment and apparatus in the space is to be arranged such that it may be shut off by a central switch located outside the space. This switch is not to control the ventilation system.

i) The electrical equipment and apparatus in the space is to comply with the requirements for electrical installations in dangerous areas as per Ch 2, Sec 3, [10].

2.3.2 Ammonia in machinery spaces

When installation of ammonia is allowed in the machinery space in accordance with the provision of [2.3.1] a), the area where ammonia machinery is installed is to be served by a hood with a negative ventilation system, having a capacity of not less than 30 changes per hour, independent from any other ship ventilation system, so as to prevent any leakage of ammonia from dissipating into other areas.

2.3.3 Unattended machinery spaces

Where the refrigerating machinery spaces are not permanently attended, a gas detection system with an audible and visual alarm is to be arranged in a suitable location. This system is also to stop the compressor when a flammable gas concentration is reached.

2.3.4 Segregation

Ammonia piping is not to pass through accommodation spaces.

2.4 Special requirements for carbon dioxide (R744)

2.4.1 General *(1/7/2019)*

The requirements contained in Pt F, Ch 8, Sec 1, [1.3], [2.1.1], [2.1.2] and [3] apply.

In general, carbon dioxide as refrigerant may be used solely in indirect refrigerating systems.

Mechanical joints are to be made by means of flanges. Pipes passing through accommodation are to be joined only by welding.

2.4.2 Refrigerating machinery compartment *(1/7/2019)*

a) The refrigerating machinery compartment and the compartments where carbon dioxide storage containers are located are to be separated by gastight bulkheads from the accommodation spaces, control stations, the engine room (including the shaft tunnel) and other machinery spaces intended for essential services such as those containing:
   - steering systems and steering control systems,
   - systems for fill, transfer and service of fuel oil and/or gas fuels,
   - fire and bilge pumps, sprinkler pumps or water mist pump units,
   - power generation systems;

b) the space is to be arranged with an exhaust type ventilation system in the lower part of the space, distinct from that of other spaces, having a capacity of at least 10 changes per hour. Provision is to be made for starting and stopping the ventilation fans from outside refrigerating machinery compartment;

c) the working pressure is to comply with the requirements in Pt F, Ch 8, Sec 1, [6.2];

d) where the refrigerating machinery spaces are not permanently attended, a gas detection system with an audible and visual alarm is to be arranged in a suitable location.

SECTION 14 TURBOCHARGERS

1 General

1.1 Application

1.1.1 *(1/7/2016)*
These Rules apply to turbochargers with regard to design approval, type testing and certification and their matching on engines.

1.1.2 *(1/7/2016)*
Turbochargers are to be type approved, either separately or as a part of an engine. The requirements are written for exhaust gas driven turbochargers, but apply in principle also for engine driven chargers.

The requirements escalate with the size of the turbochargers. The parameter for size is the engine power (at MCR) supplied by a group of cylinders served by the actual turbocharger, (e.g. for a V-engine with one turbocharger for each bank the size is half of the total engine power).

1.1.3 *(1/7/2016)*
Turbochargers are categorized in three groups depending on served power by cylinder groups with:

- Category A: ≤ 1000 kW
- Category B: > 1000 kW and ≤ 2500 kW
- Category C: > 2500 kW

1.1.4 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.

1.1.5 *(1/1/2023)*
Turbochargers with an existing type approval on 1 January 2023 are not required to be re-type approved in accordance with this Section until the current Type Approval reaches its expiry date.

1.2 Documentation to be submitted

1.2.1 *(1/7/2016)*
The Manufacturer is to submit to the Society the following documents.

1.2.2 *(1/7/2016)*
For Category A turbochargers:

On request:

- containment test report;
- cross sectional drawing with principal dimensions and names of components;
- test program.

1.2.3 *(1/7/2016)*
For Category B and C turbochargers:

- cross sectional drawing with principal dimensions and materials of housing components for containment evaluation;
- documentation of containment in the event of disc fracture;
- operational data and limitations as;
- maximum permissible operating speed (rpm);
- alarm level for over-speed;
- maximum permissible exhaust gas temperature before turbine;
- alarm level for exhaust gas temperature before turbine;
- minimum lubrication oil inlet pressure;
- lubrication oil inlet pressure low alarm set point;

- maximum lubrication oil outlet temperature;
- lubrication oil outlet temperature high alarm set point;
- maximum permissible vibration levels, i.e. self- and externally generated vibration.

  (Alarm levels may be equal to permissible limits but shall not be reached when operating the engine at 110% power or at any approved intermittent overload be-yond the 110%);
- arrangement of lubrication system, all variants within a range;
- type test reports;
- test program.

1.2.4 *(1/7/2016)*

For Category C turbochargers:

- drawings of the housing and rotating parts including details of blade fixing;
- material specifications (chemical composition and mechanical properties) of all parts mentioned above;
- welding details and welding procedure of above mentioned parts, if applicable;
- documentation of safe torque transmission when the disc is connected to the shaft by an interference fit, see [2.2.4];
- information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue;
- operation and maintenance manuals (see Note 1).

Note 1: Applicable to two sizes in a generic range of turbochargers.

1.2.5 *(1/7/2016)*

When the turbochargers are manufactured by a licensee on the basis of a previously type approved licensor design, but using parts manufactured outside of the licensor premises and making use of other than the original licensor drawings and specifications, the licensee is to submit, for each turbocharger type, a list of all the drawings specified above, 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, with a Licensor statement confirming 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 above.

2 Design and construction

2.1 Application

2.1.1 *(1/7/2016)*

The turbochargers shall be designed to operate under conditions given in Sec 1, [2.4] and Sec 1, [2.5].

The component lifetime and the alarm level for speed shall be based on 45°C air inlet temperature.

2.2 Materials

2.2.1 *(1/7/2016)*

The requirements of Sec 5, [2.1.1] are to be complied with, as far as applicable, at the Society's discretion.

2.3 Design

2.3.1 Stress analyses *(1/7/2016)*

a) For Category B and C turbochargers, the manufacturer is to submit a calculation report concerning the stresses on each rotor under the most severe service conditions.

b) The results of previous in-service experience on similar applications may be considered by the Society as an alternative to item a) above.

Data on the design service life and test results used to substantiate calculation assumptions are also to be provided.

2.3.2 Vibrations *(1/7/2016)*

The range of service speeds is not to give rise to unacceptable vibrations affecting the rotor and blades.

Calculations of the critical speeds including details of their basic assumptions are to be submitted for Category B and C turbochargers.

2.3.3 Containment *(1/7/2024)*

a) Turbochargers shall fulfil containment in the event of a rotor burst. This means that at a rotor burst no part may penetrate the casing of the turbocharger or escape through the air intake. For documentation purposes (test/calculation), it shall be assumed that the discs disintegrate in the worst possible way.

b) For category B and C, containment shall be documented by testing. Fulfilment of this requirement can be awarded to a generic range of turbochargers based on testing of one specific unit. Testing of a large unit is preferred as this is considered conservative for all smaller units in the generic range. In any case, it must be documented (e.g. by calculation) that the selected test unit really is representative for the whole generic range.

Note 1: A generic range means a series of turbocharger which are of the same design, but scaled to each other.

c) The minimum test speeds, relative to the maximum permissible operating speed, are:
- for the compressor:120%
- for the turbine: 140% or the natural burst speed, whichever is lower.

d) Containment tests shall be performed at a temperature which is not lower than the maximum allowable temperature of the turbocharger to be specified by the manufacturer.

e) Manufacturers are to determine whether cases more critical than those defined in [2.3.3] c) and d) exist with respect to containment safety. Where such a case is identified, evidence of containment safety is also to be provided for that case.

f) A numerical analysis simulation such as Finite Element Method (FEM) of sufficient containment integrity of the casing based on calculations by means of a simulation model may be accepted in lieu of the practical containment test, provided that:
- the numerical simulation model has been tested and its suitability/accuracy has been proven by direct comparison between calculation results and the practical containment test for a reference application (reference containment test). This test shall be performed at least once by the manufacturer for acceptance of the numerical simulation method in lieu of tests;
- the corresponding numerical simulation for the containment is performed for the same speeds as specified for the containment test;
- material properties for high-speed deformations are to be applied in the numeric simulation. The correlation between normal properties and the properties at the pertinent deformation speed are to be substantiated;
- the design of the turbocharger regarding geometry and kinematics is to be similar to the turbocharger that was used for the reference containment test.

g) In cases where a totally new design is adopted for a turbocharger for which an application for type approval certification has been requested, new reference containment tests are to be performed.

Note 2: Totally new design means the principal differences between a new turbocharger and previous ones are related to geometry and kinematics. The turbochargers are to be regarded as having a totally new design if the structure and/or material of the turbocharger casings are changed, or any of, but not limited to, the following items is changed from the previous design.
- Maximum permissible exhaust gas temperature
- Number of bearings
- Number of turbine blades
- Number of turbine wheels and/or compressor wheels
- Direction of inlet air and/or exhaust gas (e.g., axial flow orientation, radial flow orientation)
- Type of the turbocharger drive (e.g., axial turbine type, radial turbine type, mixed flow turbine type).

2.3.4 Disc-shaft shrinkage fit *(1/7/2016)*

For Category C turbochargers, in cases where the disc is connected to the shaft with interference fit, calculations shall substantiate safe torque transmission during all relevant operating conditions such as maximum speed, maximum torque and maximum temperature gradient combined with minimum shrinkage amount.

2.3.5 Bearings *(1/7/2013)*

a) Turbine bearings are to be so located that their lubrication is not impaired by overheating from hot gases or adjacent hot parts.

b) Lubricating oil is to be prevented from dripping on high temperature parts.

c) Roller bearings are to be identifiable and are to have a life adequate for their intended purpose.

2.3.6 Welded fabrication *(1/7/2013)*

The manufacturer's requirements relative to the welding of turbine rotors or major forged or cast pieces, where permitted, are to be readily identifiable by the Society in the plans submitted for approval.

Requirements relative to fabrication, welding, heat treatments, examinations, testing and acceptance will be stipulated on a case by case basis.

In general, all welding is to be carried out by qualified welders in accordance with qualified welding procedures using approved consumables.

2.4 Alarms and Monitoring

2.4.1 *(1/7/2016)*
For all turbochargers of Categories B and C, indications and alarms as listed in Tab 1 are required.

2.4.2 *(1/7/2016)*
Indications may be provided at either local or remote locations.

3 Type tests, material tests, workshop inspection and testing, certification

3.1 Type testing

3.1.1 *(1/7/2016)*
Applicable to Categories B and C.

3.1.2 *(1/7/2016)*
The type test for a generic range of turbochargers may be carried out either on an engine (for which the turbocharger is foreseen) or in a test rig.

3.1.3 *(1/7/2024)*
Turbochargers for the low, medium, and high-speed engines are to be subjected to at least 500 load cycles at the limits of operation. This test may be waived if the turbocharger together with the engine is subjected to this kind of low cycle testing, according to Sec 2 The suitability of the turbocharger for such kind of operation is to be preliminarily stated by the manufacture.

3.1.4 *(1/7/2016)*
The rotor vibration characteristics shall be measured and recorded in order to identify possible sub-synchronous vibrations and resonances.

3.1.5 *(1/7/2016)*
The type test shall be completed by a hot running test at maximum permissible speed combined with maximum permissible temperature for at least one hour. After this test, the turbo-charger shall be opened for examination, with focus on possible rubbing and the bearing conditions.

3.1.6 *(1/7/2016)*
Normally the surveyor's presence during the various parts of the type tests is required.

3.2 Workshop inspections and testing

3.2.1 *(1/7/2016)*
The manufacturer shall adhere to a quality system designed to ensure that the designer's specifications are met, and that manufacturing is in accordance with the approved drawings; the verification of compliance with this requirement is within the scope of a Type approval.

3.2.2 *(1/7/2024)*
For category C, this shall be verified by means of periodic product audits of an Alternative Certification Scheme (ACS; see TASNEEF Rules for testing and certification of marine materials and equipment, Chapter 2, [4]) by the Society.

These audits shall focus on:

- chemical composition of material for the rotating parts;
- mechanical properties of the material of a representative specimen for the rotating parts and the casing;
- UT and crack detection of rotating parts;
- dimensional inspection of rotating parts;
- rotor balancing;
- hydraulic testing of cooling spaces to 4 bars or 1.5 times maximum working pressure, whichever is higher;

- overspeed test of all compressor wheels for a duration of 3 minutes at either 20% above alarm level speed at room temperature or 10% above alarm level speed at 45°C inlet temperature when tested in the actual housing with the corresponding pressure ratio. The over-speed test may be waived for forged wheels that are individually controlled by an approved non-destructive method.

Table 1 *(1/7/2016)*

Pos.	Monitored Parameters	Category of Turbochargers				Notes
		B		C		
		Alarm	Indication	Alarm	Indication	
1	Speed	High **(4)**	X **(4)**	High **(4)**	X **(4)**	
2	Exhaust gas at each turbocharger inlet, temperature	High **(1)**	X **(1)**	High	X	High temp. alarms for each cylinder at engine is acceptable **(2)**
3	Lub. oil at turbocharger outlet, temperature			High	X	If not forced system, oil temperature near bearings
4	Lub. oil at turbocharger outlet, temperature	Low	X	Low	X	Only for forced lubrication systems **(3)**

(1) For Category B turbochargers, the exhaust gas temperature may be alternatively monitored at the turbocharger outlet, provided that the alarm level is set to a safe level for the turbine and that correlation between inlet and outlet temperatures is substantiated.

(2) Alarm and indication of the exhaust gas temperature at turbocharger inlet may be waived if alarm and indication for individual exhaust gas temperature is provided for each cylinder and the alarm level is set to a value safe for the turbocharger.

(3) Separate sensors are to be provided if the lubrication oil system of the turbocharger is not integrated with the lubrication oil system of the diesel engine or if it is separated by a throttle or pressure reduction valve from the diesel engine lubrication oil system.

(4) On turbocharging systems where turbochargers are activated sequentially, speed monitoring is not required for the turbocharger(s) being activated last in the sequence, provided all turbo-chargers share the same intake air filter and they are not fitted with waste gates.

3.3 Type approval certificate and its validity

3.3.1 *(1/7/2016)*

Subject to the satisfactory outcome of the type tests specified in [3.1] and a factory audit specified in [3.2.1], the Society will issue to the turbocharger Manufacturer a Type Approval Certificate valid for all turbochargers of the same type.

Where changes are made to a turbocharger and upon satisfactory review of documents as per [1.2.2], the extension to the modified turbocharger of the validity of the type tests and containment test previously carried out will be evaluated on a case by case basis.

3.4 Testing certification

3.4.1 *(1/7/2024)*

Turbochargers shall be delivered with:

- For category C, a society certificate, which as a minimum cites the applicable type approval and the Alternative Certification Scheme (ACS), when ACS applies.
- For category B, a work's certificate, which as a minimum cites the applicable type approval, which includes production assessment according to [3.2.1].

3.4.2 *(1/7/2016)*

The same applies to replacement of rotating parts and casing.

3.4.3 *(1/7/2016)*

Rotating parts of category C turbochargers are to be marked for easy identification with the appropriate certificate.

3.4.4 *(1/7/2016)*

Alternatively to the Alternative Certification Scheme and periodic product audits according to [3.2.2] individual certification of a turbocharger and its parts may be made at the discretion of the Society. However, such individual certification of category C turbocharger and its parts shall also be based on test requirements specified in [3.2.2].

SECTION 15 ANCHOR WINDLASS

1 General

1.1 Application

1.1.1 *(1/7/2018)*
A windlass used for handling anchors, suitable for the size of chain cable and complying with the following criteria is to be fitted to the ship. Windlasses are also to comply with requirements given in Pt B, Ch 10, Sec 4, [3.7].

1.2 Standards of compliance

1.2.1 *(1/7/2018)*
The design, construction and testing of windlasses are to conform to an acceptable standard or code of practice. To be considered acceptable, the standard or code of practice is to specify criteria for stresses, performance and testing.

1.2.2 *(1/7/2020)*
The following are examples of standard recognized:

- SNAME T & R Bulletin 3-15:2018 - Guide to the Design and Testing of Anchor Windlasses for Merchant Ships
- ISO 7825:2017 - Deck machinery general requirements
- ISO 4568:2006 - Shipbuilding - Seagoing vessels - Windlasses and anchor capstans
- JIS F6714:1995 - Windlasses.

1.3 Documentation to be submitted

1.3.1 *(1/7/2018)*
The following plans showing the design specifications, the standard of compliance, engineering analyses and details of construction, as applicable, are to be submitted to the Society for evaluation:

a) windlass design specifications; anchor and chain cable particulars; anchorage depth; performance criteria; standard of compliance;

b) windlass arrangement plan showing all of the components of the anchoring/mooring system such as the prime mover, shafting, cable lifter, anchors and chain cables; mooring winches, wires and fairleads, if they form part of the windlass machinery; brakes; controls; etc;

c) windlass arrangement plan showing all of the components of the anchoring/mooring system such as the prime mover, shafting, cable lifter, anchors and chain cables; mooring winches, wires and fairleads, if they form part of the windlass machinery; brakes; controls; etc;

d) hydraulic system, to include:
   1) piping diagram along with system design pressure,
   2) safety valves arrangement and settings,
   3) material specifications for pipes and equipment,
   4) typical pipe joints, as applicable, and
   5) technical data and details for hydraulic motors;

e) electric one line diagram along with cable specification and size; motor controller; protective device rating or setting; as applicable;

f) control, monitoring and instrumentation arrangements;

g) engineering analyses for torque-transmitting and load-bearing components demonstrating their compliance with recognized standards or codes of practice. Analyses for gears are to be in accordance with a recognized standard;

h) plans and data for windlass electric motors including associated gears rated 100 kW and over;

i) calculations demonstrating that the windlass prime mover is capable of attaining the hoisting speed, the required continuous duty pull, and the overload capacity are to be submitted if the "load testing" including "overload" capacity of the entire windlass unit is not carried out at the shop (see b)).

2 Design and construction

2.1 Materials

2.1.1 *(1/7/2018)*

Materials used in the construction of torque-transmitting and load-bearing parts of windlasses are to comply with the requirements of Part D or of a national or international material standard. The proposed materials are to be indicated in the construction plans and are to be approved in connection with the design. All such materials are to be certified by the material manufacturers and are to be traceable to the manufacturers' certificates.

2.2 Welded fabrication

2.2.1 *(1/7/2020)*

Weld joint designs are to be shown in the construction plans and are to be approved in association with the approval of the windlass design. Welding procedures and welders are to be qualified in accordance with the requirements of Pt D, Ch 5. Welding consumables are to be approved by the Society in the case their type and grade fall within the scope of Pt D, Ch 5, Sec 2, [1] to [8]; when their type and grade fall outside the scope of Pt D, Ch 5, Sec 2, [1] to [8], the welding consumables are to comply with Pt D, Ch 5, Sec 2, [9], [10], [11] and [12] or to national or international standards. The degree of non-destructive examination of welds and post-weld heat treatment, if any, are to be specified and submitted for consideration.

3 Design

3.1 General

3.1.1 Application *(1/7/2018)*

Along with and notwithstanding the requirements of the chosen standard of compliance, the following requirements are also to be complied with. In lieu of conducting engineering analyses and submitting them for review, approval of the windlass mechanical design may be based on a type test, in which case the testing procedure is to be submitted for consideration.

The structure and the support structure of windlasses and chain stopper are to comply with the requirements of Pt B, Ch 10, Sec 4, [3.7], [3.8], [3.9].

3.2 Mechanical design

3.2.1 Design loads *(1/7/2018)*

a) Holding loads

Calculations are to be made to show that, in the holding condition (single anchor, brake fully applied and chain cable lifter declutched), and under a load equal to 80% of the specified minimum breaking strength of the chain cable, the maximum stress in each load bearing component will not exceed yield strength (or 0.2% proof stress) of the material. For installations fitted with a chain cable stopper, 45% of the specified minimum breaking strength of the chain cable may instead be used for the calculation.

b) Inertia loads

The design of the drive train, including prime mover, reduction gears, bearings, clutches, shafts, cable lifter and bolting is to consider the dynamic effects of sudden stopping and starting of the prime mover or chain cable so as to limit inertial load.

3.2.2 Continuous Duty Pull *(1/7/2018)*

The windlass prime mover is to be able to exert for at least 30 minutes a continuous duty pull (e.g., 30-minute short time rating corresponding to S2-30 min. of IEC 60034-1), P_{C1}, in kN, corresponding to the grade and diameter, d, of the chain cables as given in Tab 1.

Table 1 : Continuous duty pull *(1/7/2018)*

Material of chain cables	Continuous duty pull, in kN
Mild steel	$P_{C1} = 0,0375\ d^2$
High tensile strength steel	$P_{C1} = 0,0425\ d^2$
Very high tensile strength steel	$P_{C1} = 0,0475\ d^2$
Note 1: d: chain cable diameter, in mm.	

The values of the above table are applicable when using ordinary stockless anchors for anchorage depth down to 82.5 m.

For anchorage depth deeper than 82.5 m, a continuous duty pull P_{C2}, in kN, is to be taken as:

$P_{C2} = P_{C1} + 0,00027\ d^2\ (D - 82,5)$

where:

D : anchor depth, in m.

The anchor masses are to be taken as specified in Pt B, Ch 10, Sec 4, [2.1]. Also, the value of PC is based on the hoisting of one anchor at a time, and that the effects of buoyancy and hawse pipe efficiency (assumed to be 70%) have been accounted for. In general, stresses in each torque-transmitting component are not to exceed 40% of yield strength (or 0.2% proof stress) of the material under these loading conditions.

3.2.3 Overload capability *(1/7/2018)*

The windlass unit prime mover is to provide the necessary temporary overload capacity for breaking out the anchor.

The temporary overload capacity, or short term pull, is to be not less than 1,5 times the continuous duty pull P_C and it is to be provided for at least two minutes.

The speed in this overload period may be lower than the nominal speed specified in [3.2.4].

3.2.4 Hoisting speed *(1/7/2018)*

The mean speed of the chain cable during hoisting of the anchor and cable is to be at least 0.15 m/s. For testing purposes, the speed is to be measured over two shots of chain cable and initially with at least three shots of chain (82.5 m in length) and the anchor submerged and hanging free.

3.2.5 Brake capacity *(1/7/2018)*

The capacity of the windlass brake is to be sufficient to stop the anchor and chain cable when paying out the chain cable. Where a chain cable stopper is not fitted, the brake is to produce a torque capable of withstanding a pull equal to 80% of the specified minimum breaking strength of the chain cable without any permanent deformation of strength members and without brake slip. Where a chain cable stopper is fitted, 45% of the breaking strength may instead be applied.

3.2.6 Chain cable stopper *(1/7/2018)*

Chain cable stopper, if fitted, along with its attachments is to be designed to withstand, without any permanent deformation, 80% of the specified minimum breaking strength of the chain cable.

3.3 Hydraulic system

3.3.1 *(1/7/2018)*

Hydraulic systems where employed for driving windlasses are to comply with the requirements of Pt C, Ch 1, Sec 10, [14].

3.4 Electrical system

3.4.1 Electric motors *(1/7/2018)*

Electric motors are to meet the requirements of Pt C, Ch 2, Sec 4 and those rated 100 kW and over are to be certified. Motors exposed to weather are to have enclosures suitable for their location as provided for in the requirements of Pt C, Ch 2, Sec 3, [4]. Where gears are fitted, they are to meet the requirements of Pt C, Ch 2, Sec 8 and those rated 100 kW and over are to be certified.

3.4.2 Electrical circuits *(1/7/2018)*

Motor branch circuits are to be protected in accordance with the requirements of Pt C, Ch 2, Sec 3, [7.10] and cable sizing is to be in accordance with the requirements of Pt C, Ch 2, Sec 3, [9]. Electrical cables installed in locations subjected to the sea are to be provided with effective mechanical protection.

3.5 Protection of mechanical components

3.5.1 *(1/7/2018)*

To protect mechanical parts including component housings, a suitable protection system is to be fitted to limit the speed and torque at the prime mover. Consideration is to be given to a means to contain debris consequent to a severe damage of the prime mover due to overspeed in the event of uncontrolled rendering of the cable, particularly when an axial piston type hydraulic motor forms the prime mover.

3.6 Couplings

3.6.1 *(1/7/2018)*

Windlasses are to be fitted with couplings which are capable of disengaging between the cable lifter and the drive shaft. Hydraulically or electrically operated couplings are to be capable of being disengaged manually.

4 Workshop inspection and testing

4.1 General

4.1.1 *(1/7/2018)*

Windlasses are to be inspected during fabrication at the manufacturers' facilities by a Surveyor for conformance with the approved plans. Acceptance tests, as specified in the specified standard of compliance, are to be witnessed by the Surveyor and include the test described in [4.2], as a minimum.

4.2 Tests

4.2.1 No-load test *(1/7/2018)*

The windlass is to be run without load at nominal speed in each direction for a total of 30 minutes. If the windlass is provided with a gear change, additional run in each direction for 5 minutes at each gear change is required.

4.2.2 Load test *(1/7/2018)*

The windlass is to be tested to verify that the continuous duty pull, overload capacity and hoisting speed as specified in [3.2] can be attained.

Where the manufacturing works does not have adequate facilities, these tests, including the adjustment of the overload protection, can be carried out on board ship. In these cases, functional testing in the manufacturer's works is to be performed under no-load conditions.

4.2.3 Brake capacity test *(1/7/2018)*

The holding power of the brake is to be verified either through testing or by calculation.

5 Marking

5.1 General

5.1.1 *(1/7/2020)*

Windlass shall be permanently marked with the following information:

a) nominal size of the windlass (e.g. 100/3/45 is the size designation of a windlass for 100 mm diameter chain cable of Grade 3, with a holding load of 45% of the breaking load of the chain cable);

b) maximum anchorage depth, in metres.

SECTION 16 TESTS ON BOARD

1 General

1.1 Application

1.1.1 This Section covers shipboard tests, both at the moorings 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 the main and auxiliary machinery and associated systems are functioning properly, in particular in respect of the criteria imposed by the Rules. The 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.

2 General requirements for shipboard tests

2.1 Trials at the moorings

2.1.1 Trials at the moorings are to demonstrate the following:

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

b) quick and easy response to operational commands

c) safety of the various installations, as regards:
   - the protection of mechanical parts
   - the safeguards for personnel

d) 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 at the moorings and are to include the following:

a) demonstration of the proper operation of the main and auxiliary machinery, including monitoring, alarm and safety systems, under realistic service conditions

b) check of the propulsion capability when one of the essential auxiliaries becomes inoperative

c) detection of dangerous vibrations by taking the necessary readings when required

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 *(1/7/2012)*

Except in cases of practical impossibility, or in other cases to be considered individually, the sea trials are to be carried out at a displacement as close as possible to the deadweight (full load).

3.1.2 Power of the machinery

a) 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. In general, this power is not to exceed the maximum continuous power at which the weakest component of the propulsion system can be operated. In cases of diesel engines and gas turbines, it is not to exceed the maximum continuous power for which the engine type concerned has been approved.

b) Where the rotational speed of the shafting is different from the design value, thereby increasing the stresses in excess of the maximum allowable limits, the power developed in the trials is to be suitably modified so as to confine the stresses within the design limits.

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.

As an alternative, for reciprocating internal combustion engines and gas turbines, the power may be determined by measuring the fuel consumption and on the basis of the other operating characteristics, in comparison with the results of bench tests of the prototype engine.

Other 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 (see Pt A, Ch 1, Sec 2, [4.9.4]), the speed of the ship is to be determined using procedures deemed suitable by the Society.

b) The ship 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 *(1/1/2026)*

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.

b) The stopping times, ship headings and distances recorded on trials, together with the results of trials to determine the ability of ships having multiple propellers to navigate and manoeuvre with one or more propellers inoperative, 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 paragraphs a) and b).

d) The astern tests are to be carried out from control positions. A test plan is to be provided by the yard and accepted by the surveyor. If specific operational characteristics have been defined by the manufacturer these shall be included in the test plan.

For electric propulsion systems, see [3.7].

3.3 Tests of boilers

3.3.1 General

The satisfactory operation of the main and auxiliary boilers supplying essential services is to be ascertained in all operating conditions during the trials at the moorings and the sea trials.

3.3.2 Tests to be performed

After installation on board, the following tests are to be carried out in the presence of the Surveyor:

a) Test in the hot condition of boilers and superheaters

b) Accumulation tests and setting of safety valves of boilers and superheaters
   - Safety valves are to be set to lift at a pressure not exceeding 103% of the design pressure
   - For boilers fitted with superheaters, the safety valves of the latter are to be set to lift before or, at the latest, at the same time as the valves of the saturated steam chest

c) Verification that, at the maximum steaming rate, the boiler pressure does not exceed 110% of the design pressure when the stop valves of the boiler, except those which must remain open for the burning operation, are closed. The boiler is to be fed so that the water level remains normal throughout the test. The test is to last:
   - 15 minutes for fire tube boilers
   - 7 minutes for water tube boilers.

d) Test and simulation of all safety devices, alarms, shut-off and automatic starting of standby equipment.

3.3.3 Alternative requirement

a) When it is recognised, for certain types of boilers, that accumulation tests might endanger the superheaters, the omission of such tests may be considered.

b) Such omission can be permitted, however, only if the drawings and the size of safety valves have been reviewed by the Society, and provided that the safety valves are of a type whose relieving capacity has been established by a test carried out in the presence of the Surveyor, or in other conditions deemed equivalent to those of the actual boiler.

c) When the Society does not agree to proceed with an accumulation test, the valve manufacturer is to supply, for each safety valve, a certificate specifying its relieving capacity for the working conditions of the boiler. In addition, the boiler manufacturer is to supply a certificate specifying the maximum steam capacity of the boiler.

3.4 Tests of diesel engines

3.4.1 General *(1/7/2018)*

a) The purpose of the shipboard testing is to verify compatibility with power transmission and driven machinery in the system, control systems and auxiliary systems necessary for the engine and integration of engine / shipboard control systems, as well as other items that had not been dealt with in the FAT (Factory Acceptance Testing)

b) Where the machinery installation is designed for residual or other special fuels, the ability of engines to burn such fuels is to be demonstrated.

c) Tests other than those listed below may be required by statutory instruments (e.g. EEDI verification).

3.4.2 Starting capacity *(1/7/2018)*

Starting manoeuvres are to be carried out in order to verify that the capacity of the starting media satisfies the required number of start attempts.

3.4.3 Monitoring and alarm system *(1/7/2018)*

The monitoring and alarm systems are to be checked to the full extent for all engines, except items already verified during the works trials.

3.4.4 Test loads *(1/7/2018)*

Test loads for various engine applications are given below in [3.4.5] to [3.4.9]. In addition, the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

3.4.5 Main propulsion engines driving fixed propeller or impellers *(1/7/2018)*

a) at rated engine speed n_0: at least 4 hours

b) at engine speed n = 1,032 n_0 for 30 minutes

Note 1: The test in b) is to be performed only where permitted by the engine adjustment, see Note 3 to Sec 2, [7.4.4].

c) at approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer

d) minimum engine speed to be determined

e) the ability of reversible engines to be operated in reverse direction is to be demonstrated.

Note 2: To be carried out during stopping tests according to Resolution MSC.137 (76), see [3.4.10] for additional requirements in the case of a barred speed range.

Note 3: The test in e) may be performed during the dock or sea trials.

3.4.6 Main propulsion engines driving controllable pitch propellers *(1/7/2018)*

a) At rated engine speed n_0 with a propeller pitch leading to rated engine power (or to the maximum achievable power if 100% cannot be reached): at least 4 hours

b) At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer

c) With reverse pitch suitable for manoeuvring, see [3.4.10] for additional requirements in the case of a barred speed range.

3.4.7 Engines driving generators for electrical propulsion and/or main power supply *(1/7/2018)*

a) At 100% power (rated electrical power of generator): at least 60 min

b) At 110% power (rated electrical power of generator): at least 10 min

c) Demonstration of the generator prime movers' and governors' ability to handle load steps as described in Sec 2.

Note 1: Each engine is to be tested 100% electrical power for at least 60 min and 110% of rated electrical power of the generator for at least 10 min. This may, if possible, be done during the electrical propulsion plant test, which is required to be tested with 100% propulsion power (i.e. total electric motor capacity for propulsion) by distributing the power on as few generators as possible. The duration of this test is to be sufficient to reach stable operating temperatures of all rotating machines or for at least 4 hours. When some of the gen. set(s) cannot be tested due to insufficient time during the propulsion system test mentioned above, those required tests are to be carried out separately.

3.4.8 Propulsion engines also driving power take off (PTO) generator *(1/7/2018)*

a) 100% engine power (MCR) at corresponding speed n_0: at least 4 hours

b) 100% propeller branch power at engine speed n_0 (unless already covered in a): 2 hours

c) 100% PTO branch power at engine speed n_0: at least 1 hour.

3.4.9 Engines driving auxiliaries *(1/7/2018)*

a) 100% power (MCR) at corresponding speed n0: at least 30 min

b) Approved intermittent overload: testing for duration as approved. shipboard generating sets, account is to be taken of the times needed to actuate the generator's overload protection system.

3.4.10 Torsional vibrations *(1/7/2018)*

Barred speed range

Where a barred speed range is required, passages through this barred speed range, both accelerating and decelerating, are to be demonstrated. The times taken are to be recorded and are to be equal to or below those times stipulated in the approved documentation, if any. This also includes when passing through the barred speed range in reverse rotational direction, especially during the stopping test.

Note 1: Applies both for manual and automatic passing-through systems.

The ship's draft and speed during all these demonstrations is to be recorded. In the case of a controllable pitch propeller, the pitch is also to be recorded.

The engine is to be checked for stable running (steady fuel index) at both upper and lower borders of the barred speed range. Steady fuel index means an oscillation range less than 5% of the effective stroke (idle to full index).

3.5 Tests of steam turbines

3.5.1 Main propulsion turbines *(1/1/2026)*

Main turbines are to be subjected during dock trials and subsequent sea trials to the following tests:

- operation at rated rpm for at least 3 hours
- reversing manoeuvres
- the astern trial is to demonstrate that they are capable of operating at their maximum permissible astern power (MPAP) for a period of at least 15 minutes. The astern trial is to be limited to 30 minutes or in accordance with the Manufacturer's recommendation to avoid overheating of the turbine due to the effects of "windage" and friction.

During astern and subsequent forward operation, the steam pressures and temperatures and the relative expansion are not to assume magnitudes liable to endanger the safe operation of the plant.

During the trials all safety, alarm, shut-off and control systems associated to the turbine are to be tested or properly simulated.

3.5.2 Auxiliary turbines

Turbines driving electric generators or auxiliary machines are to be run for at least 4 hours at their rated power and for 30 minutes at 110% of rated power.

During the trials all safety, alarm, shut-off and control systems associated to the turbine are to be tested or properly simulated.

3.6 Tests of gas turbines

3.6.1 Main propulsion turbines

Main turbines are to be subjected during dock trials and subsequent sea trials to the following tests:

- operation at rated rpm for at least 3 hours
- ship reversing manoeuvres.

During the various operations, the pressures, temperatures and relative expansion are not to assume magnitudes liable to endanger the safe operation of the plant.

During the trials all safety, alarm, shut-off and control systems associated to the turbine are to be tested or properly simulated.

3.6.2 Auxiliary turbines

Turbines driving electric generators or auxiliary machines are to be run for at least 4 hours at their rated power and for 30 minutes at 110% of rated power.

During the trials all safety, alarm, shut-off and control systems associated to the turbine are to be tested or properly simulated.

3.7 Tests of electric propulsion system

3.7.1 Dock trials

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

3.7.2 Sea trials *(1/7/2002)*

Testing of the performance of the electric propulsion system is to be effected in accordance with an approved test program.

This test program is to include at least:

a) Speed rate of rise

b) Endurance test:
   - 4 hours at 100% rated output power
   - 2 hours at the maximum continuous output power normally used at sea
   - 10 minutes at maximum astern running power

c) 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. During this test, all necessary data concerning any effects of the reversing of power on the generators are to be recorded, including the power and speed variation

d) Test of functionality of electric propulsion, when manoeuvring and during the ship turning test

e) Test of power management performance: reduction of power due to loss of one or several generators to check, in each case, the power limitation and propulsion availability.

3.8 Tests of gears

3.8.1 Tests during sea trials

During the sea trials, the performance of reverse and/or reduction gearing is to be verified, both when running ahead and astern.

In addition, the following checks are to be carried out:

- check of the bearing and oil temperature
- detection of possible gear hammering, where required by Sec 9, [3.6.1]
- test of the monitoring, alarm and safety systems.

3.8.2 Check of the tooth contact

a) Prior to the sea trials, the tooth surfaces of the pinions and wheels are to be coated with a thin layer of suitable coloured compound.

Upon completion of the trials, the tooth contact is to be inspected. The contact marking is to appear uniformly distributed without hard bearing at the ends of the teeth and without preferential contact lines.

The tooth contact is to comply with Tab 1.

b) The verification of tooth contact at sea trials by methods other than that described above will be given special consideration by the Society.

c) In the case of reverse and/or reduction gearing with several gear trains mounted on roller bearings, manufactured with a high standard of accuracy and having an input torque not exceeding 20 000 N·m, the check of the tooth contact may be reduced at the Society's discretion.

Such a reduction may also be granted for gearing which has undergone long workshop testing at full load and for which the tooth contact has been checked positively.

In any case, the teeth of the gears are to be examined by the Surveyor after the sea trials. Subject to the results, additional inspections or re-examinations after a specified period of service may be required.

Table 1 : Tooth contact for gears

Heat treatment and machining	Percentage of tooth contact	
	across the whole face width	of the tooth working depth
quenched and tempered, cut	70	40
• quenched and tempered, shaved or ground • surface-hardened	90	40

3.9 Tests of main propulsion shafting and propellers

3.9.1 Shafting alignment

Where alignment calculations are required to be submitted in pursuance of Sec 7, [3.3.2], 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)
   - check of the crankshaft deflections before and after the connection of the engine with the shaft line, by measuring the variation in the distance between adjacent webs in the course of one complete revolution of the engine

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.

3.9.2 Shafting vibrations

Torsional, bending and axial vibration measurements are to be carried out where required by Sec 9. The type of the measuring equipment and the location of the measurement points are to be specified.

3.9.3 Bearings

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

3.9.4 Stern tube sealing gland

The stern tube oil system is to be checked for possible oil leakage through the stern tube sealing gland.

3.9.5 Propellers *(1/1/2025)*

The proper functioning of the devices for emergency operations is to be tested during the sea trials.

3.9.6 Control system of controllable pitch propellers *(1/1/2025)*

a) General

The functioning of the system controlling the pitch from full ahead to full astern position is to be demonstrated. It is also to be checked that this system does not induce any overload of the engine.

The following requirements apply to all replacements, modifications, repairs, or re-adjustments that may affect the pitch control or response characteristics for main propulsion.

b) Pitch response test

A full range of tests is to be carried out to get the pitch response and verify that it coincides with the combinator curve of the propeller (see Note 1). The tests are to be carried out for at least three positions of the control lever in ahead and astern directions (e.g., dead slow ahead / astern, half ahead / astern, full ahead / astern).

The tests are to be carried out in normal and emergency operating conditions.

Tests that are not affected by the control position may be carried out from one control position only.

Note 1: The combinator curve is the relationship between the propeller pitch setting and the propeller speed.

c) Test of the fail-to-safe characteristics

A test of the fail-to-safe characteristics of the propeller pitch control system is to be carried out to demonstrate that failures in the pitch command and control or feedback signals are alarmed and do not cause any change of thrust. Such failures are to be clearly identified and included in the test procedure.

d) Test procedure

Test procedure is to be prepared and proposed by the pitch control system manufacturer or integrator and agreed with Society.

e) Parameters to be recorded

The list of the parameters to be recorded during the pitch response test within this Article is to be established by the pitch control system manufacturer or integrator and agreed with the Society. This should include at least the following parameters:

- Position of the control handle,
- Actual pitch indication (local indication, remote indications),
- Rotational speed of the propeller,
- Response time between the pitch change order (modification of the lever position) and the instant when the pitch and propeller speed have reached their final position,
- Propelling thrust variation during the transfer of the control from one location to another one.

f) Tests results

Tests are to demonstrate:

- that the propelling thrust is not significantly altered when transferring control from one location to another and in case of failures in the pitch command and control or feedback signals.
- that the pitch response times measured during the test do not exceed the maximum value to be defined by the pitch control system manufacturer or integrator.

3.10 Tests of piping systems

3.10.1 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. Operating

parameters (pressure, temperature, consumption) are to comply with the values recommended by the equipment manufacturer.

3.10.2 Performance tests

The Society reserves the right to require performance tests, such as flow rate measurements, should doubts arise from the functional tests.

3.11 Tests of steering gear

3.11.1 General *(1/7/2012)*

a) 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 of Sec 11 are fulfilled.

b) For controllable pitch propellers, the propeller pitch is to be set at the maximum design pitch approved for the maximum continuous ahead rotational speed.

c) If the ship cannot be tested at the deepest draught, steering gear trials shall be conducted at a displacement as close as reasonably possible to full-load displacement as required by Section 6.1.2 of ISO 19019:2005 on the conditions that either the rudder is fully submerged (zero speed waterline) and the vessel is in an acceptable trim condition, or the rudder load and torque at the specified trial loading condition have been predicted and extrapolated to the full load condition. In any case, the speed of ship corresponding to the number of maximum continuous revolution of main engine and maximum design pitch applies.

3.11.2 Tests to be performed

Tests of the steering gear are to include at least:

a) functional test of the main and auxiliary steering gear with demonstration of the performances required by Sec 11, [3.3] and Sec 11, [4.3].

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

c) test of the isolation of one power actuating system, checking the time for regaining steering capability

d) test of the hydraulic fluid refilling system

e) test of the alternative power supply required by Sec 11, [2.3.2], item e)

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

g) test of the means of communication between the navigation bridge, the engine room and the steering gear compartment

h) test of the alarms and indicators

i) where the steering gear design is required to take into account the risk of hydraulic locking, a test is to be performed to demonstrate the efficiency of the devices intended to detect this.

Note 1: Tests d) to i) may be carried out either during the mooring trials or during the sea trials.

Note 2: For ships of less than 500 tons gross tonnage and for fishing vessels, the Society may accept departures from the above list, in particular to take into account the actual design features of their steering gear.

Note 3: Azimuth thrusters are to be subjected to the above tests, as far as applicable.

3.12 Tests of anchor windlasses

3.12.1 General *(1/7/2018)*

a) Each windlass is to be tested under working conditions after installation onboard to demonstrate satisfactory operation. Each unit is to be independently tested for braking, clutch functioning, lowering and hoisting of chain cable and anchor, proper riding of the chain over the cable lifter, proper transit of the chain through the hawse pipe and the chain pipe, and effecting proper stowage of the chain and the anchor;

b) it is to be confirmed that anchors properly seat in the stored position and that chain stoppers function as designed if fitted. The mean hoisting speed, as specified in Sec 15, [3.2.4], is to be measured and verified. The braking capacity is to be tested by intermittently paying out and holding the chain cable by means of the application of the brake. Where the available water depth is insufficient, the proposed test method is to be specially considered by the Society.

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

a) 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
   - the cleanliness of the lubricating oil filters.

b) In the case of propulsion engines for which power tests have not been carried out in the workshop, some parts, agreed upon by the interested parties, are to be disassembled for inspection after the sea trials.

APPENDIX 1 CHECK FOR SCANTLINGS OF CRANKSHAFTS FOR DIESEL ENGINES

1 General

1.1 Application

1.1.1 *(1/1/2007)*

a) The requirements for the check of scantlings of crankshaft given in this Appendix apply to diesel engines as per Sec 2, [5.1.1] a) and b) capable of continuous operation of their maximum continuous power P as defined in Sec 2, [1.5.3], at the nominal maximum speed n.
Where a crankshaft design involves the use of surface treated fillets, or when fatigue parameter influences are tested, or when working stresses are measured, the relevant documents with calculations/analysis are to be submitted to the Society in order to demonstrate equivalence to these requirements.

b) The requirements of this Appendix apply only to solid forged and semi-built crankshafts of forged or cast steel, with one crankthrow between main bearings.

1.2 Documentation to be submitted

1.2.1 *(1/1/2007)*

Required data for the check of the scantlings are indicated in the specific Society form as per item 1) of Sec 2, Tab 1.

1.3 Principles of calculation

1.3.1 *(1/1/2007)*

The design of crankshafts is based on an evaluation of safety against fatigue 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 to or larger than crankpin diameter, 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.

Calculation of crankshaft strength consists initially in determining the nominal alternating bending (see [2.1]) and nominal alternating torsional stresses (see [2.2]) which, multiplied by the appropriate stress concentration factors (see [3]), result in an equivalent alternating stress (uni-axial stress) (see [5]). This equivalent alternating stress is then compared with the fatigue strength of the selected crankshaft material (see [6]). This comparison will show whether or not the crankshaft concerned is dimensioned adequately (see [7]).

2 Calculation of stresses

2.1 Calculation of alternating stresses due to bending moments and radial forces

2.1.1 **Assumptions** *(1/1/2007)*

The calculation is based on a statically determined system, composed of a single crankthrow supported in the centre of adjacent main journals and subject to gas and inertia forces. The bending length is taken as the length between the two main bearing mid-points (distance L_3, see Fig 1).

The bending moments M_{BR}, M_{BT} are calculated in the relevant section based on triangular bending moment diagrams due to the radial component F_R and tangential component F_T of the connecting rod force, respectively (see Fig 1a)).

For crankthrows with two connecting rods acting upon one crankpin, the relevant bending moments are obtained by superposition of the two triangular bending moment diagrams according to phase (see Fig 1b)).

a) Bending moments and radial forces acting in web

The bending moment M_{BRF} and the radial force Q_{RF} are taken as acting in the centre of the solid web (distance L_1) and are derived from the radial component of the connecting rod force.

The alternating bending and compressive stresses due to bending moments and radial forces are to be related to the cross-section of the crank web. This reference section results from the web thickness W and the web width B (see Fig 2).

Mean stresses are disregarded.

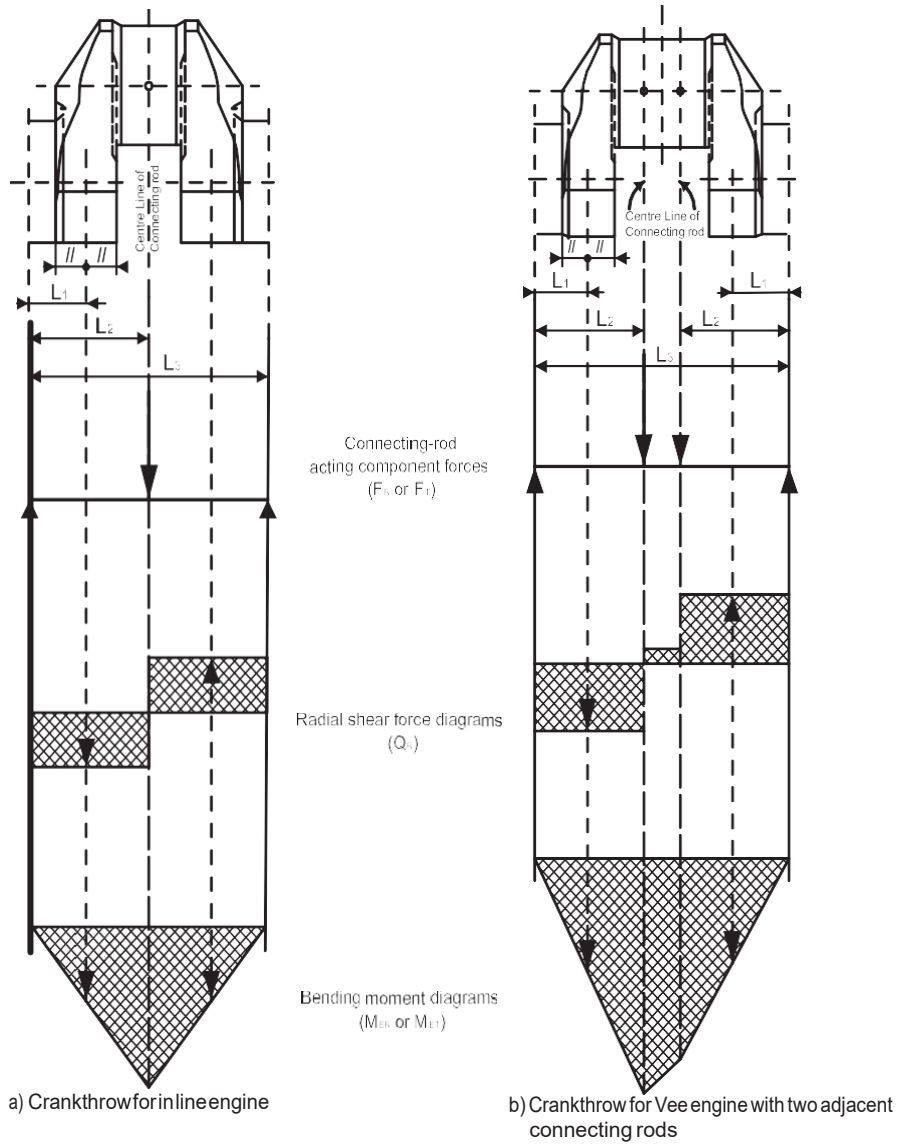
b) Bending acting in outlet of crankpin oil bore

The two relevant bending moments are taken in the crankpin cross-section through the oil bore (see Fig 3).

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 disregarded.

Figure 1 : Crankthrow of solid crankshaft *(1/1/2007)*

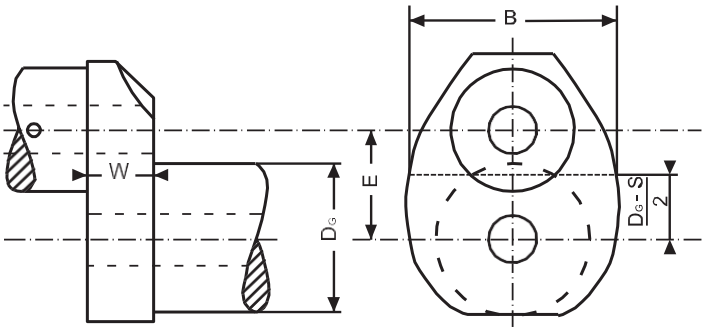


a) Crankthrow for in line engine

b) Crankthrow for Vee engine with two adjacent connecting rods

L1 = Distance between main journal centre line and crankweb centre (see also Fig 2 for crankshaft without overlap)
L2 = Distance between main journal centre line and connecting-rod centre
L3 = Distance between two adjacent main journal centre lines

Figure 2 : Reference area of crankweb cross-section *(1/1/2007)*



Overlapped crankshaft

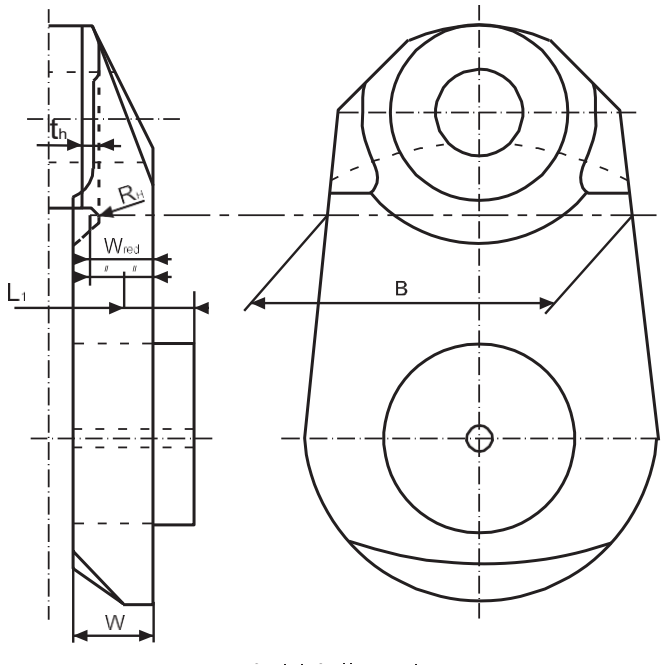
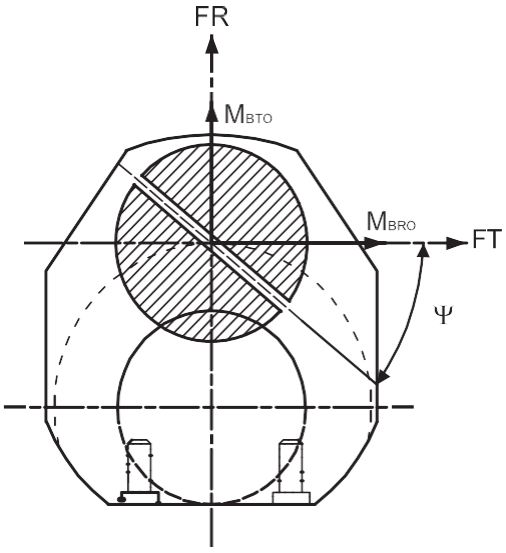


Figure 3 : Crankpin section through the oil bore *(1/1/2007)*



M_{BRO} is the bending moment of the radial component of the connecting-rod force

M_{BTO} is the bending moment of the tangential component of the connecting-rod force

2.1.2 Calculation of nominal alternating bending and compressive stresses in web *(1/1/2007)*

a) The radial and tangential forces due to gas and inertia loads acting upon the crankpin at each connecting rod position will be calculated over one working cycle.

Using the forces calculated over one working cycle and taking into account the distance from the main bearing mid-point, the time curve of the bending moments M_{BRF}, M_{BRO} , M_{BTO} and radial forces Q_{RF} as defined in [2.1.1]b) and [2.1.1]c) will then be calculated.

In the case of V-type engines, the bending moments - progressively calculated from the gas and inertia forces - of the two cylinders acting on one crankthrow are superposed according to phase. Different designs (forked connecting rod, articulated type connecting rod or adjacent connecting rods) are to be taken into account.

Where there are cranks of different geometrical configurations in one crankshaft, the calculation is to cover all crank variants.

The decisive alternating values will then be calculated according to:

$$X_N = \pm \frac{1}{2}[X_{max} - X_{min}]$$

where:

X_N : is considered as alternating force, moment or stress

X_{max} : is maximum value within one working cycle

X_{min} : is minimum value within one working cycle

b) The calculation of the nominal alternating bending and compressive stresses in the web cross-section is as follows:

$$\sigma_{BFN} = \pm \frac{M_{BRFN}}{W_{eqw}} \cdot 10^3 \cdot K_e$$

$$\sigma_{QFN} = \pm \frac{Q_{RFN}}{F} \cdot K_e$$

where:

σ_{BFN} [N/mm²]:nominal alternating bending stress related to the web.

M_{BRFN} [Nm]:alternating bending moment related to the centre of the web (see Fig 1).

$$M_{BRFN} = \pm \frac{1}{2}[M_{BRFmax} - M_{BRFmin}]$$

W_{eqw}[mm³]:section modulus related to the cross-section of the web.

$$W_{eqw} = \frac{B \cdot W^2}{6}$$

K_e : empirical factor considering to some extent the influence of adjacent crank and bearing restraint with:

K_e = 0,8 for 2-stroke engines

K_e = 1,0 for 4-stroke engines

σ_{QFN} [N/mm²]: nominal alternating compressive stress due to radial force related to the web

Q_{RFN}[N]: alternating radial force related to the web (see Fig 1)

$$Q_{RFN} = \pm \frac{1}{2}[Q_{RF_{max}} - Q_{RF_{min}}]$$

F [mm²]: area related to the cross-section of the web F = B·W

c) The calculation of nominal alternating bending stress in the outlet of the crankpin oil bore is as follows :

$$\sigma_{BON} = \pm \frac{M_{BON}}{W_e} \cdot 10^3$$

where:

σ_{BON}[N/mm²]:nominal alternating bending stress related to the crankpin diameter

M_{BON}[Nm]:alternating bending moment calculated at the outlet of the crankpin oil bore

$$M_{BON} = \pm \frac{1}{2}[M_{BO_{max}} - M_{BO_{min}}]$$

with:

$M_{BO} = M_{BTO} \cdot \cos\psi + M_{BRO} \cdot \sin\psi$

ψ [°] : angular position (see Fig 3)

W_e [mm³]: section modulus related to the cross-section of the axially bored crankpin

$$W_e = \frac{\pi}{32}\left[\frac{D^4 - D_{BH}^4}{D}\right]$$

2.1.3 Calculation of alternating bending stresses in fillets *(1/1/2007)*

The calculation of stresses is to be carried out for the crankpin fillet as well as for the journal fillet.

For the crankpin fillet:

$$\sigma_{BH} = \pm (\alpha_B \cdot \sigma_{BFN})$$

where:

σ_{BH} [N/mm²]: alternating bending stress in the crankpin fillet

α_B [-] : stress concentration factor for bending in the crankpin fillet (determination - see [3])

For the journal fillet (not applicable to semi-built crankshafts):

$$\sigma_{BG} = \pm (\beta_B \cdot \sigma_{BFN} + \beta_Q \cdot \sigma_{QFN})$$

where:

σ_{BG} [N/mm²]: alternating bending stress in the journal fillet

β_B [-] : stress concentration factor for bending in the journal fillet (determination - see [3])

β_Q [-] : stress concentration factor for compression due to radial force in the journal fillet (determination - see [3]).

2.1.4 Calculation of alternating bending stresses in the outlet of the crankpin oil bore *(1/1/2007)*

$$\sigma_{BO} = \pm (\gamma_B \cdot \sigma_{BON})$$

where:

σ_{BO} [N/mm²]: alternating bending stress in the outlet of the crankpin oil bore

γ_B [-] : stress concentration factor for bending in the crankpin oil bore (determination - see [3]).

2.2 Calculation of alternating torsional stresses

2.2.1 General *(1/1/2007)*

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 Manufacturer is to specify the maximum nominal alternating torsional stress.

2.2.2 Calculation of nominal alternating torsional stresses *(1/1/2007)*

The maximum and minimum torques are to be ascertained for every mass point of the complete dynamic system and for the entire speed range by means of a harmonic synthesis of 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. Whilst doing so, allowance is to be made for the damping that exists in the system and for unfavourable conditions (misfiring in one of the cylinders). The speed step calculation is to be selected in such a way that any resonance found in the operational speed range of the engine will be detected.

Note 1: Misfiring is defined as a cylinder condition when no combustion occurs but only a compression cycle.

Where barred speed ranges are necessary, they are to be arranged so that satisfactory operation is possible despite their existence. There are to be no barred speed ranges above a speed ratio of $\gamma \geq 0{,}8$ for normal firing conditions.

The values received from such calculation are to be submitted to the Society.

The nominal alternating torsional stress in every mass point, which is essential to the assessment, results from the following equation:

$$\tau_N = \pm \frac{M_{TN}}{W_P} \cdot 10^3$$

$$M_{TN} = \pm \frac{1}{2} \cdot (M_{Tmax} - M_{Tmin})$$

$$W_P = \frac{\pi}{16} \cdot \left(\frac{D^4 - D_{BH}^4}{D}\right) \text{ or } W_P = \frac{\pi}{16} \cdot \left(\frac{D^4 - D_{BG}^4}{D}\right)$$

where:

τ_N [N/mm²]: nominal alternating torsional stress referred to the crankpin or journal

M_{TN} [Nm]: maximum alternating torque

W_P [mm³]: polar section modulus related to the cross-section of the axially bored crankpin or bored journal

M_{Tmax} [Nm]: maximum value of the torque

M_{Tmin} [Nm]: minimum value of the torque.

For the purpose of the crankshaft assessment, the nominal alternating torsional stress considered in further calculations is the highest calculated value, according to above method, occurring at the most torsionally loaded mass point of the crankshaft system.

Where barred speed ranges exist, the torsional stresses within these ranges are not to be considered for assessment calculations.

The approval of the crankshaft will be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum figure specified by the engine Manufacturer).

Thus, for each installation, it is to be ensured by suitable calculation that this approved nominal alternating torsional stress is not exceeded. This calculation is to be submitted for assessment.

2.2.3 Calculation of alternating torsional stresses in fillets and the outlet of the crankpin oil bore *(1/1/2007)*

The calculation of stresses is to be carried out for the crankpin fillet, the journal fillet and the outlet of the crankpin oil bore. For the crankpin fillet:

$$\tau_H = \pm (\alpha_T \cdot \tau_N)$$

where:

τ_H [N/mm²]: alternating torsional stress in the crankpin fillet

α_T [-] : stress concentration factor for torsion in the crankpin fillet (determination - see [3])

τ_N [N/mm²]: nominal alternating torsional stress related to the crankpin diameter.

For the journal fillet (not applicable to semi-built crankshafts):

$$\tau_G = \pm (\beta_T \cdot \tau_N)$$

where:

τ_G [N/mm²]: alternating torsional stress in the journal fillet

β_T [-] : stress concentration factor for torsion in the journal fillet (determination - see [3])

τ_N [N/mm²]: nominal alternating torsional stress related to the journal diameter.

For the outlet of the crankpin oil bore:

$$\sigma_{TO} = \pm (\gamma_T \cdot \tau_N)$$

where:

σ_{TO} [N/mm²]: alternating stress in the outlet of the crankpin oil bore due to torsion

γ_T [-] : stress concentration factor for torsion in the outlet of the crankpin oil bore (determination- see [3])

τ_N [N/mm²]: nominal alternating torsional stress related to crankpin diameter.

3 Evaluation of stress concentration factors

3.1 General

3.1.1 *(1/7/2018)*

The stress concentration factors are evaluated by means of the formulae according to items [3.2], [3.3] and [3.4] applicable to the fillets and crankpin oil bore of solid forged web type crankshafts and to the crankpin fillets of semi-built crankshafts only. It is to be noted that stress concentration factor formulae concerning the oil bore are only applicable to a radially drilled oil hole. All formulae are based on investigations of FVV (Forschungsvereinigung Verbrennungskraftmaschinen) for fillets and on investigations of ESDU (Engineering Science Data Unit) for oil holes.

Where the geometry of the crankshaft is outside the boundaries of the analytical stress concentration factors (SCF), the calculation method detailed in [9] may be undertaken.

All crank dimensions necessary for the calculation of stress concentration factors are shown in Fig 4 and Tab 1.

The stress concentration factor for bending (α_B, β_B) is defined as the ratio of the maximum equivalent stress (VON MISES) - occurring in the fillets under bending load - to the nominal bending stress related to the web cross-section (see Tab 4).

The stress concentration factor for compression (β_Q) in the journal fillet is defined as the ratio of the maximum equivalent stress (VON MISES) - occurring in the fillet due to the radial force - to the nominal compressive stress related to the web cross-section.

The stress concentration factor for torsion (α_T, β_T) is defined as the ratio of the maximum equivalent shear stress - occurring in the fillets under torsional load - to the nominal torsional stress related to the axially bored crankpin or journal cross-section (see Tab 4).

The stress concentration factors for bending (γ_B) and torsion (γ_T) are defined as the ratio of the maximum principal stress - occurring at the outlet of the crankpin oil hole under bending and torsional loads - to the corresponding nominal stress related to the axially bored crankpin cross-section (see Tab 5).

When reliable measurements and/or calculations are available, which can allow direct assessment of stress concentration factors, the relevant documents and their method of analysis are to be submitted to the Society in order to demonstrate their equivalence to the present Rule evaluation. This is always to be performed when dimensions are outside of any of the validity ranges for the empirical formulae presented in [3.2] to [3.4].

Item [9] and [12] describes how FE analyses can be used for the calculation of the stress concentration factors. Care should be taken to avoid mixing equivalent (von Mises) stresses and principal stresses.

Figure 4 : Crank dimensions *(1/1/2007)*

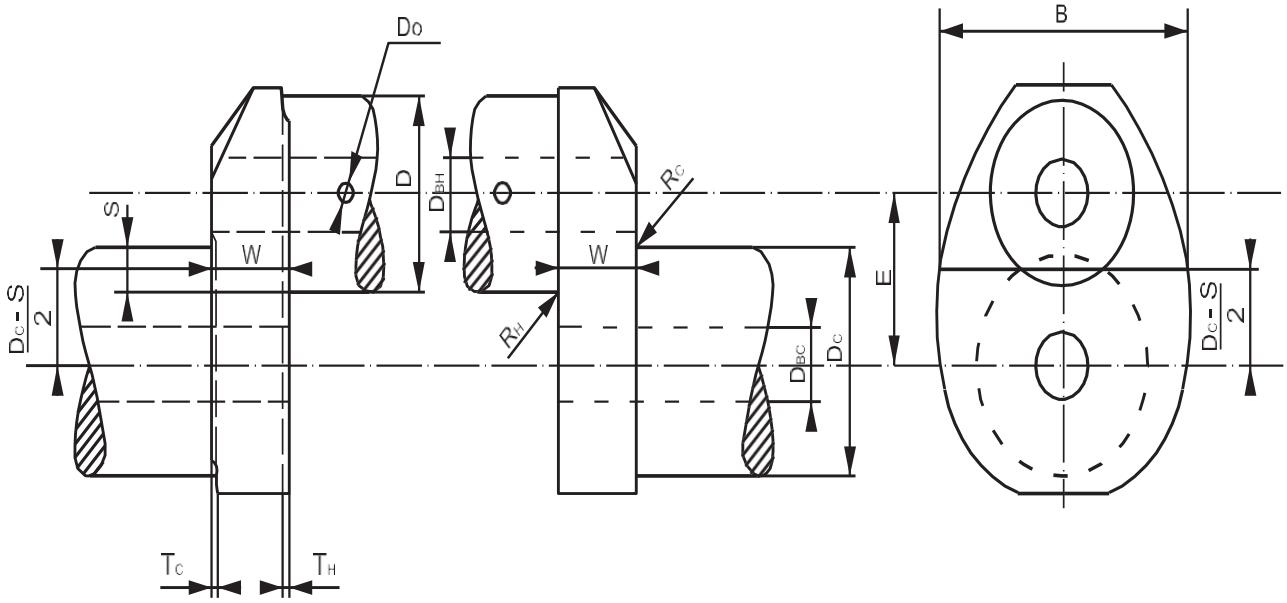


Table 1 : Actual dimensions *(1/1/2007)*

D	[mm]	crankpin diameter
D_{BH}	[mm]	diameter of axial bore in crankpin
D_O	[mm]	diameter of oil bore in crankpin
R_H	[mm]	fillet radius of crankpin
T_H	[mm]	recess of crankpin fillet
D_G	[mm]	journal diameter
D_{BG}	[mm]	diameter of axial bore in journal

(*) In the case of 2-stroke semi-built crankshafts:

- when $T_H > R_H$, the web thickness is to be considered as equal to:
  $W_{red} = W - (T_H - R_H)$ [refer to Fig 2]
- web width B is to be taken in way of the crankpin fillet radius centre according to Fig 2

R_G	[mm]	fillet radius of journal
T_G	[mm]	recess of journal fillet
E	[mm]	pin eccentricity
S	[mm] $S = \frac{D + D_G}{2} - E$	pin overlap
W (*)	[mm]	web thickness
B (*)	[mm]	web width

(*) In the case of 2-stroke semi-built crankshafts:
- when $T_H > R_H$, the web thickness is to be considered as equal to: $W_{red} = W - (T_H - R_H)$ [refer to Fig 2]
- web width B is to be taken in way of the crankpin fillet radius centre according to Fig 2

The related dimensions in Tab 2 will be applied for the calculation of stress concentration factors in the crankpin fillet and in the journal fillet.

Table 2 : Related dimensions *(1/1/2007)*

Crankpin fillet	Journal fillet
$r = R_H / D$	$r = R_G / D$
s	= S/D
w	= W/D crankshafts with overlap W_{red}/D crankshafts without overlap
b	= B/D
d_o	= D_o/D
d_G	= D_{BG}/D
d_H	= D_{BH}/D
t_H	= T_H/D
t_G	= T_G/D

Stress concentration factors are valid for the ranges of related dimensions for which the investigations have been carried out. Ranges are as follows:

$S \leq 5$

$0,2 \leq w \leq 0,8$

$1,1 \leq b \leq 2,2$

$0,03 \leq r \leq 0,13$

$0 \leq d_G \leq 0,8$

$0 \leq d_H \leq 0,8$

$0 \leq d_o \leq 0,2$

Low range of s can be extended down to large negative values provided that:
- If calculated f (recess) < 1 then the factor f (recess) is not to be considered (f (recess) = 1)
- If s < - 0,5 then f (s,w) and f (r,s) are to be evaluated replacing the actual value of s by - 0,5.

3.2 Crankpin fillet

3.2.1 *(1/1/2022)*

The stress concentration factor for bending (α_B) is :

$$\alpha_B = 2,6914 \cdot f(s, w) \cdot f(w) \cdot f(b) \cdot f(r) \cdot f(d_G) \cdot f(d_H) \cdot f(recess)$$

where:

$$f(s,w) = -4,1883 + 29,2004 \cdot w - 77,5925 \cdot w^2 + 91,9454 \cdot w^3 - 40,0416 \cdot w^4 + (1-s) \cdot (9,5440 - 58,3480 \cdot w + 159,3415 \cdot w^2 - 192,5846 \cdot w^3 + 85,2916 \cdot w^4) + (1-s)^2 \cdot (-3,8399 + 25,0444 \cdot w - 70,5571 \cdot w^2 + 87,0328 \cdot w^3 - 39,1832 \cdot w^4)$$

$$f(w) = 2,1790 \cdot w^{0,7171}$$

$$f(b) = 0,6840 - 0,0077 \cdot b + 0,1473 \cdot b^2$$

$$f(r) = 0,2081 \cdot r^{(-0,5231)}$$

$$f(d_G) = 0,9993 + 0,27 \cdot d_G - 1,0211 \cdot d^2_G + 0,5306 \cdot d^3_G$$

$$f(d_H) = 0,9978 + 0,3145 \cdot d_H - 1,5241 \cdot d^2_H + 2,4147 \cdot d^3_H$$

$$f(recess) = 1 + (t_H + t_G) \cdot (1,8 + 3,2 \cdot s)$$

The stress concentration factor for torsion (α_T) is :

$$\alpha_T = 0,8 \cdot f(r,s) \cdot f(b) \cdot f(w)$$

where:

$$f(r, s) = r^{(-0,322 + 0,1015 \cdot (1-s))}$$

$$f(b) = 7,8955 - 10,654 \cdot b + 5,3482 \cdot b^2 - 0,857 \cdot b^3$$

$$f(w) = w^{(-0,145)}$$

3.3 Journal fillet (not applicable to semi-built crankshafts)

3.3.1 *(1/1/2007)*

The stress concentration factor for bending (β_B) is:

$$\beta_B = 2,7146 \cdot f_B(s, w) \cdot f_B(w) \cdot f_B(b) \cdot f_B(r) \cdot f_B(d_G) \cdot f_B(d_H) \cdot f(recess)$$

where:

$$f_B(s,w) = -1,7625 + 2,9821 \cdot w - 1,5276 \cdot w^2 + (1-s) \cdot (5,1169 - 5,8089 \cdot w + 3,1391 \cdot w^2) + (1-s)^2 \cdot (-2,1567 + 2,3297 \cdot w - 1,2952 \cdot w^2)$$

$$f_B(w) = 2,2422 \cdot w^{0,7548}$$

$$f_B(b) = 0,5616 + 0,1197 \cdot b + 0,1176 \cdot b^2$$

$$f_B(r) = 0,1908 \cdot r^{(-0,5568)}$$

$$f_B(d_G) = 1,0012 - 0,6441 \cdot d_G + 1,2265 \cdot d^2_G$$

$$f_B(d_H) = 1,0022 - 0,1903 \cdot d_H + 0,0073 \cdot d^2_H$$

$$f(recess) = 1 + (t_H + t_G) \cdot (1,8 + 3,2 \cdot s)$$

The stress concentration factor for compression (β_Q) due to the radial force is:

$$\beta_Q = 3,0128 \cdot f_Q(s) \cdot f_Q(w) \cdot f_Q(b) \cdot f_Q(r) \cdot f_Q(d_H) \cdot f(recess)$$

where:

$$f_Q(s) = 0,4368 + 2,1630 \cdot (1-s) - (1,5212) \cdot (1-s)^2$$

$$f_Q(w) = \frac{w}{0,0637 + 0,9369 \cdot w}$$

$$f_Q(b) = -0,5 + b$$

$$f_Q(r) = 0,5331 \cdot r^{(-0,2038)}$$

$$f_Q(d_H) = 0,9937 - 1,1949 \cdot d_H + 1,7373 \cdot d^2_H$$

$$f(recess) = 1 + (t_H + t_G) \cdot (1,8 + 3,2 \cdot s)$$

The stress concentration factor for torsion (β_T) is:

$$\beta_T = \alpha_T$$

if the diameters and fillet radii of crankpin and journal are the same.

If crankpin and journal diameters and/or radii are of different sizes

$\beta_T = 0,8 \cdot f(r,s) \cdot f(b) \cdot f(w)$

where:

f (r,s), f (b) and f (w) are to be determined in accordance with item [3.2] (see calculation of α_T); however, the radius of the journal fillet is to be related to the journal diameter :

$r = \frac{R_G}{D_G}$

3.4 Outlet of the crankpin oil bore

3.4.1 *(1/1/2007)*

The stress concentration factor for bending (γ_B) is:

$\gamma_B = 3 - 5,88 \cdot d_o + 34,6 \cdot d_o^2$

The stress concentration factor for torsion (γ_T) is:

$\gamma_T = 4 - 6 \cdot d_o + 30 \cdot d_o^2$

4 Additional bending stresses

4.1 General

4.1.1 *(1/1/2007)*

In addition to the alternating bending stresses in fillets (see item [2.1.3]), further bending stresses due to misalignment and bedplate deformation as well as due to axial and bending vibrations are to be considered by applying σ_{add} as given by Tab 3.

Table 3 *(1/1/2007)*

Type of engine	σ_{add} [N/mm^2]
Crosshead engines	± 30 **(1)**
Trunk piston engines	± 10

(1) The additional stress of ± 30 N/mm^2 is composed of two components:
- an additional stress of ± 20 N/mm² resulting from axial vibration
- an additional stress of ± 10 N/mm^2 resulting from misalignment / bedplate deformation.

It is recommended that a value of ± 20 N/mm^2 be used for the axial vibration component for assessment purposes where axial vibration calculation results of the complete dynamic system.(engine/shafting/gearing/propeller) are not available. Where axial vibration calculation results of the complete dynamic system are available, the calculated figures may be used instead.

5 Calculation of equivalent alternating stress

5.1 General

5.1.1 *(1/1/2007)*

In the fillets, bending and torsion lead to two different biaxial stress fields which can be represented by a Von Mises equivalent stress with the additional assumptions that bending and torsion stresses are time phased and the corresponding peak values occur at the same location (see Tab 4).

As a result, the equivalent alternating stress is to be calculated for the crankpin fillet as well as for the journal fillet by using the Von Mises criterion.

At the oil hole outlet, bending and torsion lead to two different stress fields which can be represented by an equivalent principal stress equal to the maximum of principal stress resulting from the combination of these two stress fields with the assumption that bending and torsion are time phased (see Tab 5).

The above two different ways of equivalent stress evaluation both lead to stresses which may be compared to the same fatigue strength value of crankshaft assessed according to the Von Mises criterion.

5.2 Equivalent alternating stress

5.2.1 *(1/1/2007)*

The equivalent alternating stress is calculated in accordance with the formulae given.

For the crankpin fillet:

$$\sigma_V = \pm\sqrt{(\sigma_{BH} + \sigma_{add})^2 + 3 \cdot \tau_H^2}$$

For the journal fillet:

$$\sigma_V = \pm\sqrt{(\sigma_{BG} + \sigma_{add})^2 + 3 \cdot \tau_G^2}$$

For the outlet of the crankpin oil bore:

$$\sigma_V = \pm\frac{1}{3}\sigma_{BO} \cdot \left[1 + 2\sqrt{1 + \frac{9}{4} \cdot \left(\frac{\sigma_{TC}}{\sigma_{BO}}\right)^2}\right]$$

where:

σ_V [N/mm^2] : equivalent alternating stress.

For other parameters see [2.1.3], [2.2.3] and [4].

6 Calculation of fatigue strength

6.1 General

6.1.1 *(1/7/2018)*

The fatigue strength is to be understood as that value of equivalent alternating stress (Von Mises) which a crankshaft can permanently withstand at the most highly stressed points. The fatigue strength may be evaluated by means of the following formulae.

Related to the crankpin diameter:

$$\sigma_{DW} = \pm K \cdot (0,42 \cdot \sigma_B + 39,3) \cdot \left[0,264 + 1,073 \cdot D^{-0,2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{R_X}}\right]$$

with:

$R_X = R_H$ in the fillet area

$R_X = D_0 / 2$ in the oil bore area

Related to the journal diameter:

$$\sigma_{DW} = \pm K \cdot (0,42 \cdot \sigma_B + 39,3) \cdot \left[0,264 + 1,073 \cdot D_G^{-0,2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{R_G}}\right]$$

where:

σ_{DW} [N/mm^2]: allowable fatigue strength of crankshaft

K [-] : factor for different types of crankshafts without surface treatment. Values greater than 1 are only applicable to fatigue strength in the fillet area.

K = 1,05 for continuous grain flow forged or drop-forged crankshafts

K = 1,0 for free form forged crankshaft (without continuous grain flow)

Factor for cast steel crankshafts with cold rolling treatment in fillet area

K = 0,93 for cast steel crankshafts manufactured by companies using a classification society approved cold rolling process

σ_B [N/mm^2]: minimum tensile strength of crankshaft material.

For other parameters see [3.3].

When a surface treatment process is applied, it is to be approved by the Society.

Guidance for calculation of surface treated fillets and oil bore outlets is presented in [11].

These formulae are subject to the following conditions:

- surfaces of the fillet, the outlet of the oil bore and inside the oil bore (down to a minimum depth equal to 1,5 times the oil bore diameter) are to be smoothly finished.
- for calculation purposes R_H, R_G or R_X are to be taken as not less than 2 mm.

As an alternative, the fatigue strength of the crankshaft can be determined by experiment based either on a full size crankthrow (or crankshaft) or on specimens taken from a full size crankthrow. For evaluation of test results, see [10].

7 Acceptability criteria

7.1 General

7.1.1 *(1/1/2007)*

The sufficient dimensioning of a crankshaft is confirmed by a comparison of the equivalent alternating stress and the fatigue strength. This comparison is to be carried out for the crankpin fillet, the journal fillet and the outlet of the crankpin oil bore and is based on the formula:

$$Q = \frac{\sigma_{DW}}{\sigma_V}$$

where:

Q [-] : acceptability factor

Adequate dimensioning of the crankshaft is ensured if the smallest of all acceptability factors satisfies the criteria:

$Q \geq 1,15$

8 Calculation of shrink-fits of semi-built crankshafts

8.1 General

8.1.1 *(1/1/2007)*

All crank dimensions necessary for the calculation of the shrink-fit are shown in Fig 5, where:

D_A [mm]: outside diameter of web or twice the minimum distance x between centreline of journals and outer contour of web, whichever is the lesser

D_S [mm]: shrink diameter

D_G [mm] : journal diameter

D_{BG} [mm]: diameter of axial bore in journal

L_S [mm]: length of shrink-fit

R_G [mm]: fillet radius of journal

y [mm] : distance between the adjacent generating lines of journal and pin $y \geq 0,05 \cdot D_S$

Where y is less than $0,1 \cdot D_S$ special consideration is to be given to the effect of the stress due to the shrink-fit on the fatigue strength at the crankpin fillet.

Respecting the radius of the transition from the journal to the shrink diameter, the following is to be complied with:

$R_G \geq 0,015 \cdot D_G$

and

$R_G \geq 0,5 \cdot (D_S - D_G)$

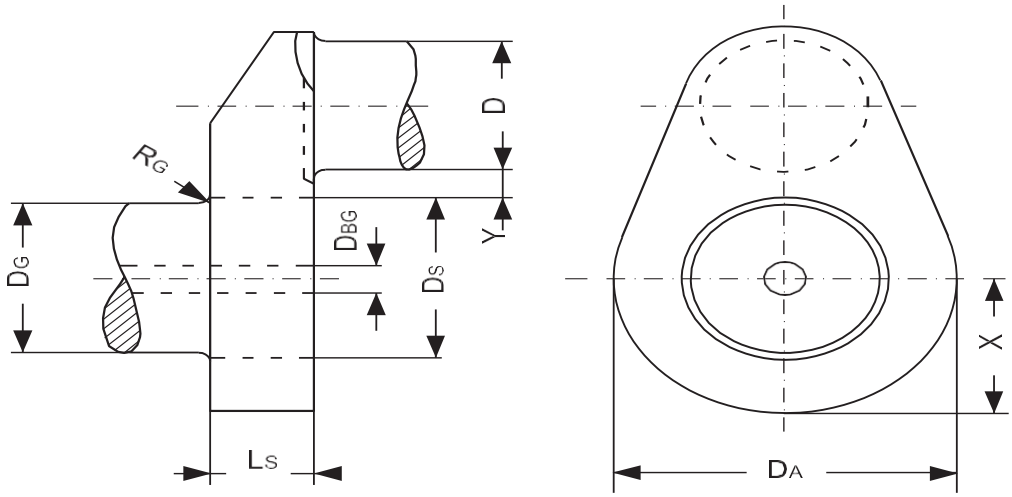
where the greater value is to be considered.

The actual oversize Z of the shrink-fit is to be within the limits Z_{min} and Z_{max} calculated in accordance with items [8.3] and [8.4].

Where the condition in [8.2] cannot be fulfilled, then calculation methods of Z_{min} and Z_{max} in [8.3] and [8.4] are not applicable due to multizone-plasticity problems.

In such case Z_{min} and Z_{max} are to be established based on FEM calculations.

Figure 5 : Crankthrow of semi-built crankshaft *(1/1/2007)*



8.2 Maximum permissible hole in the journal pin

8.2.1 *(1/1/2007)*

The maximum permissible hole diameter in the journal pin is calculated in accordance with the following formula:

$$D_{BG} = D_S \cdot \sqrt{1 - \frac{4000 \cdot S_R \cdot M_{max}}{\mu \cdot \pi \cdot D_S^2 \cdot L_S \cdot \sigma_{SP}}}$$

where:

S_R [-] : safety factor against slipping; however a value not less than 2 is to be taken unless documented by experiments

M_{max} [Nm]:absolute maximum value of the torque MTmax in accordance with [2.2.2].

μ [-] : coefficient for static friction; however a value not greater than 0,2 is to be taken unless documented by experiments

σ_{SP} [N/mm²]: minimum yield strength of material for journal pin.

This condition serves to avoid plasticity in the hole of the journal pin.

8.3 Necessary minimum oversize of shrink-fit

8.3.1 *(1/1/2007)*

The necessary minimum oversize is determined by the greater value calculated according to:

$$Z_{min} \geq \frac{\sigma_{SW} \cdot D_S}{E_m}$$

and

$$Z_{min} \geq \frac{4000\, S_R \cdot M_{max}}{\mu \cdot \pi \cdot E_m \cdot D_S \cdot L_S} \cdot \frac{1 - (Q_A^2 \cdot Q_S^2)}{(1 - Q_A^2) \cdot (1 - Q_S^2)}$$

where:

Z_{min} [mm]: minimum oversize

E_m [N/mm²]: Young's modulus

σ_{SW} [N/mm²]: minimum yield strength of material for crank web

Q_A [-] : web ratio, $Q_A = D_S / D_A$

Q_S [-] : shaft ratio, $Q_S = D_{BG} / D_S$

8.4 Maximum permissible oversize of shrink-fit

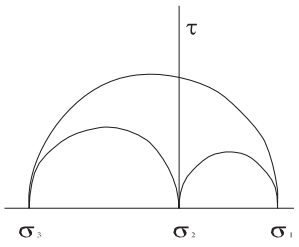
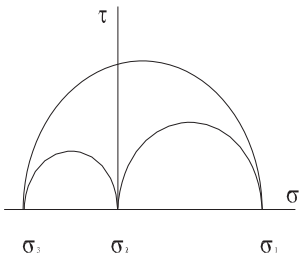
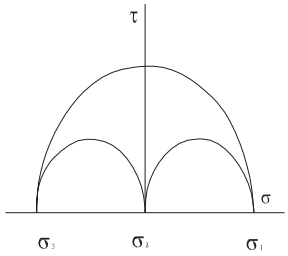
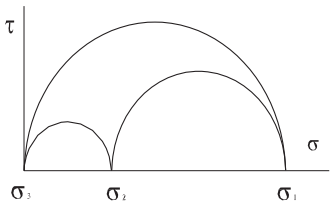
8.4.1 *(1/1/2007)*

The maximum permissible oversize is calculated according to:

$$Z_{max} \leq D_s \cdot \left(\frac{\sigma_{sw}}{E_m} + \frac{0,8}{1000} \right)$$

This condition serves to restrict the shrinkage induced mean stress in the fillet.

Table 4 : Definition of Stress Concentration Factors in crankshaft fillets *(1/1/2007)*

	Stress	Max II σ_3II	Max σ_1	
Torsional loading	Location of maximal stresses	A	C	B
	Typical principal stress system Mohr's circle diagram with $\sigma_2 = 0$	 II σ_3II > s1	 σ_1 > II σ_3II	 σ_1 = II s_3II
	Equivalent stress and S.C.F.	$\tau_{equiv} = \frac{\sigma_1 - \sigma_3}{2}$ S.C.F. $= \frac{\tau_{equiv}}{\tau_n}$ for α , β		
Bending loading	Location of maximal stresses	B	B	B
	Typical principal stress system Mohr's circle diagram with $\sigma_3 = 0$	$\sigma \neq 0$ 		
	Equivalent stress and S.C.F.	$\sigma_{equiv} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \cdot \sigma_2}$ S.C.F. $= \frac{\sigma_{equiv}}{\sigma_n}$ for α , β , β		

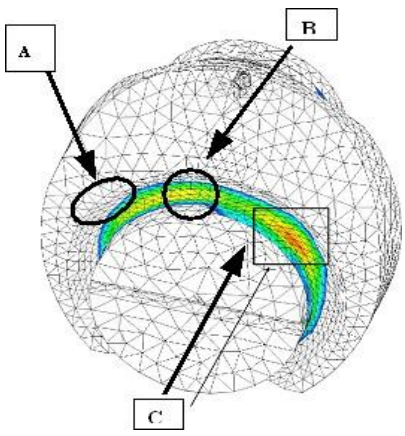
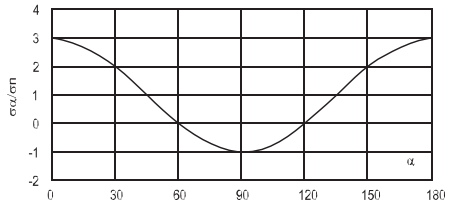
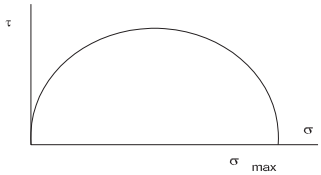
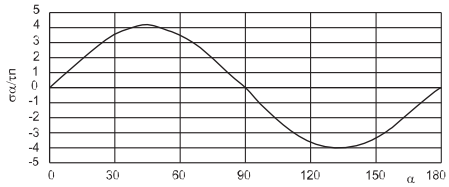
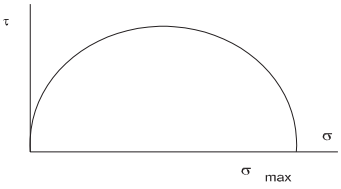
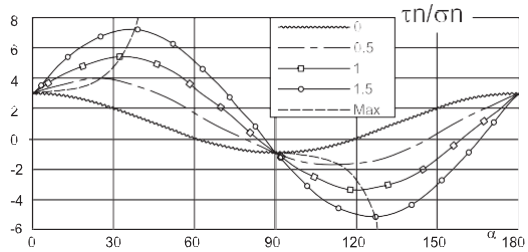
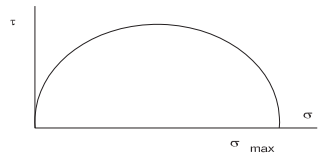
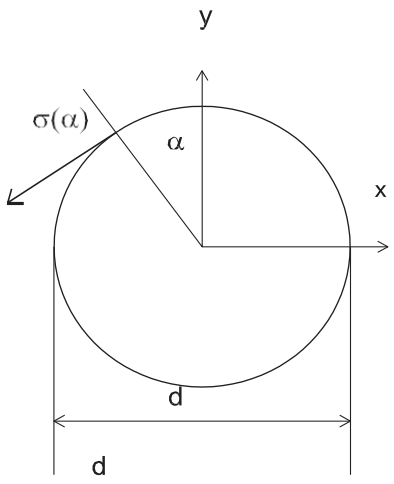


Table 5 : Stress Concentration Factors and stress distribution at the edge of oil drillings *(1/1/2007)*

Stress type	Nominal stress tensor	Uniaxial stress distribution around the edge	Mohr's circle diagram
Tension	$\begin{bmatrix}\sigma_n & 0\\ 0 & 0\end{bmatrix}$	$\sigma_\alpha = \sigma_n \gamma_B / 3[1 + 2\cos(2\alpha)]$ 	 $\gamma_B = (\sigma_{max} / \sigma_n)$ for $\alpha = k\pi$
Shear	$\begin{bmatrix}0 & \tau_n\\ \tau_n & 0\end{bmatrix}$	$\sigma_\alpha = \gamma_T \tau_n \sin(2\alpha)$ 	 $\gamma_T = (\sigma_{max} / \tau_n)$ for $\alpha = \frac{\pi}{4} + k\frac{\pi}{2}$
Tension + shear	$\begin{bmatrix}\sigma_n & \tau_n\\ \tau_n & 0\end{bmatrix}$	$\sigma_\alpha = \frac{\gamma_B}{3}\sigma_n\left\{1 + 2\left[\cos(2\alpha) + \frac{3\gamma_T \tau_n}{2\gamma_B \sigma_n}\sin(2\alpha)\right]\right\}$ 	 $\sigma_{max} = \frac{\gamma_B}{3}\sigma_n\left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\gamma_T \tau_n}{\gamma_B \sigma_n}\right)^2}\right]$ for $\alpha = \frac{1}{2}\text{tg}^{-1}\left(\frac{3\gamma_T \tau_n}{2\gamma_B \sigma_n}\right)$



9 Guidance for calculation of Stress Concentration Factors in the web fillet radii of crankshafts by utilising the Finite Element Method

9.1 General

9.1.1 *(1/1/2012)*

The objective of the analysis is to develop Finite Element Method (FEM) calculated figures as an alternative to the analytically calculated Stress Concentration Factors (SCF) at the crankshaft fillets.

The analytical method is based on empirical formulae developed from strain gauge measurements of various crank geometries and accordingly the application of these formulae is limited to those geometries.

The SCFs calculated according to this item [9] are defined as the ratio of stresses calculated by FEM to nominal stresses in both journal and pin fillets. When used in connection with the present method, Von Mises stresses shall be calculated for bending and principal stresses for torsion.

The procedure is valid for both solid cranks and semi-built cranks (except journal fillets).

The analysis is to be conducted as linear elastic FE analysis, and unit loads of appropriate magnitude are to be applied for all load cases.

The calculation of SCF at the oil bores is not covered by this item [9].

It is advised to check the element accuracy of the FE solver in use, e.g. by modelling a simple geometry and comparing the stresses obtained by FEM with the analytical solution for pure bending and torsion.

Boundary Element Method (BEM) may be used instead of FEM.

9.2 Model requirements

9.2.1 *(1/1/2012)*

The basic recommendations and perceptions for building the FE model are presented in [9.2.2]. The final FE model is to fulfil the requirements in [9.2.3].

9.2.2 Element mesh recommendations *(1/1/2012)*

In order to fulfil the mesh quality criteria it is advisable to construct the FE model for the evaluation of Stress Concentration Factors according to the following recommendations:

a) The model consists of one complete crank, from the main bearing centreline to the opposite side main bearing centreline

b) Element types used in the vicinity of the fillets:
   - 10 node tetrahedral elements
   - 8 node hexahedral elements
   - 20 node hexahedral elements

c) Mesh properties in fillet radii. The following applies to ±90 degrees in the circumferential direction from the crank plane

d) Maximum element size a=r/4 through the entire fillet as well as in the circumferential direction. When using 20 node hexahedral elements, the element size in the circumferential direction may be extended up to 5a. In the case of multi-radii fillet, r is the local fillet radius. (If 8 node hexahedral elements are used, even smaller element size is required to meet the quality criteria)

e) Recommended arrangement for element size in fillet depth direction:
   - First layer thickness equal to element size of a
   - Second layer thickness equal to element to size of 2a
   - Third layer thickness equal to element to size of 3a

f) Minimum 6 elements across web thickness

g) Generally the rest of the crank should be suitable for the numerical stability of the solver

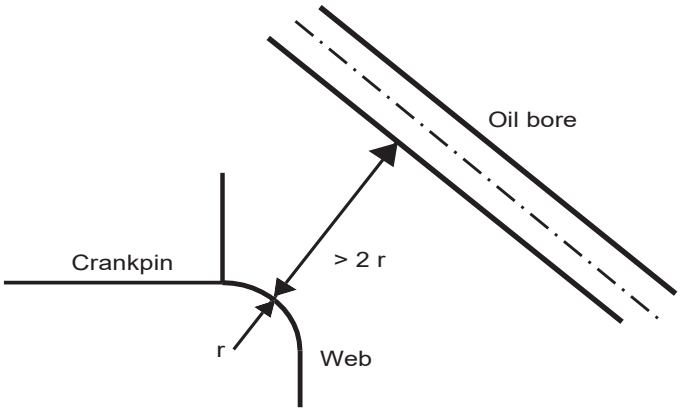
h) Counterweights need to be modelled only when influencing the global stiffness of the crank significantly

i) Modelling of oil drillings is not necessary as long as the influence on global stiffness is negligible and the proximity to the fillet is more than 2r; see Fig 6

j) Drillings and holes for weight reduction are to be modelled

k) Sub-modelling may be used as far as the software requirements are fulfilled.

Figure 6 : Oil bore proximity to fillet *(1/1/2012)*



9.2.3 Material *(1/1/2012)*

The formulae in [3] do not consider material properties such as Young's Modulus (E) and Poisson's ratio (ν). In FE analysis those material parameters are required, as strain is primarily calculated and stress is derived from strain using the Young's Modulus and Poisson's ratio.

Reliable values for material parameters need to be used, either as quoted in the literature or as measured on representative material samples.

For steel the following is advised:
E= $2{,}05 \cdot 10^5$ MPa and ν = 0,3.

9.2.4 Element mesh quality criteria *(1/1/2012)*

If the actual element mesh does not fulfil any of the following criteria in the area examined for SCF evaluation, then a second calculation with a refined mesh is to be performed.

a) Principal stresses criterion

The quality of the mesh should be assured by checking the stress component normal to the surface of the fillet radius. Ideally, this stress should be zero. With principal stresses σ_1, σ_2 and σ_3 the following criterion is required:

$$\min(|\sigma_1|, |\sigma_2|, |\sigma_3|) < 0,03 \max(|\sigma_1|, |\sigma_2|, |\sigma_3|)$$

b) Averaged/unaveraged stresses criterion

The criterion is based on observing the discontinuity of stress results over elements at the fillet for the calculation of SCF:

- Unaveraged nodal stress results calculated from each element connected to a node$_i$ should differ by less than 5% from the 100% averaged nodal stress results at this node$_i$ at the examined location.

9.3 Load cases

9.3.1 *(1/1/2012)*

To replace the analytically determined SCF in [3], the following load cases are to be calculated.

9.3.2 Torsion *(1/1/2012)*

The structure is loaded in pure torsion. In the model, surface warp at the end faces is suppressed.

Torque is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is connected rigidly to all nodes of the end face.

Boundary and load conditions are valid for both in-line and V-type engines.

For all nodes in both the journal and crank pin fillet, principal stresses are extracted and the equivalent torsional stress is calculated:

$$\tau_{equiv} = \max\left(\frac{|\sigma_1 - \sigma_2|}{2}, \frac{|\sigma_2 - \sigma_3|}{2}, \frac{|\sigma_1 - \sigma_3|}{2}\right)$$

The maximum value taken for the subsequent calculation of the SCF:

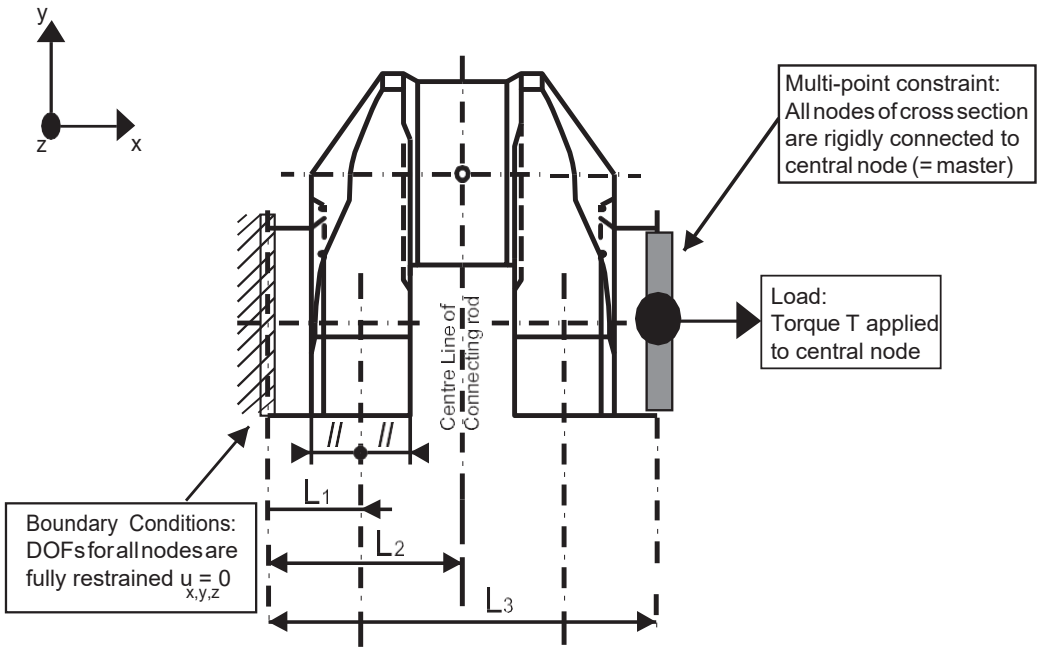
$$\alpha_T = \frac{\tau_{equiv,\alpha}}{\tau_N}$$

$$\beta_T = \frac{\tau_{equiv,\beta}}{\tau_N}$$

where τ_N is nominal torsional stress referred to the crankpin or journal, respectively, as per [2.2.2] with the torsional torque T:

$$\tau_N = \frac{T}{W_P}$$

Figure 7 : Boundary and load conditions for the torsion load case *(1/1/2012)*



9.3.3 Pure bending (4 point bending) *(1/1/2012)*

The structure is loaded in pure bending. In the model surface, warp at the end faces is suppressed.

The bending moment is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is connected rigidly to all nodes of the end face.

Boundary and load conditions are valid for both in-line and V-type engines.

For all nodes in both the journal and pin fillet, Von Mises equivalent stresses σ_{equiv} are extracted. The maximum value is used to calculate the SCF according to:

$$\alpha_B = \frac{\sigma_{equiv,\alpha}}{\sigma_N}$$

$$\beta_B = \frac{\sigma_{equiv,\beta}}{\sigma_N}$$

Nominal stress σ_N is calculated as per item b) of [2.1.2] with the bending moment M:

$$\sigma_N = \frac{M}{W_{eqw}}$$

9.3.4 Bending with shear force (3-point bending) *(1/1/2012)*

This load case is calculated to determine the SCF for pure transverse force (radial force, β_Q) for the journal fillet.

The structure is loaded in 3-point bending. In the model, surface warp at both end faces is suppressed. All nodes are connected rigidly to the centre node; boundary conditions are applied to the centre nodes. These nodes act as master nodes with 6 degrees of freedom.

The force is applied to the central node located at the pin centreline of the connecting rod. This node is connected to all nodes of the pin cross-sectional area. Warping of the sectional area is not suppressed.

Boundary and load conditions are valid for in-line and V-type engines. V-type engines can be modelled with one connecting rod force only. Using two connecting rod forces will make no significant change in the SCF.

Figure 8 : Boundary and load conditions for the pure bending load case *(1/1/2012)*

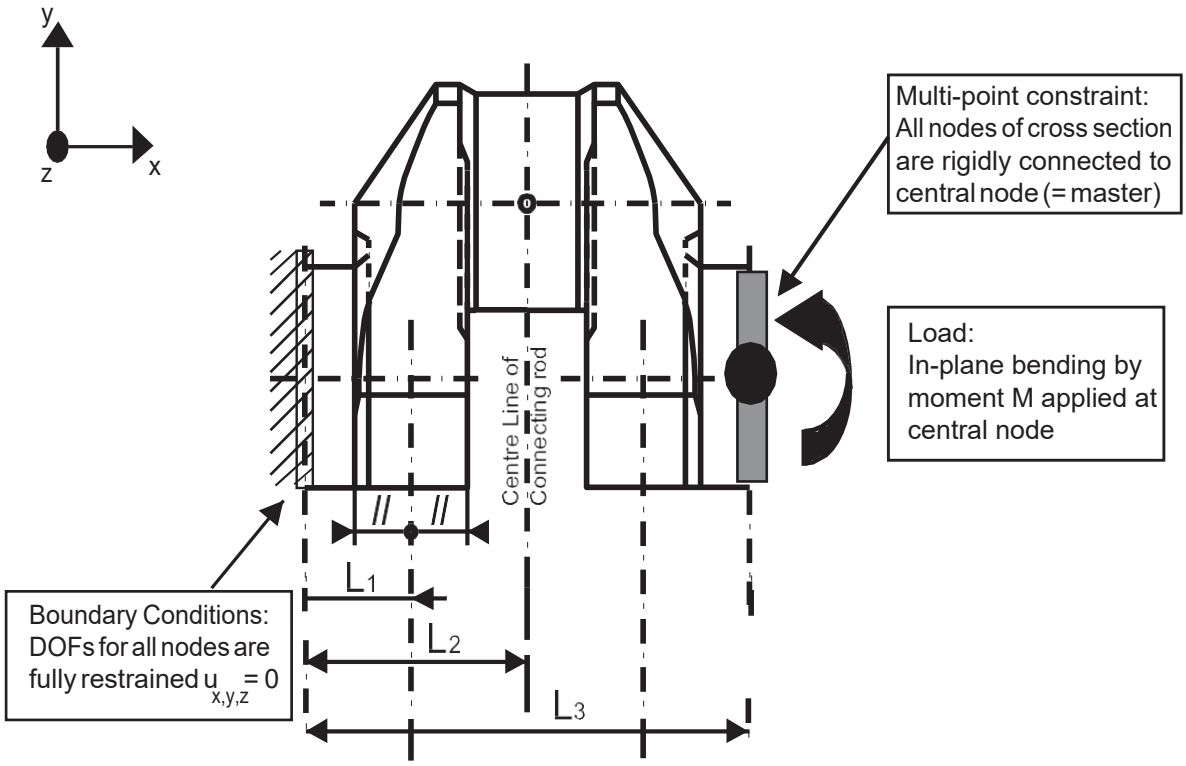


Figure 9 : Boundary and load conditions for the 3-point bending load case of an in-line engine *(1/1/2012)*

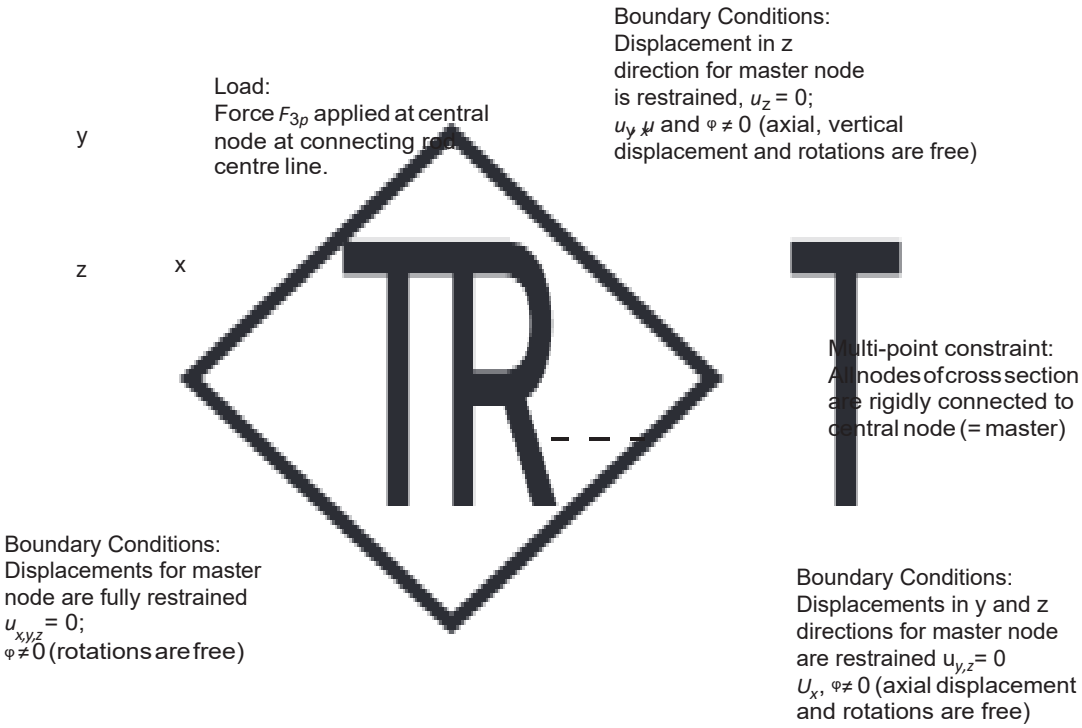
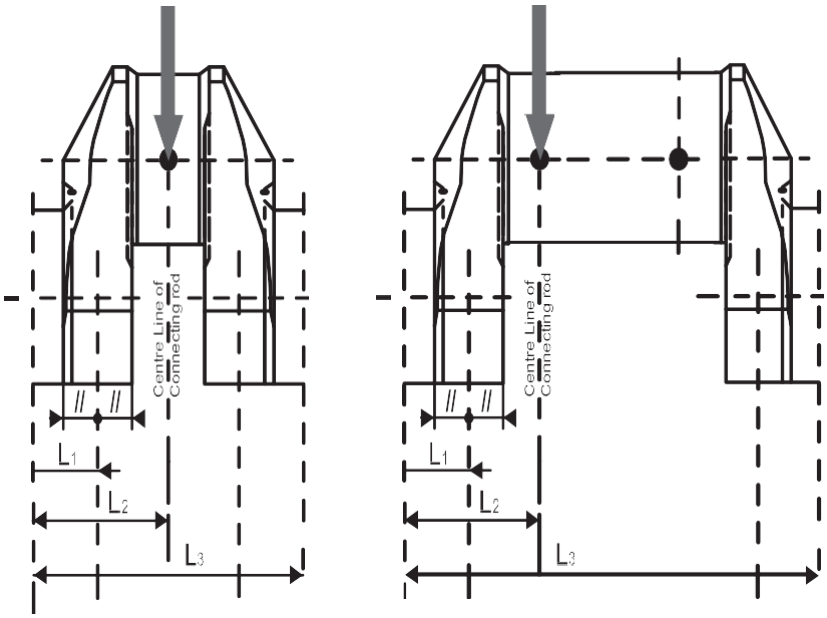


Figure 10 : Load applications for in-line and V-type engines *(1/1/2012)*



The maximum equivalent Von Mises stress σ_{3P} in the journal fillet is evaluated. The SCF in the journal fillet can be determined in two ways as shown in a) and b) below.

a) Method 1

The results from 3-point and 4-point bending are combined as follows:

$\sigma_{3P} = \sigma_{N3P} \times \beta_B + \sigma_{Q3P} \times \beta_Q$

where:

σ_{3P} : as found by the FE calculation

σ_{N3P} : Nominal bending stress in the web centre due to the force F_{3P} [N] applied to the centreline of the actual connecting rod; see Fig 10

β_B : as determined in [9.3.3]

σ_{Q3P} : Q_{3P} / (BW) where Q_{3P} is the radial (shear) force in the web due to the force F_{3P} [N] applied to the centreline of the actual connecting rod; see also Fig 1.

b) Method 2

In a statically determined system with one crank throw supported by two bearings, the bending moment and radial (shear) force are proportional. Therefore the journal fillet SCF can be found directly by the 3-point bending FE calculation.

The SCF is then calculated according to:

$$\beta_{BQ} = \frac{\sigma_{3P}}{\sigma_{N3P}}$$

For symbols, see item a) above.

When using this method, the radial force and stress determination become superfluous. The alternating bending stress in the journal fillet as per [2.1.3] is then evaluated:

$$\sigma_{BG} = \pm|\beta_{BQ} \cdot \sigma_{BFN}|$$

Note that the use of this method does not apply to the crankpin fillet and that this SCF must not be used in connection with calculation methods other than those assuming a statically determined system.

10 Guidance for Evaluation of Fatigue Tests

10.1 Introduction

10.1.1 *(1/7/2018)*

Fatigue testing can be divided into two main groups; testing of small specimens and full-size crank throws. Testing can be made using the staircase method or a modified version thereof which is presented in this document. Other statistical evaluation methods may also be applied.

10.1.2 Small specimen testing *(1/7/2018)*

For crankshafts without any fillet surface treatment, the fatigue strength can be determined by testing small specimens taken from a full-size crank throw. When other areas in the vicinity of the fillets are surface treated introducing residual stresses in the fillets, this approach cannot be applied.

One advantage of this approach is the rather high number of specimens which can be then manufactured. Another advantage is that the tests can be made with different stress ratios (R-ratios) and/or different modes e.g. axial, bending and torsion, with or without a notch. This is required for evaluation of the material data to be used with critical plane criteria.

10.1.3 Full-size crank throw testing *(1/7/2018)*

For crankshafts with surface treatment the fatigue strength can only be determined through testing of full size crank throws. For cost reasons, this usually means a low number of crank throws. The load can be applied by hydraulic actuators in a 3- or 4- point bending arrangement, or by an exciter in a resonance test rig. The latter is frequently used, although it usually limits the stress ratio to R = -1.

10.2 Evaluation of test results

10.2.1 Principles *(1/7/2018)*

Prior to fatigue testing the crankshaft must be tested as required by quality control procedures, e.g. for chemical composition, mechanical properties, surface hardness, hardness depth and extension, fillet surface finish, etc.

The test samples should be prepared so as to represent the "lower end" of the acceptance range e.g. for induction hardened crankshafts this means the lower range of acceptable hardness depth, the shortest extension through a fillet, etc. Otherwise the mean value test results should be corrected with a confidence interval: a 90% confidence interval may be used both for the sample mean and the standard deviation.

The test results, when applied in this App 1, shall be evaluated to represent the mean fatigue strength, with or without taking into consideration the 90% confidence interval as mentioned above. The standard deviation should be considered by taking the 90% confidence into account. Subsequently the result to be used as the fatigue strength is then the mean fatigue strength minus one standard deviation.

If the evaluation aims to find a relationship between (static) mechanical properties and the fatigue strength, the relation must be based on the real (measured) mechanical properties, not on the specified minimum properties.

The calculation technique presented in Chapter 2.4 was developed for the original staircase method. However, since there is no similar method dedicated to the modified staircase method the same is applied for both.

10.2.2 Staircase method *(1/7/2018)*

In the original staircase method, the first specimen is subjected to a stress corresponding to the expected average fatigue strength. If the specimen survives 10^7 cycles, it is discarded and the next specimen is subjected to a stress that is one increment above the previous, i.e. a survivor is always followed by the next using a stress one increment above the previous. The increment should be selected to correspond to the expected level of the standard deviation.

When a specimen fails prior to reaching 107 cycles, the obtained number of cycles is noted and the next specimen is subjected to a stress that is one increment below the previous. With this approach, the sum of failures and run-outs is equal to the number of specimens.

This original staircase method is only suitable when a high number of specimens are available. Through simulations it has been found that the use of about 25 specimens in a staircase test leads to a sufficient accuracy in the result.

10.2.3 Modified staircase method *(1/7/2018)*

When a limited number of specimens are available, it is advisable to apply the modified staircase method. Here the first specimen is subjected to a stress level that is most likely well below the average fatigue strength. When this specimen has survived 10^7 cycles, this same specimen is subjected to a stress level one increment above the previous. The increment should be selected to correspond to the expected level of the standard deviation. This is continued with the same specimen until failure.

Then the number of cycles is recorded and the next specimen is subjected to a stress that is at least 2 increments below the level where the previous specimen failed.

With this approach, the number of failures usually equals the number of specimens.

The number of run-outs, counted as the highest level where 107 cycles were reached, also equals the number of specimens.

The acquired result of a modified staircase method should be used with care, since some results available indicate that testing a runout on a higher test level, especially at high mean stresses, tends to increase the fatigue limit. However, this "training effect" is less pronounced for high strength steels (e.g. UTS > 800 MPa).

If the confidence calculation is desired or necessary, the minimum number of test specimens is 3.

10.2.4 Calculation of sample mean and standard deviation *(1/7/2018)*

A hypothetical example of tests for 5 crank throws is presented further in the subsequent text. When using the modified staircase method and the evaluation method of Dixon and Mood, the number of samples will be 10, meaning 5 run-outs and 5 failures, i.e.:

Number of samples, n=10

Furthermore, the method distinguishes between

Less frequent event is failures C=1

Less frequent event is run-outs C=2

The method uses only the less frequent occurrence in the test results, i.e. if there are more failures than run-outs, then the number of run-outs is used, and vice versa.

In the modified staircase method, the number of run-outs and failures are usually equal. However, the testing can be unsuccessful, e.g. the number of run-outs can be less than the number of failures if a specimen with 2 increments below the previous failure level goes directly to failure. On the other hand, if this unexpected premature failure occurs after a rather high number of cycles, it is possible to define the level below this as a run-out.

Dixon and Mood's approach, derived from the maximum likelihood theory, which also may be applied here, especially on tests with few samples, presented some simple approximate equations for calculating the sample mean and the standard deviation from the outcome of the staircase test. The sample mean can be calculated as follows:

- when C=1

$$\overline{S_a} = S_{a0} + d \cdot \left(\frac{A}{F} - \frac{1}{2}\right)$$

- when C=2

$$\overline{S_a} = S_{a0} + d \cdot \left(\frac{A}{F} + \frac{1}{2}\right)$$

The standard deviation can be found by:

$$s = 1,62 \cdot d \cdot \left(\frac{F \cdot B - A^2}{F^2} + 0,029\right)$$

where:

S_{a0} : is the lowest stress level for the less frequent occurrence

d : is the stress increment

F : Σ fi

A : Σ i · fi

B : Σ i² · fi

i : is the stress level numbering

fi : is the number of samples at stress level i

The formula for the standard deviation is an approximation and can be used when:

$$\frac{B \cdot F - A^2}{F^2} > 0,3 \text{ and } 0,5 \cdot s < d < 1,5 \cdot s$$

If any of these two conditions are not fulfilled, a new staircase test should be considered or the standard deviation should be taken quite large in order to be on the safe side.

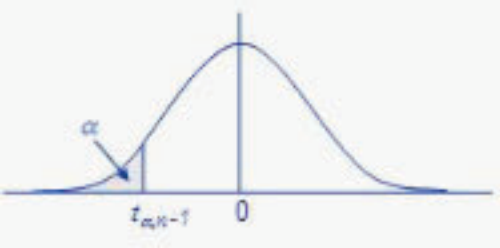
If increment d is greatly higher than the standard deviation s, the procedure leads to a lower standard deviation and a slightly higher sample mean, both compared to values calculated when the difference between the increment and the standard deviation is relatively small. Respectively, if increment d is much less than the standard deviation s, the procedure leads to a higher standard deviation and a slightly lower sample mean.

10.2.5 Confidence interval for mean fatigue limit *(1/7/2018)*

If the staircase fatigue test is repeated, the sample mean and the standard deviation will most likely be different from the previous test. Therefore, it is necessary to assure with a given confidence that the repeated test values will be above the chosen fatigue limit by using a confidence interval for the sample mean.

The confidence interval for the sample mean value with unknown variance is known to be distributed according to the t-distribution (also called student's t-distribution) which is a distribution symmetric around the average.

Figure 11 : Student's t-distribution *(1/7/2018)*



The confidence level normally used for the sample mean is 90 %, meaning that 90 % of sample means from repeated tests will be above the value calculated with the chosen confidence level. The figure shows the *t*-value for (1 - α) · 100% confidence interval for the sample mean.

If S_a is the empirical mean and s is the empirical standard deviation over a series of n samples, in which the variable values are normally distributed with an unknown sample mean and unknown variance, the (1 - α) · 100% confidence interval for the mean is:

$$P\left(S_a - t_{a,n-1} \cdot \frac{s}{\sqrt{n}} < S_{ax\%}\right) = 1 - \alpha$$

The resulting confidence interval is symmetric around the empirical mean of the sample values, and the lower endpoint can be found as:

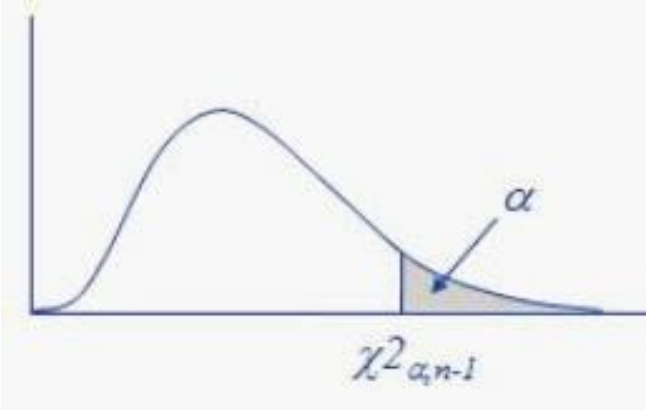
$$S_{ax\%} = S_a - t_{a,n-1} \cdot \frac{s}{\sqrt{n}}$$

which is the mean fatigue limit (population value) to be used to obtain the reduced fatigue limit where the limits for the probability of failure are taken into consideration.

10.2.6 Confidence interval for standard deviation *(1/7/2018)*

The confidence interval for the variance of a normal random variable is known to possess a chi-square distribution with n - 1 degrees of freedom.

Figure 12 : Chi-square distribution *(1/7/2018)*



The confidence level on the standard deviation is used to ensure that the standard deviations for repeated tests are below an upper limit obtained from the fatigue test standard deviation with a confidence level. The figure shows the chi-square for (1 - α) · 100% confidence interval for the variance.

An assumed fatigue test value from n samples is a normal random variable with a variance of σ^2 and has an empirical variance s^2. Then a (1 - α) · 100% confidence interval for the variance is:

$$P\left(\frac{(n-1)s^2}{\sigma^2} < \chi^2_{a,n-1}\right) = 1 - \alpha$$

A (1 - α) · 100% confidence interval for the standard deviation is obtained by the square root of the upper limit of the confidence interval for the variance and can be found by:

$$S_{x\%} = \sqrt{\frac{n-1}{\chi^2_{a,n-1}}}s$$

This standard deviation (population value) is to be used to obtain the fatigue limit, where the limits for the probability of failure are taken into consideration.

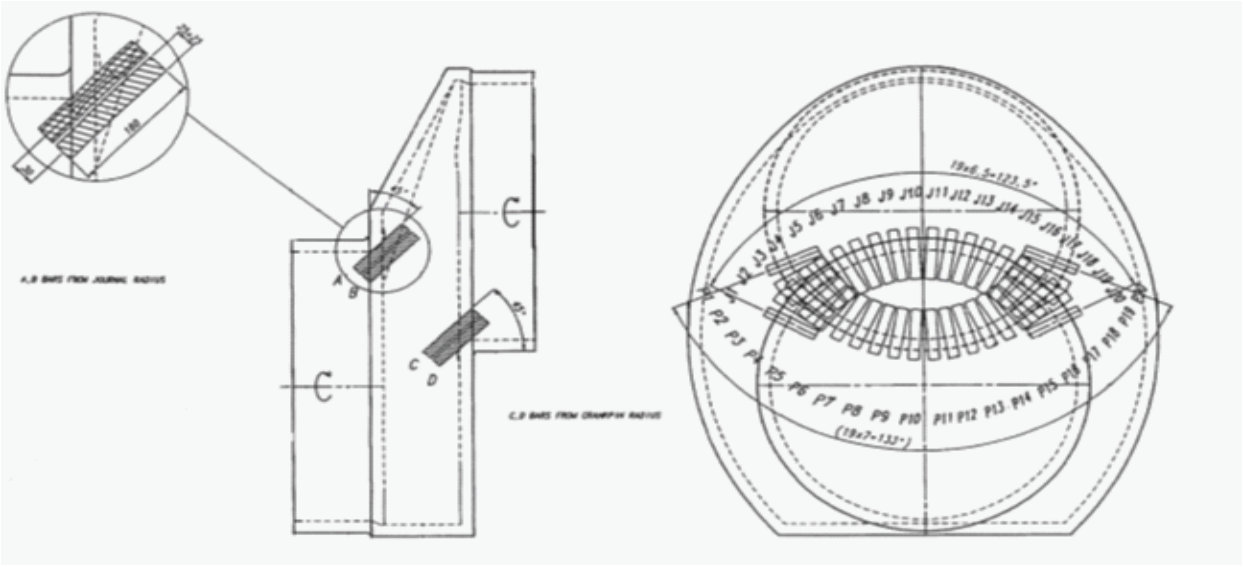
10.3 Small specimen testing

10.3.1 *(1/7/2018)*

In this connection, a small specimen is considered to be one of the specimens taken from a crank throw. Since the specimens shall be representative for the fillet fatigue strength, they should be taken out close to the fillets, as shown in Figure 13.

It should be made certain that the principal stress direction in the specimen testing is equivalent to the full-size crank throw. The verification is recommended to be done by utilising the finite element method.

Figure 13 : Specimen locations in a crank throw *(1/7/2018)*



The (static) mechanical properties are to be determined as stipulated by the quality control procedures.

10.3.2 Determination of bending fatigue strength *(1/7/2018)*

It is advisable to use un-notched specimens in order to avoid uncertainties related to the stress gradient influence. Push-pull testing method (stress ratio R = -1) is preferred, but especially for the purpose of critical plane criteria other stress ratios and methods may be added.

In order to ensure principal stress direction in push-pull testing to represent the full-size crank throw principal stress direction and when no further information is available, the specimen shall be taken in 45 degrees angle as shown in Figure 13.

a) If the objective of the testing is to document the influence of high cleanliness, test samples taken from positions approximately 120 degrees in a circumferential direction may be used. See Figure 3.1.

b) If the objective of the testing is to document the influence of continuous grain flow (cgf) forging, the specimens should be restricted to the vicinity of the crank plane.

10.3.3 Determination of torsional fatigue strength *(1/7/2018)*

a) If the specimens are subjected to torsional testing, the selection of samples should follow the same guidelines as for bending above. The stress gradient influence has to be considered in the evaluation.

b) If the specimens are tested in push-pull and no further information is available, the samples should be taken out at an angle of 45 degrees to the crank plane in order to ensure collinearity of the principal stress direction between the specimen and the full-size crank throw. When taking the specimen at a distance from the (crank) middle plane of the crankshaft along the fillet, this plane rotates around the pin centre point making it possible to resample the fracture direction due to torsion (the results are to be converted into the pertinent torsional values).

10.3.4 Other test positions *(1/7/2018)*

If the test purpose is to find fatigue properties and the crankshaft is forged in a manner likely to lead to c_{gf}, the specimens may also be taken longitudinally from a prolonged shaft piece where specimens for mechanical testing are usually taken. The condition is that this prolonged shaft piece is heat treated as a part of the crankshaft and that the size is so as to result in a similar quenching rate as the crank throw.

When using test results from a prolonged shaft piece, it must be considered how well the grain flow in that shaft piece is representative for the crank fillets.

10.3.5 Correlation of test results *(1/7/2018)*

The fatigue strength achieved by specimen testing shall be converted to correspond to the full-size crankshaft fatigue strength with an appropriate method (size effect).

When using the bending fatigue properties from tests mentioned in this section, it should be kept in mind that successful continuous grain flow (c_{gf}) forging leading to elevated values compared to other (non c_{gf}) forging, will normally not lead to a torsional fatigue strength improvement of the same magnitude.

In such cases it is advised to either carry out also torsional testing or to make a conservative assessment of the torsional fatigue strength, e.g. by using no credit for cgf. This approach is applicable when using the Gough Pollard criterion. However, this approach is not recognised when using the von Mises or a multi-axial criterion such as Findley.

If the found ratio between bending and torsion fatigue differs significantly from $\sqrt{3}$, one should consider replacing the use of the von Mises criterion with the Gough Pollard criterion. Also, if critical plane criteria are used, it must be kept in mind that c_{gf} makes the material inhomogeneous in terms of fatigue strength, meaning that the material parameters differ with the directions of the planes.

Any addition of influence factors must be made with caution. If for example a certain addition for clean steel is documented, it may not necessarily be fully combined with a K-factor for c_{gf}. Direct testing of samples from a clean and c_{gf} forged crank is preferred.

10.4 Full size testing

10.4.1 Hydraulic pulsation *(1/7/2018)*

A hydraulic test rig can be arranged for testing a crankshaft in 3-point or 4-point bending as well as in torsion. This allows for testing with any R-ratio.

Although the applied load should be verified by strain gauge measurements on plain shaft sections for the initiation of the test, it is not necessarily used during the test for controlling load. It is also pertinent to check fillet stresses with strain gauge chains.

Furthermore, it is important that the test rig provides boundary conditions as defined in [9.3.2] to [9.3.4].

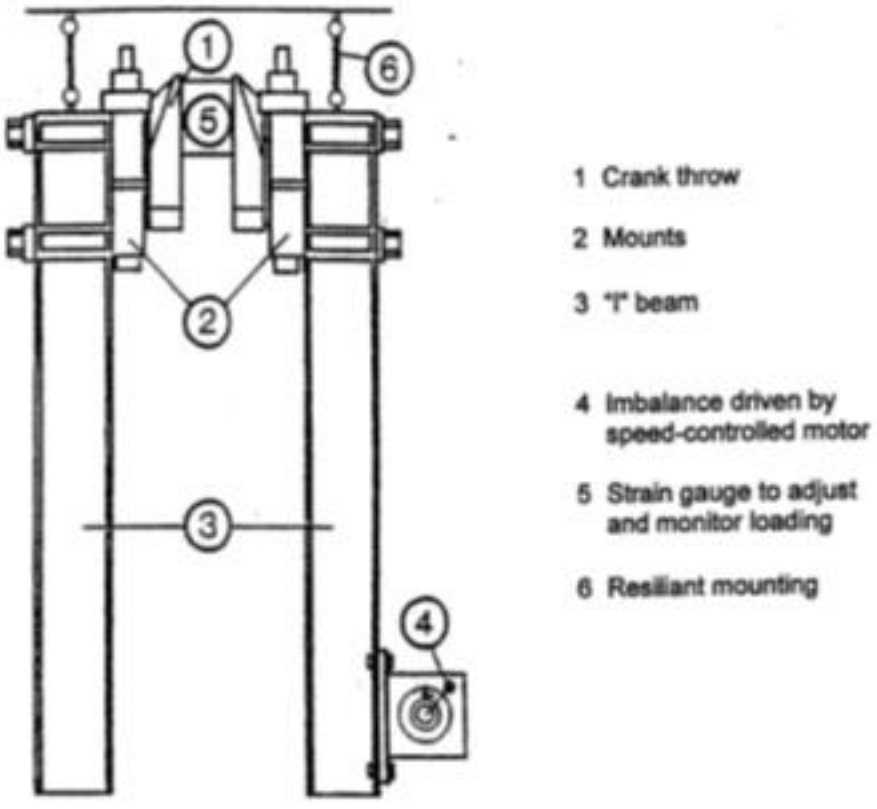
The (static) mechanical properties are to be determined as stipulated by the quality control procedures.

10.4.2 Resonance tester *(1/7/2018)*

A rig for bending fatigue normally works with an R-ratio of -1. Due to operation close to resonance, the energy consumption is moderate. Moreover, the frequency is usually relatively high, meaning that 107 cycles can be reached within some days. Fig 14 shows a layout of the testing arrangement.

The applied load should be verified by strain gauge measurements on plain shaft sections. It is also pertinent to check fillet stresses with strain gauge chains.

Figure 14 : Example of testing arrangement of the resonance tester for bending loading *(1/7/2018)*



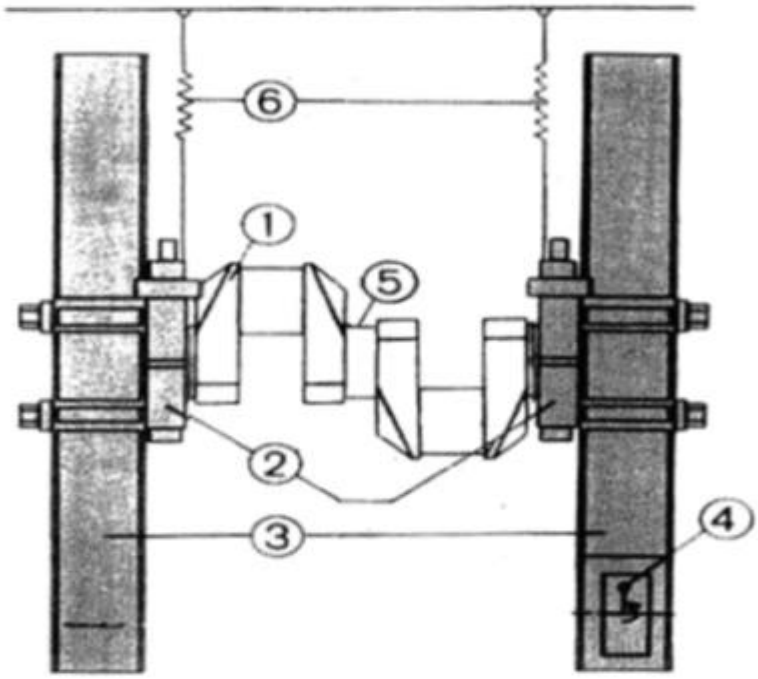
Clamping around the journals must be arranged in a way that prevents severe fretting which could lead to a failure under the edges of the clamps. If some distance between the clamps and the journal fillets is provided, the loading is consistent with 4-point bending and thus representative for the journal fillets also.

In an engine, the crankpin fillets normally operate with an R-ratio slightly above -1 and the journal fillets slightly below -1. If found necessary, it is possible to introduce a mean load (deviate from R = -1) by means of a spring preload.

A rig for torsion fatigue can also be arranged as shown in Figure 15. When a crank throw is subjected to torsion, the twist of the crankpin makes the journals move sideways. If one single crank throw is tested in a torsion resonance test rig, the journals with their clamped-on weights will vibrate heavily sideways.

This sideway movement of the clamped-on weights can be reduced by having two crank throws, especially if the cranks are almost in the same direction. However, the journal in the middle will move more.

Figure 15 : Example of testing arrangement of the resonance tester for torsion loading with double crank throw section *(1/7/2018)*



① crankthrow
② clamping jaw
③ I-profiled beams
④ motor-driven eccentric weight
⑤ strain gage
⑥ elastic suspension

Since sideway movements can cause some bending stresses, the plain portions of the crankpins should also be provided with strain gauges arranged to measure any possible bending that could have an influence on the test results.

Similarly, to the bending case the applied load shall be verified by strain gauge measurements on plain shaft sections. It is also pertinent to check fillet stresses with strain gauge chains as well.

10.4.3 Use of results and crankshaft acceptability *(1/7/2024)*

In order to combine tested bending and torsion fatigue strength results in calculation of crankshaft acceptability, see [7], the Gough-Pollard approach and the maximum principal equivalent stress formulation can be applied for the following cases:

At the crankpin fillet:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BH} + \sigma_{add}}{\sigma_{DWCT}} \right)^2 + \left(\frac{\tau_H}{\tau_{DWCT}} \right)^2} \right)^{-1}$$

where:

σ_{DWCT} : fatigue strength by bending testing

τ_{DWCT} : fatigue strength by torsion testing

for other parameters see items [2.1.3], [2.2.3] and [4]

Related to crankpin oil bore:

$$Q = \frac{\sigma_{DWOT}}{\sigma_v}; \qquad \sigma_v = \frac{1}{3} \cdot \sigma_{BO} \cdot \left(1 + 2 \cdot \sqrt{1 + \frac{9}{4} \cdot \left(\frac{\sigma_{T(}}{\sigma_{BO}}\right)^2}\right)$$

where:

σ_{DWOT} : fatigue strength by means of largest principal stress from torsion testing

At the journal fillet:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BG} + \sigma_{add}}{\sigma_{DWJT}}\right)^2 + \left(\frac{\tau_G}{\tau_{DWJT}}\right)^2}\right)^{-1}$$

where:

σ_{DWJT} : fatigue strength by bending testing

τ_{DWJT} : fatigue strength by torsion testing

for other parameters see items [2.1.3], [2.2.3] and [4].

In case increase in fatigue strength due to the surface treatment is considered to be similar between the above cases, it is sufficient to test only the most critical location according to the calculation where the surface treatment had not been taken into account.

10.5 Use of existing results for similar crankshafts

10.5.1 *(1/7/2018)*

For fillets or oil bores without surface treatment, the fatigue properties found by testing may be used for similar crankshaft designs providing:

a) Material:
- Similar material type
- Cleanliness on the same or better level
- The same mechanical properties can be granted (size versus hardenability)

b) Geometry:
- Difference in the size effect of stress gradient is insignificant or it is considered
- Principal stress direction is equivalent. See Chapter 3.

c) Manufacturing:
- Similar manufacturing process

Induction hardened or gas nitrited crankshafts will suffer fatigue either at the surface or at the transition to the core. The surface fatigue strength as determined by fatigue tests of full size cranks, may be used on an equal or similar design as the tested crankshaft when the fatigue initiation occurred at the surface. With the similar design, it is meant that a similar material type and surface hardness are used and the fillet radius and hardening depth are within approximately ± 30 % of the tested crankshaft.

Fatigue initiation in the transition zone can be either subsurface, i.e. below the hard layer, or at the surface where the hardening ends. The fatigue strength at the transition to the core can be determined by fatigue tests as described above, provided that the fatigue initiation occurred at the transition to the core. Tests made with the core material only will not be representative since the tension residual stresses at the transition are lacking.

It has to be noted also what some recent research has shown: The fatigue limit can decrease in the very high cycle domain with subsurface crack initiation due to trapped hydrogen that accumulates through diffusion around some internal defect functioning as an initiation point. In these cases, it would be appropriate to reduce the fatigue limit by some percent per decade of cycles beyond 107. Based on a publication by Yukitaka Murakami "Metal Fatigue: Effects of Small Defects and Non-metallic Inclusions" the reduction is suggested to be 5 % per decade especially when the hydrogen content is considered to be high.

11 Guidance for Calculation of Surface Treated Fillets and Oil Bore Outlets

11.1 Introduction

11.1.1 *(1/7/2018)*

This article deals with surface treated fillets and oil bore outlets. The various treatments are explained and some empirical formulae are given for calculation purposes. Conservative empiricism has been applied intentionally, in order to be on the safe side from a calculation standpoint.

Please note that measurements or more specific knowledge should be used if available. However, in the case of a wide scatter (e.g. for residual stresses) the values should be chosen from the end of the range that would be on the safe side for calculation purposes.

11.2 Definition of surface treatment

11.2.1 **Principles** *(1/7/2018)*

Surface treatment' is a term covering treatments such as thermal, chemical or mechanical operations, leading to inhomogeneous material properties - such as hardness, chemistry or residual stresses - from the surface to the core.

11.2.2 **Surface treatment methods** *(1/7/2018)*

The following list covers possible treatment methods and how they influence the properties that are decisive for the fatigue strength.

Table 6 : Surface treatment methods and the characteristics they affect *(1/7/2018)*

Treatment method	Affecting
Induction hardening	Hardness and residual stresses
Nitriding	Chemistry, hardness and residual stresses
Case hardening	Chemistry, hardness and residual stresses
Die quenching (no temper)	Hardness and residual stresses
Cold rolling	Residual stresses
Stroke peening	Residual stresses
Shot peening	Residual stresses
Laser peening	Residual stresses
Ball coining	Residual stresses

It is important to note that since only induction hardening, nitriding, cold rolling and stroke peening are considered relevant for marine engines, other methods as well as combination of two or more of the above are not dealt with in this document. In addition, die quenching can be considered in the same way as induction hardening.

11.3 Calculation principles

11.3.1 *(1/7/2018)*

The basic principle is that the alternating working stresses shall be below the local fatigue strength (including the effect of surface treatment) wherein non-propagating cracks may occur, see also section 11.6.2 for details. This is then divided by a certain safety factor. This applies through the entire fillet or oil bore contour as well as below the surface to a depth below the treatment-affected zone - i.e. to cover the depth all the way to the core.

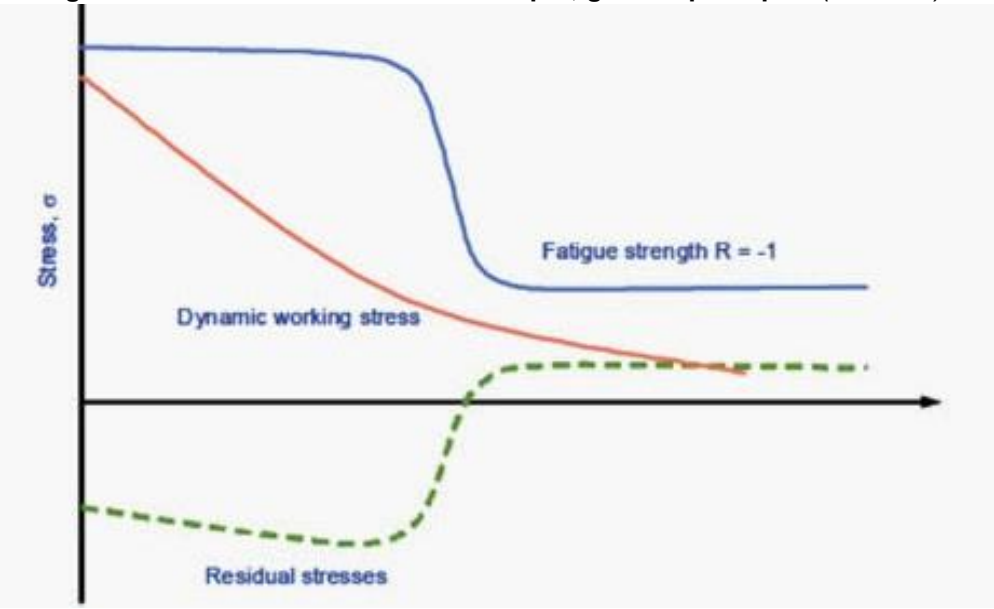
Consideration of the local fatigue strength shall include the influence of the local hardness, residual stress and mean working stress. The influence of the 'giga-cycle effect', especially for initiation of subsurface cracks, should be covered by the choice of safety margin.

It is of vital importance that the extension of hardening/peening in an area with concentrated stresses be duly considered. Any transition where the hardening/peening is ended is likely to have considerable tensile residual stresses.

This forms a 'weak spot' and is important if it coincides with an area of high stresses.

Alternating and mean working stresses must be known for the entire area of the stress concentration as well as to a depth of about 1.2 times the depth of the treatment. The following figure indicates this principle in the case of induction hardening. The base axis is either the depth (perpendicular to the surface) or along the fillet contour.

Figure 16 : Stresses as functions of depth, general principles *(1/7/2018)*



The acceptability criterion should be applied stepwise from the surface to the core as well as from the point of maximum stress concentration along the fillet surface contour to the web.

11.3.2 Evaluation of local fillet stresses *(1/7/2018)*

It is necessary to have knowledge of the stresses along the fillet contour as well as in the subsurface to a depth somewhat beyond the hardened layer. Normally this will be found via FEA as described in [9]. However, the element size in the subsurface range will have to be the same size as at the surface. For crankpin hardening only the small element size will have to be continued along the surface to the hard layer.

If no FEA is available, a simplified approach may be used. This can be based on the empirically determined stress concentration factors (SCFs), as in [3] if within its validity range, and a relative stress gradient inversely proportional to the fillet radius.

Bending and torsional stresses must be addressed separately. The combination of these is addressed by the acceptability criterion.

The subsurface transition-zone stresses, with the minimum hardening depth, can be determined by means of local stress concentration factors along an axis perpendicular to the fillet surface. These functions $\alpha_{B\text{-local}}$ and $\alpha_{T\text{-local}}$ have different shapes due to the different stress gradients.

The SCFs α_B and α_T are valid at the surface. The local $\alpha_{B\text{-local}}$ and $\alpha_{T\text{-local}}$ drop with increasing depth. The relative stress gradients at the surface depend on the kind of stress raiser, but for crankpin fillets they can be simplified to $2/R_H$ in bending and $1/R_H$ in torsion. The journal fillets are handled analogously by using R_G and D_G. The nominal stresses are assumed to be linear from the surface to a midpoint in the web between the crankpin fillet and the journal fillet for bending and to the crankpin or journal centre for torsion.

The local SCFs are then functions of depth t according to Equation 3.1 as shown in Figure 17 for bending and respectively for torsion in Equation 3.2 and Figure 18.

$$\alpha_{B-local} = (\alpha_B - 1) \cdot e^{\frac{-2 \cdot t}{R_H}} + 1 - \left(\frac{2 \cdot t}{\sqrt{W^2 + S^2}} \right)^{\frac{0,6}{\alpha_B}} \qquad (3.1)$$

$$\alpha_{T-local} = (\alpha_T - 1) \cdot e^{\frac{-t}{R_H}} + 1 - \left(\frac{2 \cdot t}{D} \right)^{\frac{1}{\sqrt{\alpha_T}}} \qquad (3.2)$$

Figure 17 : Bending SCF in the crankpin fillet as a function of depth. The corresponding SCF for the journal fillet can be found by replacing R_H with R_G *(1/7/2018)*

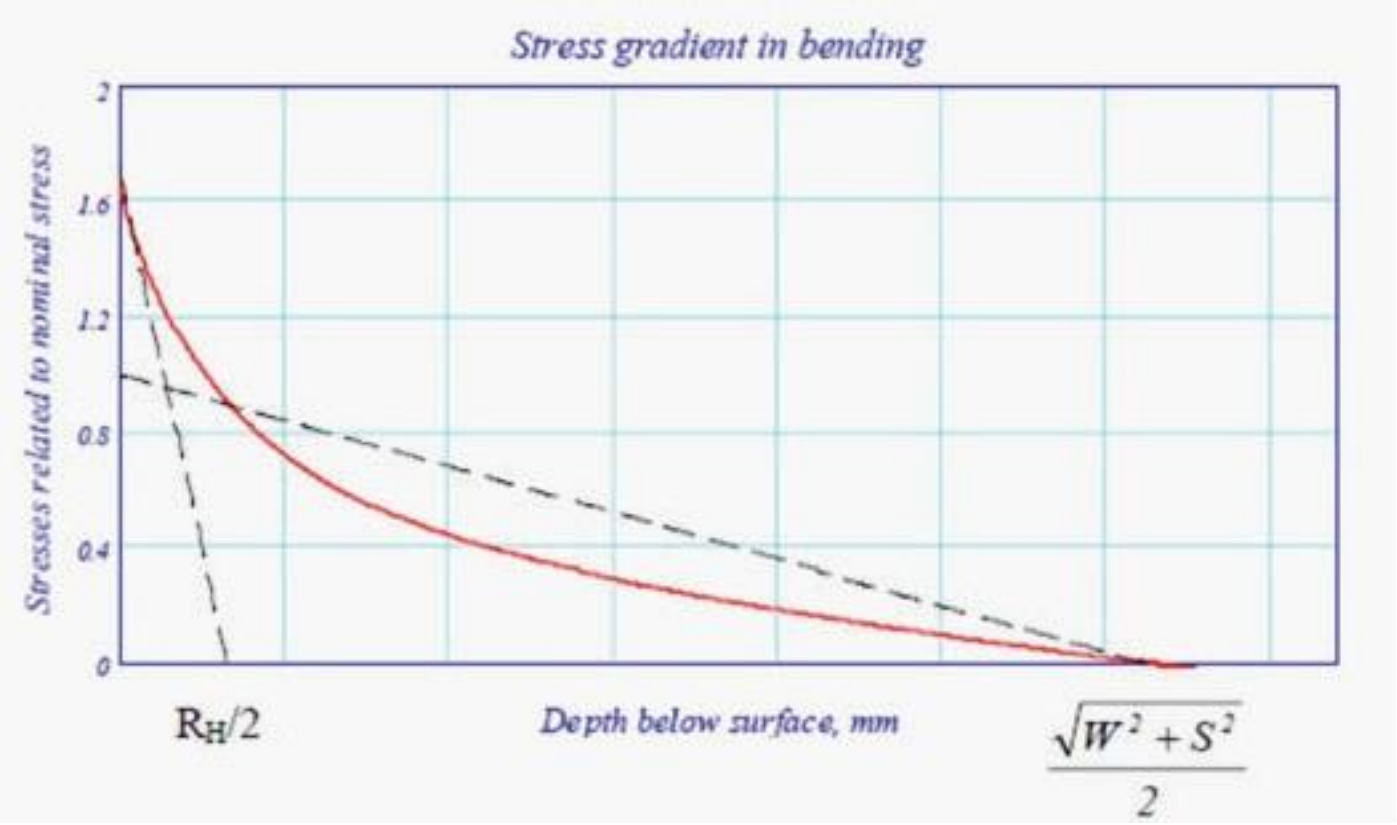


Figure 18 : Torsional SCF in the crankpin fillet as a function of depth. The corresponding SCF for the journal fillet can be found by replacing R_H with R_G and D with D_G *(1/7/2018)*

If the pin is hardened only and the end of the hardened zone is closer to the fillet than three times the maximum hardness depth, FEA should be used to determine the actual stresses in the transition zone.

11.3.3 Evaluation of oil bore stresses *(1/7/2018)*

Stresses in the oil bores can be determined also by FEA. The element size should be less than 1/8 of the oil bore diameter D_o and the element mesh quality criteria should be followed as prescribed in [9]. The fine element mesh should continue well beyond a radial depth corresponding to the hardening depth.

The loads to be applied in the FEA are the torque - see [9.3.2] - and the bending moment, with four-point bending as in [9.3.3].

If no FEA is available, a simplified approach may be used. This can be based on the empirically determined SCF from [3] if within its applicability range. Bending and torsional stresses at the point of peak stresses are combined as in [5].

Figure 19 : Stresses and hardness in induction hardened oil holes *(1/7/2018)*

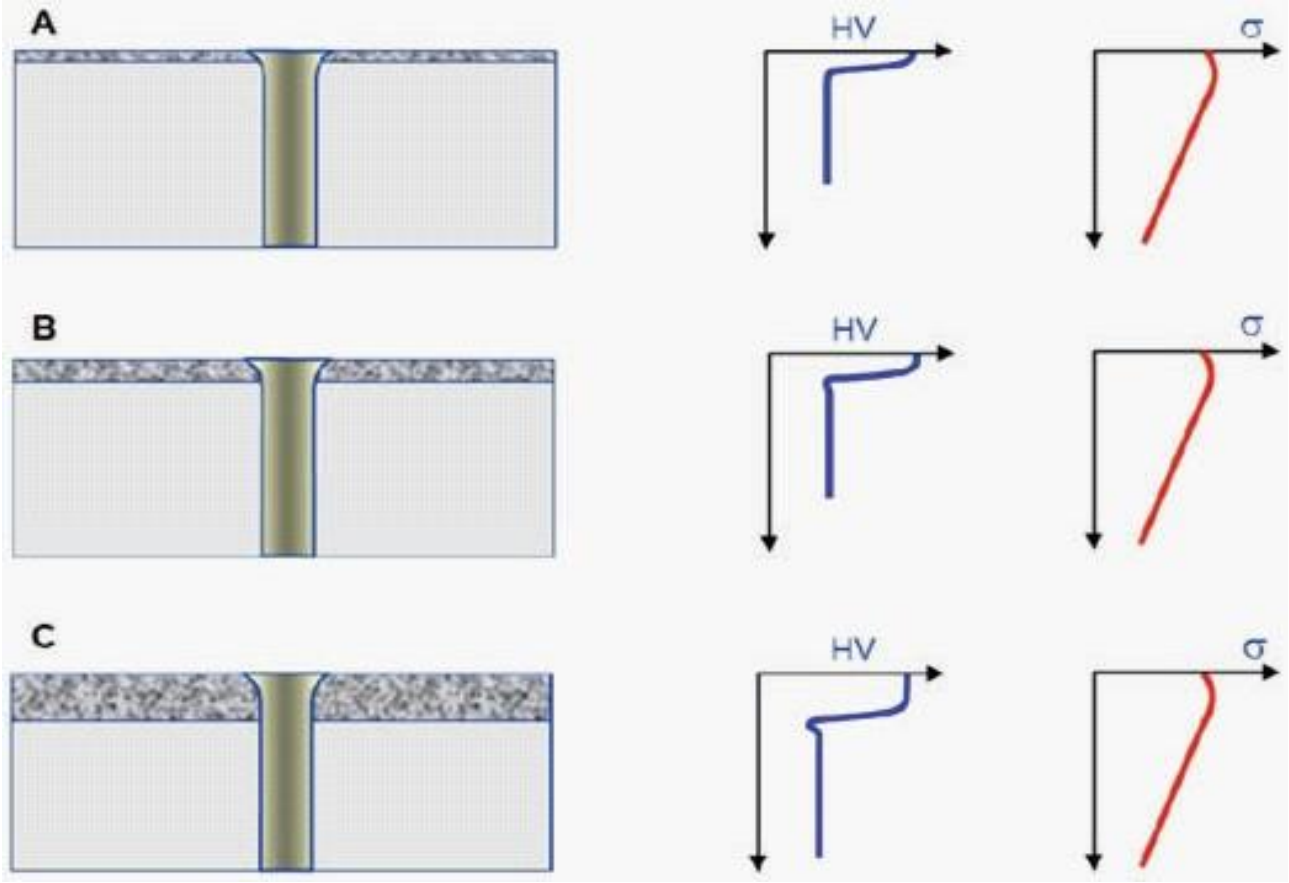


Figure 19 indicates a local drop of the hardness in the transition zone between a hard and soft material. Whether this drop occurs depends also on the tempering temperature after quenching in the QT process.

The peak stress in the bore occurs at the end of the edge rounding. Within this zone the stress drops almost linearly to the centre of the pin. As can be seen from Figure 19, for shallow (A) and intermediate (B) hardening, the transition point practically coincides with the point of maximal stresses. For deep hardening the transition point comes outside of the point of peak stress and the local stress can be assessed as a portion ($1-2t_H/D$) of the peak stresses where t_H is the hardening depth.

The subsurface transition-zone stresses (using the minimum hardening depth) can be determined by means of local stress concentration factors along an axis perpendicular to the oil bore surface. These functions $\gamma_{B\text{-local}}$ and $\gamma_{T\text{-local}}$ have different shapes, because of the different stress gradients.

The stress concentration factors γ_B and γ_T are valid at the surface. The local SCFs $\gamma_{B\text{-local}}$ and $\gamma_{T\text{-local}}$ drop with increasing depth. The relative stress gradients at the surface depend on the kind of stress raiser, but for crankpin oil bores they can be simplified to $4/D_o$ in bending and $2/D_o$ in torsion. The local SCFs are then functions of the depth t:

$$\gamma_{B-local} = (\gamma_B - 1) \cdot e^{\frac{-4 \cdot t}{D_0}} + 1 \qquad (3.3)$$

$$\gamma_{T-local} = (\gamma_T - 1) \cdot e^{\frac{-2 \cdot t}{D_0}} + 1 \qquad (3.4)$$

11.3.4 Acceptability criteria *(1/7/2018)*

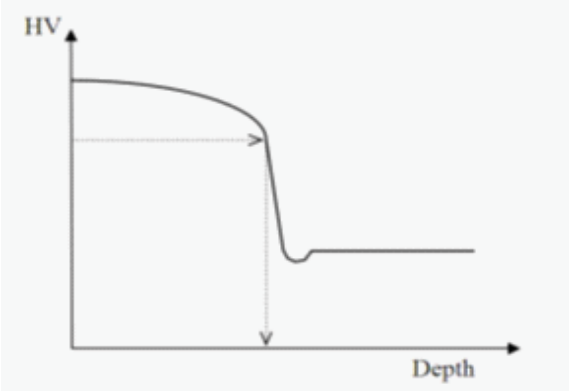
Acceptance of crankshafts is based on fatigue considerations; this App 1 compares the equivalent alternating stress and the fatigue strength ratio to an acceptability factor of $Q \geq 1.15$ for oil bore outlets, crankpin fillets and journal fillets. This shall be extended to cover also surface treated areas independent of whether surface or transition zone is examined.

11.4 Induction hardening

11.4.1 *(1/7/2018)*

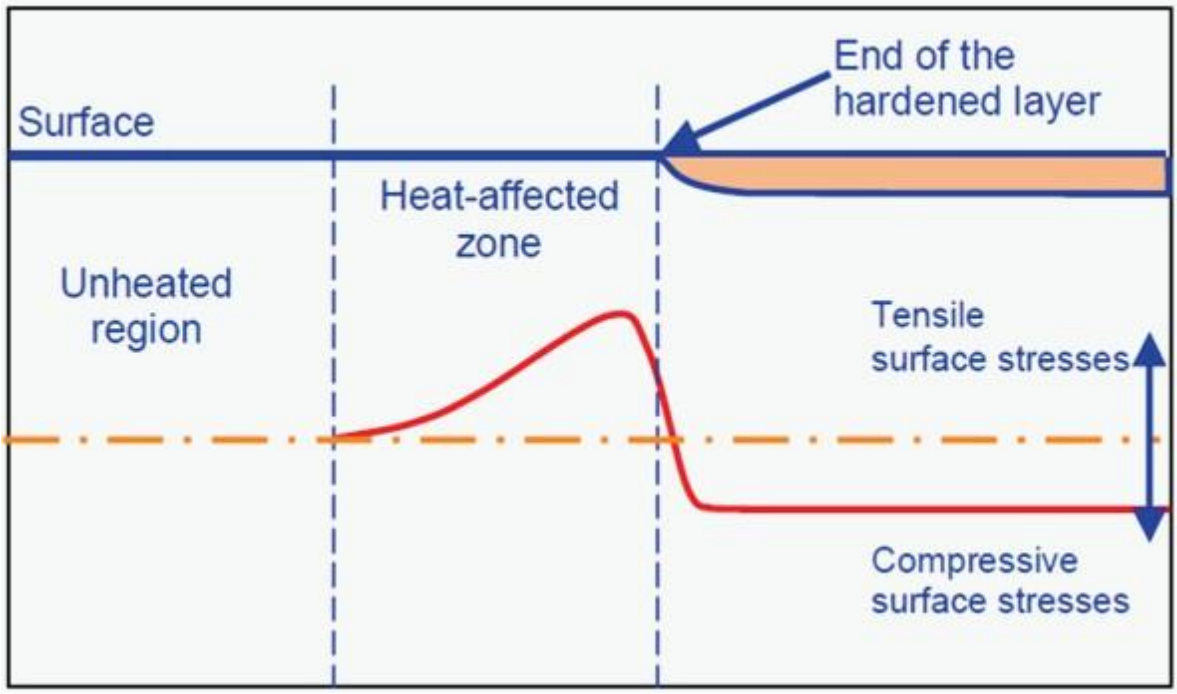
Generally, the hardness specification shall specify the surface hardness range i.e. minimum and maximum values, the minimum and maximum extension in or through the fillet and also the minimum and maximum depth along the fillet contour. The referenced Vickers hardness is considered to be HV0.5...HV5.

Figure 20 : Typical hardness as a function of depth. The arrows indicate the defined hardening depth. Note the indicated potential hardness drop at the transition to the core. This can be a weak point as local strength may be reduced and tensile residual stresses may occur *(1/7/2018)*



In the case of crankpin or journal hardening only, the minimum distance to the fillet shall be specified due to the tensile stress at the heat-affected zone as shown in Figure 21.

Figure 21 : Residual stresses along the surface of a pin and fillet *(1/7/2018)*



If the hardness-versus-depth profile and residual stresses are not known or specified, one may assume the following:

a) The hardness profile consists of two layers (see figure 20):
   - Constant hardness from the surface to the transition zone
   - Constant hardness from the transition zone to the core material

b) Residual stresses in the hard zone of 200 MPa (compression)

c) Transition-zone hardness as 90% of the core hardness unless the local hardness drop is avoided

d) Transition-zone maximum residual stresses (von Mises) of 300 MPa tension.

If the crankpin or journal hardening ends close to the fillet, the influence of tensile residual stresses has to be considered. If the minimum distance between the end of the hardening and the beginning of the fillet is more than 3 times the maximum hardening depth, the influence may be disregarded.

11.4.2 Local fatigue strength *(1/7/2018)*

Induction-hardened crankshafts will suffer fatigue either at the surface or at the transition to the core. The fatigue strengths, for both the surface and the transition zone, can be determined by fatigue testing of full size cranks as described in [10]. In the case of a transition zone, the initiation of the fatigue can be either subsurface (i.e. below the hard layer) or at the surface where the hardening ends.

Tests made with the core material only will not be representative since the tensile residual stresses at the transition are lacking.

Alternatively, the surface fatigue strength can be determined empirically as follows where HV is the surface Vickers hardness. The Equation 4.1 provides a conservative value, with which the fatigue strength is assumed to include the influence of the residual stress. The resulting value is valid for a working stress ratio of R = -1:

$$\sigma_{Fsurface} = 400 + 0,5 \cdot (HV - 400) \quad [MPA] \quad (4.1)$$

It has to be noted also that the mean stress influence of induction-hardened steels may be significantly higher than that for QT steels.

The fatigue strength in the transition zone, without taking into account any possible local hardness drop, shall be determined by the equation introduced in [6].

For journal and respectively to crankpin fillet applies:

$$\sigma_{Ftransition,\ cpin} = \pm K \cdot (0,42 \cdot \sigma_B + 39,3) \cdot \left[0,264 + 1,073 \cdot Y^{-0,2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{X}}\right] \quad (4.2)$$

where:

Y = D_G and X = R_G ------ > for journal fillet

Y = D and X = R_H-------> for crankpin fillet

Y = D and X = $D_0/2$------ > for oil bore outlet

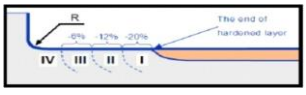
The influence of the residual stress is not included in 4.2.

For the purpose of considering subsurface fatigue, below the hard layer, the disadvantage of tensile residual stresses has to be considered by subtracting 20% from the value determined above. This 20% is based on the mean stress influence of alloyed quenched and tempered steel having a residual tensile stress of 300 MPa.

When the residual stresses are known to be lower, also smaller value of subtraction shall be used. For low-strength steels the percentage chosen should be higher.

For the purpose of considering surface fatigue near the end of the hardened zone - i.e. in the heat-affected zone shown in the Figure 21 - the influence of the tensile residual stresses can be considered by subtracting a certain percentage, in accordance with Table 11, from the value determined by the above formula.

Table 7 : The influence of tensile residual stresses at a given distance from the end of the hardening towards the fillet *(1/7/2018)*

I	0 to 1.0 of the max. hardening depth	20%	
II	1.0 to 2.0 of the max. hardening depth:	12%	
III	2.0 to 3.0 of the max. hardening depth:	6%	
IV	3.0 or more of the max. hardening depth:	0%	

11.5 Nitriding

11.5.1 *(1/7/2018)*

The hardness specification shall include the surface hardness range (min and max) and the minimum and maximum depth. Only gas nitriding is considered. The referenced Vickers hardness is considered to be HV0.5.

The depth of the hardening is defined in different ways in the various standards and the literature. The most practical method to use in this context is to define the nitriding depth t_N as the depth to a hardness of 50 HV above the core hardness.

The hardening profile should be specified all the way to the core. If this is not known, it may be determined empirically via the following formula:

$$HV(T) = HV_{core} + (HV_{surface} - HV_{core}) \cdot \left\{ \frac{t_N}{HV_{surface} - 50 - HV_{core}} \right\}^{\left(\frac{t}{\quad}\right)^2}$$

where:

t : The local depth

HV(t) : Hardness at depth t

HVcore : Core hardness (minimum)

HVsurface :Surface hardness (minimum)

tN : Nitriding depth as defined above (minimum)

11.5.2 Local fatigue strength *(1/7/2018)*

It is important to note that in nitrided crankshaft cases, fatigue is found either at the surface or at the transition to the core. This means that the fatigue strength can be determined by tests as described in [10].

Alternatively, the surface fatigue strength (principal stress) can be determined empirically and conservatively as follows. This is valid for a surface hardness of 600 HV or greater:

$$\sigma_{Fsurface} = 450MPA \qquad (5.2)$$

Note that this fatigue strength is assumed to include the influence of the surface residual stress and applies for a working stress ratio of R = -1.

The fatigue strength in the transition zone can be determined by the equation introduced in [6]. For crankpin and respectively to journal applies:

$$\sigma_{Ftransition,\,cpin} = \pm K \cdot (0,42 \cdot \sigma_B + 39,3) \cdot \left[0,264 + 1,073 \cdot Y^{-0,2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{X}} \right] \qquad (5.3)$$

where:

Y = D_G and X = R_G ------ > for journal fillet

Y = D and X = R_H-------> for crankpin fillet

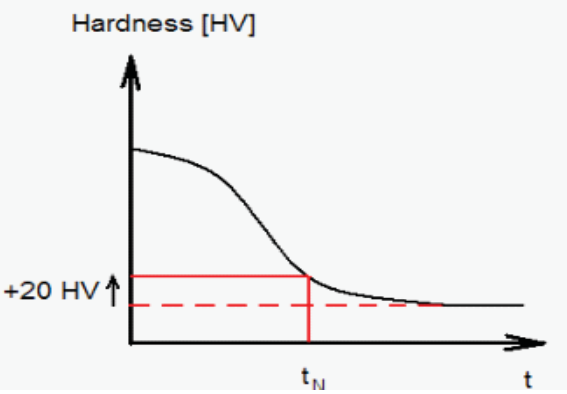
Y = D and X = D_0/2------ > for oil bore outlet

Note that this fatigue strength is not assumed to include the influence of the residual stresses.

In contrast to induction-hardening the nitrited components have no such distinct transition to the core. Although the compressive residual stresses at the surface are high, the balancing tensile stresses in the core are moderate because of the shallow depth. For the purpose of analysis of subsurface fatigue the disadvantage of tensile residual stresses in and below the transition zone may be even disregarded in view of this smooth contour of a nitriding hardness profile.

Although in principle the calculation should be carried out along the entire hardness profile, it can be limited to a simplified approach of examining the surface and an artificial transition point. This artificial transition point can be taken at the depth where the local hardness is approximately 20 HV above the core hardness. In such a case, the properties of the core material should be used. This means that the stresses at the transition to the core can be found by using the local SCF formulae mentioned earlier when inserting t=1.2tN.

Figure 22 : Sketch of the location for the artificial transition point in the depth direction *(1/7/2018)*



11.6 Cold forming

11.6.1 *(1/7/2018)*

The advantage of stroke peening or cold rolling of fillets is the compressive residual stresses introduced in the high-loaded area. Even though surface residual stresses can be determined by X-ray diffraction technique and subsurface residual stresses can be determined through neutron diffraction, the local fatigue strength is virtually non-assessable on that basis since suitable and reliable correlation formulae are hardly known.

Therefore, the fatigue strength has to be determined by fatigue testing; see also [10]. Such testing is normally carried out as four-point bending, with a working stress ratio of R = -1. From these results, the bending fatigue strength - surface- or subsurface-initiated depending on the manner of failure - can be determined and expressed as the representative fatigue strength for applied bending in the fillet.

In comparison to bending, the torsion fatigue strength in the fillet may differ considerably from the ratio √3 (utilized by the von Mises criterion). The forming-affected depth that is sufficient to prevent subsurface fatigue in bending, may still allow subsurface fatigue in torsion. Another possible reason for the difference in bending and torsion could be the extension of the highly stressed area.

The results obtained in a full-size crank test can be applied for another crank size provided that the base material (alloyed Q+T) is of the similar type and that the forming is done so as to obtain the similar level of compressive residual stresses at the surface as well as through the depth. This means that both the extension and the depth of the cold forming must be proportional to the fillet radius.

11.6.2 **Stroke peening by means of a ball** *(1/7/2018)*

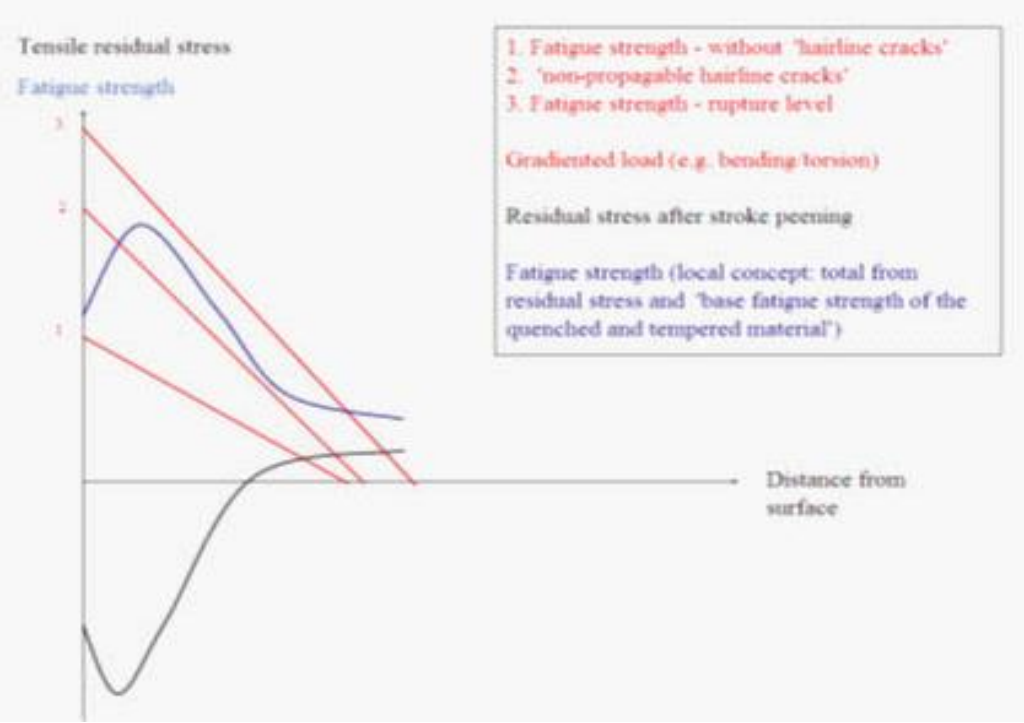
The fatigue strength obtained can be documented by means of full size crank tests or by empirical methods if applied on the safe side. If both bending and torsion fatigue strengths have been investigated and differ from the ratio √3, the von Mises criterion should be excluded.

If only bending fatigue strength has been investigated, the torsional fatigue strength should be assessed conservatively. If the bending fatigue strength is concluded to be x% above the fatigue strength of the non-peened material, the torsional fatigue strength should not be assumed to be more than 2/3 of x% above that of the non-peened material.

As a result of the stroke peening process the maximum of the compressive residual stress is found in the subsurface area. Therefore, depending on the fatigue testing load and the stress gradient, it is possible to have higher working stresses at the surface in comparison to the local fatigue strength of the surface. Because of this phenomenon small cracks may appear during the fatigue testing, which will not be able to propagate in further load cycles and/or with further slight increases of the testing load because of the profile of the compressive residual stress. Put simply, the high compressive residual stresses below the surface 'arrest' small surface cracks.

This is illustrated in Figure 23 as gradient load 2.

Figure 23 : Working and residual stresses below the stroke-peened surface. Straight lines 1…3 represent different possible load stress gradients *(1/7/2018)*



In fatigue testing with full-size crankshafts these small "hairline cracks" should not be considered to be the failure crack. The crack that is technically the fatigue crack leading to failure, and that therefore shuts off the test-bench, should be considered for determination of the failure load level. This also applies if induction-hardened fillets are stroke-peened.

In order to improve the fatigue strength of induction-hardened fillets it is possible to apply the stroke peening process in the crankshafts' fillets after they have been induction-hardened and tempered to the required surface hardness. If this is done, it might be necessary to adapt the stroke peening force to the hardness of the surface layer and not to the tensile strength of the base material. The effect on the fatigue strength of induction hardening and stroke peening the fillets shall be determined by a full-size crankshaft test.

The increase in fatigue strength, which is achieved by applying stroke peening, may be utilized in another similar crankshaft if all of the following criteria are fulfilled:

- Ball size relative to fillet radius within ±10% in comparison to the tested crankshaft
- At least the same circumferential extension of the stroke peening
- Angular extension of the fillet contour relative to fillet radius within ±15% in comparison to the tested crankshaft and located to cover the stress concentration during engine operation
- Similar base material, e.g. alloyed quenched and tempered
- Forward feed of ball of the same proportion of the radius
- Force applied to ball proportional to base material hardness (if different)
- Force applied to ball proportional to square of ball radius.

11.6.3 Cold rolling *(1/7/2018)*

The fatigue strength can be obtained by means of full size crank tests or by empirical methods, if these are applied so as to be on the safe side. If both, bending and torsion fatigue strengths have been investigated, and differ from the ratio √3, the von Mises criterion should be excluded.

If only bending fatigue strength has been investigated, the torsional fatigue strength should be assessed conservatively. If the bending fatigue strength is concluded to be x% above the fatigue strength of the non-rolled material, the torsional fatigue strength should not be assumed to be more than 2/3 of x% above that of the non-rolled material.

The increase in fatigue strength, which is achieved applying cold rolling, may be utilized in another similar crankshaft if all of the following criteria are fulfilled:

- At least the same circumferential extension of cold rolling

- Angular extension of the fillet contour relative to fillet radius within ±15% in comparison to the tested crankshaft and located to cover the stress concentration during engine operation
- Similar base material, e.g. alloyed quenched and tempered
- Roller force to be calculated so as to achieve at least the same relative (to fillet radius) depth of treatment.

12 Guidance for Calculation of Stress Concentration Factors in the Oil Bore Outlets of crankshafts through utilisation of the Finite Element Method

12.1 General

12.1.1 *(1/7/2018)*

The objective of the analysis described in this document is to substitute the analytical calculation of the stress concentration factor (SCF) at the oil bore outlet with suitable finite element method (FEM) calculated figures. The former method is based on empirical formulae developed from strain gauge readings or photo-elasticity measurements of various round bars. Because use of these formulae beyond any of the validity ranges can lead to erroneous results in either direction, the FEM-based method is highly recommended.

The SCF calculated according to the rules set forth in this document is defined as the ratio of FEM-calculated stresses to nominal stresses calculated analytically. In use in connection with the present method in this App 1, principal stresses shall be calculated.

The analysis is to be conducted as linear elastic FE analysis, and unit loads of appropriate magnitude are to be applied for all load cases.

It is advisable to check the element accuracy of the FE solver in use, e.g. by modelling a simple geometry and comparing the FEM-obtained stresses with the analytical solution.

A boundary element method (BEM) approach may be used instead of FEM.

12.2 Model requirements

12.2.1 *(1/7/2018)*

The basic recommendations and assumptions for building of the FE-model are presented in [12.2.1]. The final FE-model must meet one of the criteria in [12.2.4].

12.2.2 Element mesh recommendations *(1/7/2018)*

For the mesh quality criteria to be met, construction of the FE model for the evaluation of stress concentration factors according to the following recommendations is advised:

a) The model consists of one complete crank, from the main bearing centre line to the opposite side's main bearing centre line.

b) The following element types are used in the vicinity of the outlets:
   - 10-node tetrahedral elements
   - 8-node hexahedral elements
   - 20-node hexahedral elements

c) The following mesh properties for the oil bore outlet are used:
   - Maximum element size a = r / 4 through the entire outlet fillet as well as in the bore direction (if 8-node hexahedral elements are used, even smaller elements are required for meeting of the quality criterion)
   - Recommended manner for element size in the fillet depth direction
   - First layer's thickness equal to element size of a
   - Second layer's thickness equal to element size of 2a
   - Third -layer thickness equal to element size of 3a

d) In general, the rest of the crank should be suitable for numeric stability of the solver

e) Drillings and holes for weight reduction have to be modelled

Submodeling may be used as long as the software requirements are fulfilled.

12.2.3 Material *(1/7/2018)*

This App 1 does not consider material properties such as Young's modulus (E) and Poisson's ratio ( ). In the FE analysis, these material parameters are required, as primarily strain is calculated and stress is derived from strain

through the use of Young's modulus and Poisson's ratio. Reliable values for material parameters have to be used, either as quoted in the literature or measured from representative material samples.

For steel the following is advised:

$E = 2.05 \cdot 10^5$ MPa and $\upsilon = 0.3$.

12.2.4 Element mesh quality criteria *(1/7/2018)*

a) If the actual element mesh does not fulfil any of the following criteria in the area examined for SCF evaluation, a second calculation, with a finer mesh is to be performed;

b) Principal -stresses criterion

The quality of the mesh should be assured through checking of the stress component normal to the surface of the oil bore outlet radius. With principal stresses σ_1, σ_2 and σ_3 the following criterion must be met:

$$\min(|\sigma_1|, |\sigma_2|, |\sigma_3|) < 0,03 \cdot \max(|\sigma_1|, |\sigma_2|, |\sigma_3|)$$

c) Averaged/unaveraged -stresses criterion

The averaged/unaveraged -stresses criterion is based on observation of the discontinuity of stress results over elements at the fillet for the calculation of the SCF:

- Unaveraged nodal stress results calculated from each element connected to a node i should differ less than 5 % from the 100 % averaged nodal stress results at this node i at the location examined.

12.3 Load cases and assessment of stress

12.3.1 *(1/7/2018)*

For substitution of the analytically determined SCF in App 1, calculation shall be performed for the following load cases.

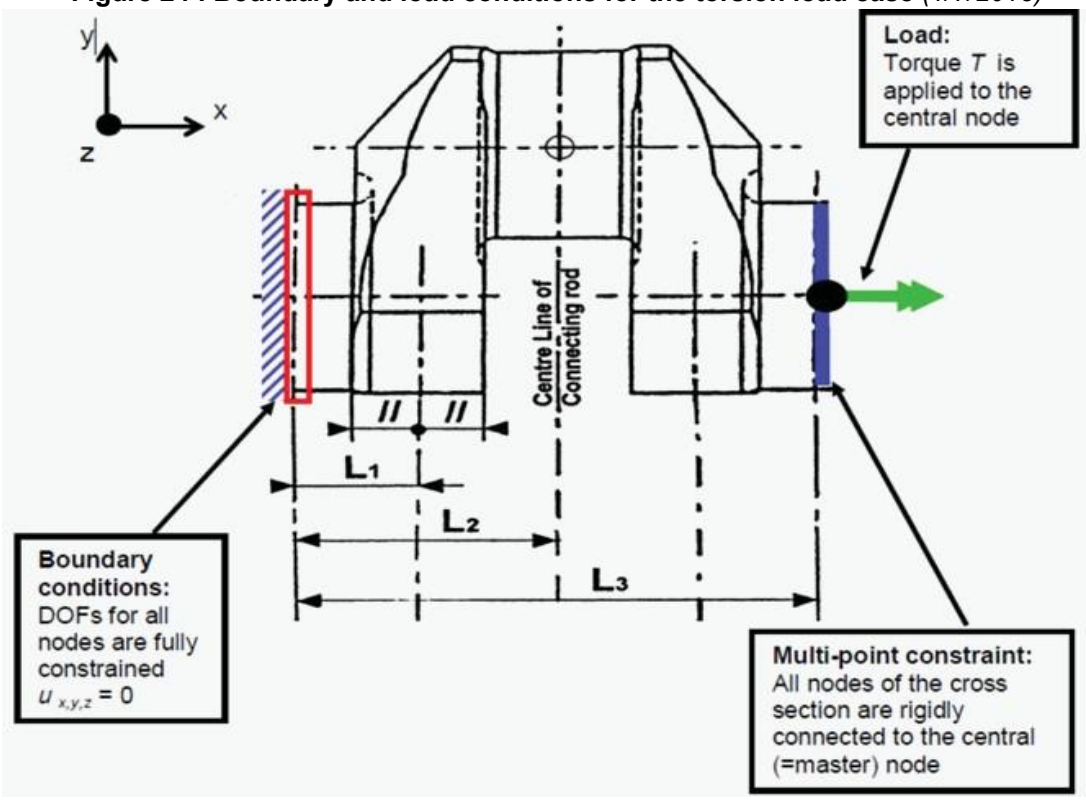
12.3.2 Torsion *(1/7/2018)*

The structure is loaded in pure torsion. The surface warp at the end faces of the model is suppressed.

Torque is applied to the central node, on the crankshaft axis. This node acts as the master node with six degrees of freedom, and is connected rigidly to all nodes of the end face.

The boundary and load conditions are valid for both in-line- and V- type engines.

Figure 24 : Boundary and load conditions for the torsion load case *(1/7/2018)*



For all nodes in an oil bore outlet, the principal stresses are obtained and the maximum value is taken for subsequent calculation of the SCF:

$$\gamma_T = \frac{\max(|\sigma_1|, |\sigma_2|, |\sigma_3|)}{\tau_N}$$

where the nominal torsion stress N referred to the crankpin is evaluated per [2.2.2] with torque M_{TN}:

$$\tau_N = \pm \frac{M_{TN}}{W_P} \cdot 10^3$$

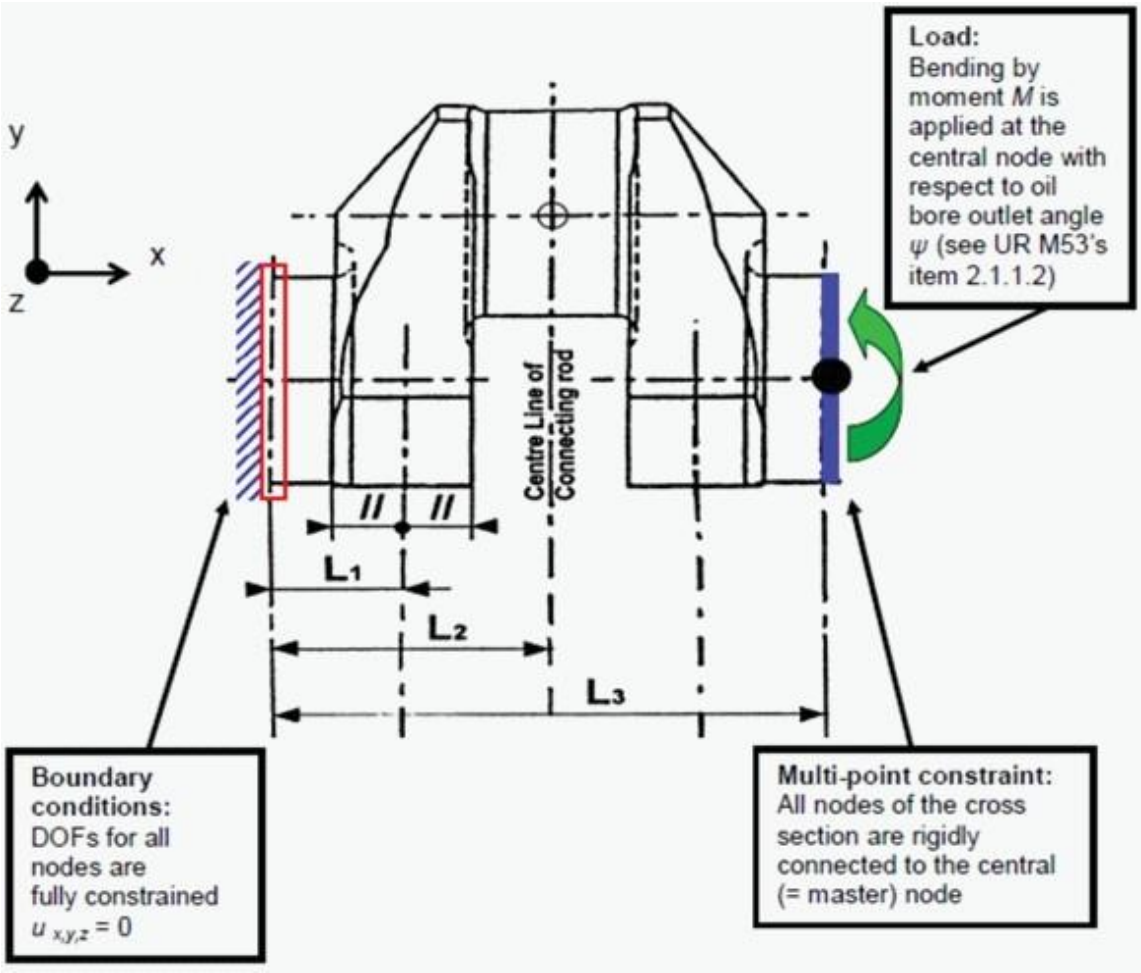
12.3.3 Bending *(1/7/2018)*

The structure is loaded in pure bending. The surface warp at the end faces of the model is suppressed.

The bending moment is applied to the central node on the crankshaft axis. This node acts as the master node, with six degrees of freedom, and is connected rigidly to all nodes of the end face.

The boundary and load conditions are valid for both in-line- and V- type engines.

Figure 25 : Boundary and load conditions for the pure bending load case *(1/7/2018)*



For all nodes in the oil bore outlet, principal stresses are obtained and the maximum value is taken for subsequent calculation of the SCF:

$$\gamma_B = \frac{\max(|\sigma_1|, |\sigma_2|, |\sigma_3|)}{\sigma_{BON}}$$

where the nominal bending stress σ_N referred to the crankpin is calculated per [2.1.2] c) with bending moment M:

$$\sigma_{BON} = \pm \frac{M_{BON}}{W_e}$$

APPENDIX 2 DUAL FUEL DIESEL ENGINES

1 General

1.1 Application

1.1.1 *(1/1/2020)*

This appendix applies to dual fuel diesel engines (hereafter referred to as DF engines), which may utilise oil fuel and high pressure methane gas fuel injection (i.e. engines fitted on gas carriers and employing boil-off gas as fuel).

As far as applicable, the requirements contained in Sec 2 and Sec 10 and in Pt E, Ch 9, Sec 16, are to be applied.

1.2 Documentation to be submitted

1.2.1 In addition to the documentation required in Sec 2, [1.4] the following is to be submitted:

- a failure mode and effect analysis (FMEA) examining all possible faults affecting the combustion process is to be submitted (see [2.5.1])
- drawings and specifications concerning the gas feed to the DF engine.

1.3 Operation mode

1.3.1 DF engines are to employ pilot oil fuel injection for gas ignition and are to be capable of immediate change-over to oil fuel only.

1.3.2 *(1/1/2020)*

Only oil fuel is, in principle, to be used when the operation of a DF engine is unstable.

1.3.3 In the event of shut-off of the gas fuel supply, the DF engines are to be capable of uninterrupted operation by oil fuel only.

2 Design, control and monitoring

2.1 Protection of crankcase

2.1.1 Crankcase relief valves are to be fitted in way of each crankthrow. The construction and operating pressure of the relief valves are to be determined considering explosions due to gas leaks.

2.2 DF engine air inlet and exhaust system

2.2.1 *(1/1/2020)*

Explosion relief valves or other appropriate protection system against explosion are to be provided in the exhaust, scavenge and air inlet manifolds unless justified by the safety concept of the engine.

2.2.2 The exhaust gas pipes from DF engines are not to be connected to the exhaust pipes of other engines or systems.

2.3 Starting air line

2.3.1 Starting air branch pipes to each cylinder are to be provided with effective flame arresters.

Table 1 : Guidance for combustion monitoring

Faulty condition	Alarm **(1)**	Aut. shut-off of the gas valves **(1) (2)**
Oil fuel pilot valve and gas valve control system failure	X	X
Exhaust gas temperature at each cylinder outlet	H	
Exhaust gas temperature deviation from average	H (positive or negative value)	H (negative value)
Cylinder pressure or ignition failure of each cylinder	X	X
(1) X = required monitoring; L = low value; H = high value. **(2)** It is recommended that the gas master valve is also closed.		

2.4 Gas fuel supply to the DF engine

2.4.1 The gas supply line is to be enclosed in protection pipes or ducts, as required in Pt E, Ch 9, Sec 16.

The protection pipes or ducts are to provide complete coverage of the gas line to the fuel injection valves.

2.5 Combustion monitoring

2.5.1 Details of required monitoring will be determined based on the outcome of the failure mode and effect analysis requested in [1.2.1]. However, Tab 1 may be used as guidance.

2.6 Emergency stop

2.6.1 The gas supply is to be stopped before the gas concentration detected by the gas detectors fitted in the machinery space as required in 16.2.2 of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code) reaches 60% of the lower flammable limit.

APPENDIX 3 PLASTIC PIPES

1 General

1.1 Application

1.1.1 *(1/7/2022)*
These requirements are applicable to all piping systems with parts made predominantly of other material than metal and addresses the provisions of IMO Resolution A.753(18), as amended by IMO Resolutions MSC.313(88) and MSC.399(95).

1.1.2 *(1/7/2023)*
The use of mechanical joints approved for the use in metallic piping systems only are not permitted.

1.1.3 *(1/1/2020)*
Piping systems intended for non-essential services are to meet only the requirements of recognised standards as well as [2.1.2], [2.3.4], [2.4.2], [3] and [4].

1.2 Use of plastic pipes

1.2.1 Plastic may be used in piping systems in accordance with the provisions of Sec 10, [2.1.3], 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 *(1/1/2020)*
Plastic includes both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and FRP (reinforced plastics pipes). Plastic includes synthetic rubber and materials of similar thermo/mechanical properties.

1.3.2 Piping systems *(1/1/2007)*
Piping systems means those made of plastic and 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 *(1/7/2023)*
Joints means the location at which two pieces of pipe or a pipe and a fitting are connected together. The joint may be made by adhesive bonding, laminating, welding, flanges and mechanical joints according to Sec 10, Fig 2.

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 [2.2.2]

1.3.6 Design pressure
Design pressure is the maximum working pressure which is expected under operation conditions or the highest set pressure of any safety valve or pressure relief device on the system, if fitted.

1.3.7 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.

***1.3.8* Essential to the safety of ship** *(1/7/2023)*
Essential to the safety of ship means all piping systems that in event of failure will pose a threat to personnel and the ship.

Note 1: Examples for piping systems essential to the safety are provided by Tab 1.

1.3.9 Essential services *(1/7/2023)*

Essential services are those services essential for propulsion and steering and safety of the ship as specified in Ch 2, Sec 1, [3].

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 Sec 10, [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 maximum permissible working pressure is to be specified with due regard for the maximum possible working temperature in accordance with manufacturer's recommendations.

2.2.2 Permissible pressure *(1/7/2023)*

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 pipe failure pressure, in MPa

P_{lth} : Long-term hydrostatic test pipe 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, and for any pipe installation required to remain operational in case of flooding damage, as per SOLAS II-1/8-1 or for any pipes that would allow progressive flooding to other compartments through damaged piping or through open ended pipes in the compartments)

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.

The pipe collapse pressure is not to be less than 0,3 MPa.

c) Notwithstanding the requirements of a) or b) as applicable, the pipe or pipe layer minimum wall thickness is to follow recognized standards. In the absence of standards for pipes not subject to external pressure, the requirements of b) are to be met.

2.2.3 Permissible temperature *(1/7/2022)*

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 in accordance with manufacturer's recommendations.

c) The maximum permissible working temperature is to be at least 20°C lower than the minimum heat distortion/deflection temperature of the pipe material, determined according to ISO 75-2:2013 method A or equivalent e.g. ASTMD648-18.

d) The minimum heat distortion/deflection temperature is not to be less than 80°C.

2.2.4 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 [2.2.2]).

2.2.5 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 *(1/7/2023)*

The requirements for fire endurance of plastic pipes and their associated joints and 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 Resolution A.753(18) as amended by IMO Resolutions MSC. 313(88) and MSC. 399(95), where indicated “L1” in Tab 1
- Level 1W - Piping systems similar to Level 1 systems except these systems do not carry flammable fluid or any gas and a maximum 5% flow loss in the system after exposure is acceptable (L1W)
- a 30 min fire endurance test in dry conditions is to be carried out according to Appendix 1 of IMO Resolution A.753(18) as amended by IMO Resolutions MSC. 313(88) and MSC. 399(95), where indicated “L2” in Tab 1
- Level 2W - Piping systems similar to Level 2 systems except a maximum 5% flow loss in the system after exposure is acceptable (L2W)
- a 30 min fire endurance test in wet conditions is to be carried out according to Appendix 2 of IMO Resolution A.753(18) as amended by IMO Resolutions MSC.313(88) and MSC.399(95), 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
- for Safe Return to Port purposes (SOLAS II-2/21.4), plastic piping can be considered to remain operational after a fire casualty if the plastic pipes and fittings have been tested to L1 standard.

Note 1: “NA” means “not applicable”.

Unless instructed otherwise by the Flag Administration, fire endurance tests are to be carried out with specimen representative for pipes, joints and fittings:

Note 2: A test specimen incorporating several components of a piping system may be tested in a single test.

a) Pipes:

- for sizes with outer diameter < 200 mm the minimum outer diameter and wall thickness

Note 3: Test conditions are most demanding for minimum wall thickness and thus larger wall thickness is covered. A key factor determining the fire performance of a pipe component variant is the thickness-to-diameter (t/D) ratio and whether it is larger or smaller than that of the variant which has been fire-tested. If fire-protective coatings or layers are included in the variant used in the fire test, only variants with the same or greater thickness of protection, regardless of the (t/D) ratio, are to be qualified by the fire test.

- for sizes with outer diameter ≥ 200 mm one test specimen for each category of t/d (D = outer diameter, t = structural wall thickness). A scattering of ± 10% for t/D is regarded as the same group. Minimum size approved is equal to the diameter of specimen successfully tested.

b) Joints:

- each type of joint applicable for applied fire endurance level tested on pipe to pipe specimen.

Means are to be provided to ensure a constant media pressure inside the test specimen during the fire test as specified in Appendix 1 or 2 of the IMO Res.A.753(18), as amended by IMO Resolutions MSC.313(88) and MSC.399(95). During the test it is not permitted to replace media drained by fresh water or nitrogen.

2.3.2 Flame spread *(1/7/2022)*

a) All pipes, except those fitted on open decks and within tanks, cofferdams, pipe tunnels and ducts if separated from accommodation, permanent manned areas and escape ways by means of an A class bulkhead are to have low spread characteristics not exceeding average values listed in Appendix 3 of IMO Resolution 753(18), as amended by IMO Resolutions MSC. 313(88) and MSC. 399(95).

b) Surface flame characteristics are to be determined using the procedure given in the 2010 FTP Code, Annex 1, Part 5 with regard to the modifications due to the curvilinear pipe surfaces as also listed in Appendix 3 of Resolution A.753(18) as amended by IMO Resolutions MSC. 313(88) and MSC. 399(95).

c) Surface flame spread characteristics may also be deter-mined using the test procedures given in ASTM D635-18, or other national equivalent standards. Under the procedure of ASTM D635-18 a maximum burning rate of 60 mm/min applies. In case of adoption of other national equivalent standards, the relevant acceptance criteria are to be defined.

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 *(1/1/2007)*

a) Piping systems conveying fluids with a conductivity less than 1000 pS/m (1pS/m=10^{-12} siemens per meter), 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) It is preferred that pipes and fittings be homogeneously conductive. 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.

e) Satisfactory earthing is to be provided.

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 *(1/7/2023)*

PIPING SYSTEM	LOCATION **(24)**										
	Machinery spaces of category A **(11)**	Other machinery spaces and pump rooms **(12)**	Cargo pump rooms **(13)**	Ro/ro cargo holds **(14)**	Other dry cargo holds **(15)**	Cargo tanks **(16)**	Fuel oil tanks **(17)**	Ballast water tanks **(18)**	Cofferdams, void spaces, pipe tunnels and ducts **(19)**	Accommodation, service and control spaces **(20)**	Open decks **(21)**
CARGO (FLAMMABLE CARGOES WITH FLASH POINT ≤ 60°C)											
Cargo lines	NA	NA	L1	NA	NA	0	NA	0 **(10)**	0	NA	L1 **(2)**
Crude oil washing lines	NA	NA	L1	NA	NA	0	NA	0 **(10)**	0	NA	L1 **(2)**
Vent lines	NA	NA	NA	NA	NA	0	NA	0 **(10)**	0	NA	X
INERT GAS											
Water seal effluent line	NA	NA	0 **(1)**	NA	NA	0 **(1)**	0 **(1)**	0 **(1)**	0 **(1)**	NA	0
Scrubber effluent line	0 **(1)**	0 **(1)**	NA	NA	NA	NA	NA	0 **(1)**	0 **(1)**	NA	0
Main line	0	0	L1	NA	NA	NA	NA	NA	0	NA	L1 **(6)**
Distribution line	NA	NA	L1	NA	NA	0	NA	NA	0	NA	L1 **(2)**
FLAMMABLE LIQUIDS (FLASH POINT > 60°C)											
Cargo lines	X	X	L1	X	X	NA **(3)**	0	0 **(10)**	0	NA	L1
Fuel oil	X	X	L1	X	X	NA **(3)**	0	0	0	L1	L1
Lubricating oil	X	X	L1	X	X	NA	NA	NA	0	L1	L1
Hydraulic oil	X	X	L1	X	X	0	0	0	0	L1	L1
SEA WATER **(1)**											
Bilge main and branches	L1 **(7)**	L1 **(7)**	L1	X	X	NA	0	0	0	NA	L1
Fire main and water spray	L1	L1	L1	X	NA	NA	NA	0	0	X	L1
Foam system	L1W	L1W	L1W	NA	NA	NA	NA	NA	0	L1W	L1W
Sprinkler system	L1W	L1W	L3	X	NA	NA	NA	0	0	L3	L3
Ballast	L3	L3	L3	L3	X	0 **(10)**	0	0	0	L2W	L2W
Cooling water, essential services	L3	L3	NA	NA	NA	NA	NA	0	0	NA	L2W
Tank cleaning services, fixed machines	NA	NA	L3	NA	NA	0	NA	0	0	NA	L3 **(2)**
Non-essential systems	0	0	0	0	0	NA	0	0	0	0	0
FRESH WATER											
Cooling water, essential services	L3	L3	NA	NA	NA	NA	0	0	0	L3	L3
Condensate return	L3	L3	L3	0	0	NA	NA	NA	0	0	0
Non-essential systems	0	0	0	0	0	NA	0	0	0	0	0
SANITARY, DRAINS, SCUPPERS											

PIPING SYSTEM	LOCATION **(24)**										
	Machinery spaces of category A **(11)**	Other machinery spaces and pump rooms **(12)**	Cargo pump rooms **(13)**	Ro/ro cargo holds **(14)**	Other dry cargo holds **(15)**	Cargo tanks **(16)**	Fuel oil tanks **(17)**	Ballast water tanks **(18)**	Cofferdams, void spaces, pipe tunnels and ducts **(19)**	Accommodation, service and control spaces **(20)**	Open decks **(21)**
Deck drains (internal)	L1W **(4)**	L1W **(4)**	NA	L1W **(4)**	0	NA	0	0	0	0	0
Sanitary drains (internal)	0	0	NA	0	0	NA	0	0	0	0	0
Scuppers and discharges (over-board)	0 **(1)** **(8)**	0 **(1)** **(8)**	0 **(1)** **(8)**	0 **(1)** **(8)**	0 **(1)** **(8)**	0	0	0	0	0 **(1)** **(8)**	0
SOUNDING, AIR											
Water tanks, dry spaces	0	0	0	0	0	0 **(10)**	0	0	0	0	0
Oil tanks (flash point > 60°C)	X	X	X	X	X	X **(3)**	0	0 **(10)**	0	X	X
MISCELLANEOUS											
Control air	L1 **(5)**	L1 **(5)**	L1 **(5)**	L1 **(5)**	L1 **(5)**	NA	0	0	0	L1 **(5)**	L1 **(5)**
Service air (non-essential)	0	0	0	0	0	NA	0	0	0	0	0
Brine	0	0	NA	0	0	NA	NA	NA	0	0	0
Auxiliary low steam pressure (≤ 0,7 MPa)	L2W	L2W	0 **(9)**	0 **(9)**	0 **(9)**	0	0	0	0	0 **(9)**	0 **(9)**
Central vacuum cleaners	NA	NA	NA	0	NA	NA	NA	NA	0	0	0
Exhaust gas cleaning system effluent line	L3 **(1)**	L3 **(1)**	NA	NA	NA	NA	NA	NA	0	L3 **(1)** **(22)**	0

PIPING SYSTEM	LOCATION **(24)**										
	Machinery spaces of category A **(11)**	Other machinery spaces and pump rooms **(12)**	Cargo pump rooms **(13)**	Ro/ro cargo holds **(14)**	Other dry cargo holds **(15)**	Cargo tanks **(16)**	Fuel oil tanks **(17)**	Ballast water tanks **(18)**	Cofferdams, void spaces, pipe tunnels and ducts **(19)**	Accommodation, service and control spaces **(20)**	Open decks **(21)**
Urea transfer/supply system (SCR installations)	L **(23)**	L **(23)**	NA	NA	NA	NA	NA	NA	NA	L3 **(22)**	0

(1) Where non-metallic piping is used, remote controlled valves to be provided at ship side (valve is to be controlled from outside space).

(2) Remote closing valves to be provided at the cargo tanks.

(3) When cargo tanks contain flammable liquids with flash point > 60 °C, “0” may replace “NA” or “X”.

(4) For drains serving only the space concerned, “0” may replace “L1W”.

(5) When controlling functions are not required by the Rules, “0” may replace “L1”.

(6) For pipes between machinery space and deck water seal, “0” may replace “L1”.

(7) For passenger vessels, “X” is to replace “L1”.

(8) Scuppers serving open decks in positions 1 and 2, as defined in Pt B, Ch 1, Sec 2, are to be “X” throughout unless fitted at the upper end with a means of closing capable of being operated from a position above the freeboard deck in order to prevent downflooding.

(9) For essential services, such as fuel oil tank heating and ship’s whistle, “X” is to replace “0”.

(10) For tankers required to comply with Pt E, Ch 7, Sec 4, [2.1.3], “NA” is to replace “0”.

(11) Machinery spaces of category A are defined in Sec 1, [1.4.1].

(12) Spaces, other than category A machinery spaces and cargo pumps rooms, containing propulsion machinery, boilers, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, pumps, oil filling stations, refrigerating, stabilising, ventilation and air-conditioning machinery, and similar spaces, and trunks to such spaces.

(13) Spaces containing cargo pumps, and entrances and trunks to such spaces.

(14) Ro-ro cargo spaces and special category spaces are defined in Ch 4, Sec 1, [3].

(15) All spaces other than ro-ro cargo holds used for non-liquid cargo and trunks to such spaces.

(16) All spaces used for liquid cargo and trunks to such spaces.

(17) All spaces used for fuel oil (excluding cargo tanks) and trunks to such spaces.

(18) All spaces used for ballast water and trunks to such spaces.

(19) Empty spaces between two bulkheads separating two adjacent compartments.

(20) Accommodation spaces, service spaces and control stations are defined in Ch 4, Sec 1, [3].

(21) Open decks are defined in Ch 4, Sec 1, [3].

(22) L3 in service spaces, NA in accommodation and control spaces.

(23) Type Approved plastic piping without fire endurance test (0) is acceptable downstream of the tank valve, provided this valve is metal seated and arranged as fail-to-closed or with quick closing from a safe position outside the space in the event of fire.

(24) For Passenger Ships subject to SOLAS II-2/21.4 (Safe return to Port), plastic pipes for services required to remain operative in the part of the ship not affected by the casualty thresholds, such as systems intended to support safe areas, are to be considered essential services. In accordance with MSC.1/Circ.1369, interpretation 12, for Safe Return to Port purposes, plastic piping can be considered to remain operational after a fire casualty if the plastic pipes and fittings have been tested to L1 standard.

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 in accordance with the manufacturer's guidelines.

3.2 Supporting of the pipes

3.2.1 *(1/1/2020)*

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
- length of the piping
- 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.

3.4.3 *(1/1/2020)*

As well as providing adequate robustness for all piping, including open-ended piping, the minimum wall thickness complying with [2.2.2] a) may be increased taking into account the conditions encountered during service on board ships.

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 x 10^6 ohm.

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 *(1/7/2023)*

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" specified in Part 3 of Annex 1 to the 2010 FTP Code.

3.6.2 *(1/1/2020)*

When plastic pipes pass through watertight bulkheads or decks, the watertight integrity of the bulkhead or deck is to be maintained.

For pipes not able to satisfy the requirements in [2.2.2] b), a metallic shut-off valve operable from above the freeboard deck should be fitted at the bulkhead or deck.

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.

3.6.3 *(1/1/2026)*

For passenger ships, the penetrations used for the passage of plastic piping systems through a watertight bulkhead or deck under SOLAS II-1/13.2.3 are to be successfully prototype tested for watertight integrity, as per paragraphs 3, 4 and 5 of the explanatory notes to SOLAS regulation II-1/13.2.3 contained in the annex of resolution MSC.429(98)/Rev.2, as applicable, after the fire test. SOLAS II-1/13.2.3 is to be applicable to heat-sensitive piping systems like plastic piping and is not to be applied to cable penetrations in watertight bulkheads and decks.

3.7 Systems connected to the hull

3.7.1 Bilge and sea water systems

a) Where, in pursuance of [2.3.1], plastic pipes are permitted in bilge and sea water systems, the ship side valves required in Sec 10, [2.8] and, where provided, the connecting pipes to the shell are to be made of metal in accordance with Sec 10, [2.1].

b) Ship side valves are to be provided with remote control from outside the space concerned. See Tab 1, footnote **(1)**.

3.7.2 Scuppers and sanitary discharges

a) Where, in pursuance of [2.3.1], plastic pipes are permitted in scuppers and sanitary discharge systems connected to the shell, their upper end is to be fitted with closing means operated from a position above the freeboard deck in order to prevent downflooding. See Tab 1, footnotes **(1)** and **(8)**.

b) Discharge valves are to be provided with remote control from outside the space concerned.

3.8 Application of fire protection coatings

3.8.1 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.

3.8.2 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 *(1/1/2007)*

Plastic pipes, fittings, joints and any internal or external liners, coverings and coatings are to be of a type approved by the Society for the intended use according to the Rules for Type Approval of Plastic Pipes.

4.1.2 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 *(1/1/2010)*

Each pipe and fitting is to be tested by the manufacturer at a hydrostatic pressure not less than 1,5 times the nominal pressure.

Alternatively, for pipes and fittings not employing hand lay-up techniques, the hydrostatic pressure test may be carried out in accordance with the hydrostatic testing requirements stipulated in the recognised national or international standard to which the pipes or fittings are manufactured, provided that there is an effective quality system in place.

4.2.2 *(1/7/2022)*

The manufacturer is to have quality system that meets ISO 9001:2015 or equivalent.

The quality system is to consist of elements necessary to ensure that pipes and fittings are produced with consistent and uniform mechanical and physical properties.

4.2.3 *(1/7/2022)*

In case the manufacturer does not have an approved quality system complying with ISO 9001:2015 or equivalent, pipes and fittings are to be tested in accordance with these requirements to the Surveyor's satisfaction for every batch of pipes.

Depending upon the intended application, the Society may require the pressure testing of each pipe and/or fitting.

4.3 Testing after installation on board

4.3.1 Hydrostatic testing *(1/7/2023)*

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.

   Notwithstanding the requirement above, the requirement in [4.3.1] b) may be applied to open ended pipes (drains, effluent, etc.).

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 4 INDEPENDENT FUEL OIL TANKS

1 General

1.1 Application

1.1.1

a) The provisions of this Appendix apply to fuel oil tanks and bunkers which are not part of the ship's structure.

b) Requirements for scantling apply only to steel tanks. Scantling of tanks not made of steel will be given special consideration.

1.2 Documents to be submitted

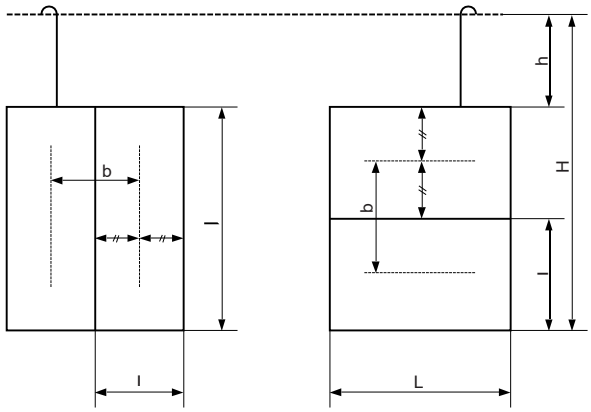
1.2.1 Constructional drawings of the tanks are to be submitted, showing the height of the overflow and air pipe above the top of the tank.

1.3 Symbols and units

1.3.1 Tanks

The meaning of the symbols used for tanks is given in Fig 1.

Figure 1 : Symbols used for tanks



L : Greater length of the considered plating element, in m

l : Smaller length of the considered plating element, in m

H : Height, in m, of the overflow or air pipe above the lower edge of the considered plating element

h : Height, in m, of overflow or air pipe above the top of the tank, subject to a minimum of:

- 3,60 m for fuel oil having a flash point below 60°C,
- 2,40 m otherwise.

1.3.2 Stiffeners

The following symbols and units are used for the stiffeners:

b : Width of the plating element supported by the stiffener, in m

w : Section modulus of the stiffeners, in cm^3.

2 Design and installation of tanks

2.1 Materials

2.1.1 General

Independent fuel oil tanks are to be made of steel except where permitted in [2.1.2].

2.1.2 Use of materials other than steel

a) On ships of less than 100 tons gross tonnage, independent fuel oil tanks may be made of:
   - aluminium alloys or equivalent material, provided that the tanks are located outside the propulsion machinery spaces or, when located within such spaces, they are insulated to A-60 class standard
   - glass reinforced plastics (GRP), provided:
     - the total volume of tanks located in the same space does not exceed 4,5 m^3, and
     - the properties of GRP including fire resistance comply with the relevant provisions of App 3.

b) On ships of 100 tons gross tonnage or more, the use of independent fuel oil tanks made of aluminium alloys or GRP will be given special consideration.

2.2 Scantling of steel tanks

2.2.1 General

a) The scantling of tanks whose dimensions are outside the range covered by the following provisions will be given special consideration.

b) The scantling of the tanks is to be calculated assuming a minimum height h of the overflow or air pipe above the top of the tank of:
   - 3,60 m for fuel oil having a flash point below 60°C,
   - 2,40 m otherwise.

c) All tanks having plating elements of a length exceeding 2,5 m are to be fitted with stiffeners.

2.2.2 Thickness of plating

The thickness of the plates is not to be less than the value given in Tab 1 for the various values of l, L/l and H. However, for tanks having a volume of more than 1 m^3, the thickness of the plates is not to be less than 5 mm.

2.2.3 Scantlings of stiffeners

a) This requirement applies only to stiffeners which are all vertical or all horizontal and attached according to the types shown in Fig 2. Other cases will be given special consideration.

b) The minimum values of the ratio w/b required for stiffeners are given in:
   - Tab 2 for vertical stiffeners
   - Tab 3 for horizontal stiffeners

   for the different types of attachments shown in Fig 2.

2.3 Installation

2.3.1 Securing

Independent tanks are to be securely fixed to hull structures and are to be so arranged as to permit inspection of adjacent structures.

2.3.2 Protection against spillage

Where permitted, independent fuel oil tanks are to be placed in an oil-tight spill tray of ample size with a suitable drain pipe leading to a suitably sized spill oil tank.

Table 1 : Thickness of plating (mm)

l (m)	L / l	H (m)													
		2,4 - 2,7	2,7 - 3,0	3,0 - 3,3	3,3 - 3,6	3,6 - 4,0	4,0 - 4,4	4,4 - 4,8	4,8 - 5,2	5,2 - 5,8	5,8 - 6,4	6,4 - 7,0	7,0 - 8,0	8,0 - 9,0	9,0 - 10,0
0,40	< 2	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,5	3,5	3,5	4,0	4,0	4,0	4,5
	≥ 2	3,0	3,0	3,0	3,5	3,5	3,5	4,0	4,0	4,0	4,5	4,5	5,0	5,0	5,5
0,45	< 2	3,0	3,0	3,0	3,0	3,0	3,5	3,5	3,5	4,0	4,0	4,0	4,5	4,5	5,0
	≥ 2	3,5	3,5	3,5	4,0	4,0	4,0	4,5	4,5	4,5	5,0	5,0	5,5	6,0	6,0
0,50	< 2	3,0	3,0	3,5	3,5	3,5	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,5	7,0
	≥ 2	3,5	4,0	4,0	4,0	4,5	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,5	7,0
0,55	< 2	3,5	3,5	3,5	4,0	4,0	4,0	4,0	4,5	4,5	5,0	5,0	5,5	5,5	6,0
	≥ 2	4,0	4,5	4,5	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,0	6,5	7,0	7,5
0,60	< 2	3,5	4,0	4,0	4,0	4,0	4,5	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,5
	≥ 2	4,5	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,0	6,5	6,5	7,0	7,5	8,0

l (m)	L / l	H (m)												
		2,4 - 2,7	2,7 - 3,0	3,0 - 3,3	3,3 - 3,6	3,6 - 4,0	4,0 - 4,4	4,4 - 4,8	4,8 - 5,2	5,2 - 5,8	5,8 - 6,4	6,4 - 7,0	7,0 - 8,0	8,0 - 9,0	9,0 - 10,0
0,65	< 2	4,0	4,0	4,0	4,0	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,0	6,5	7,0
	≥ 2	4,5	5,0	5,0	5,0	5,5	6,0	6,0	6,5	6,5	7,0	7,5	7,5	8,5	8,5
0,70	< 2	4,0	4,0	4,5	4,5	5,0	5,0	5,0	5,5	5,5	6,0	6,5	6,5	7,0	7,5
	≥ 2	5,0	5,0	5,5	5,5	6,0	6,5	6,5	7,0	7,0	7,5	8,0	8,5	9,0	----
0,75	< 2	4,5	4,5	5,0	5,0	5,0	5,5	5,5	6,0	6,0	6,5	6,5	7,0	7,5	8,0
	≥ 2	5,5	5,5	6,0	6,0	6,5	6,5	7,0	7,5	7,5	8,0	8,5	9,0	----	----
0,80	< 2	4,5	5,0	5,0	5,0	5,5	6,0	6,0	6,0	6,5	7,0	7,0	7,5	8,0	8,5
	≥ 2	5,5	6,0	6,0	6,5	6,5	7,0	7,5	7,5	8,0	8,5	9,0	----	----	----
0,85	< 2	5,0	5,0	5,5	5,5	5,5	6,0	6,5	6,5	7,0	7,0	7,5	8,0	8,5	9,0
	≥ 2	6,0	6,5	6,5	7,0	7,0	7,5	8,0	8,0	8,5	9,0	----	----	----	----
0,90	< 2	5,0	5,5	5,5	6,0	6,0	6,5	6,5	7,0	7,0	7,5	8,0	8,5	9,0	----
	≥ 2	6,5	6,5	7,0	7,0	7,5	8,0	8,5	8,5	9,0	----	----	----	----	----
0,95	< 2	5,5	5,5	6,0	6,0	6,5	7,0	7,0	7,5	7,5	8,0	8,5	9,0	----	----
	≥ 2	6,5	7,0	7,0	7,5	8,0	8,5	9,0	9,0	----	----	----	----	----	----
1,00	< 2	5,5	6,0	6,0	6,5	7,0	7,0	7,5	7,5	8,0	8,5	9,0	----	----	----
	≥ 2	7,0	7,5	7,5	8,0	8,5	8,5	9,0	----	----	----	----	----	----	----

Figure 2 : Type of stiffener end attachments

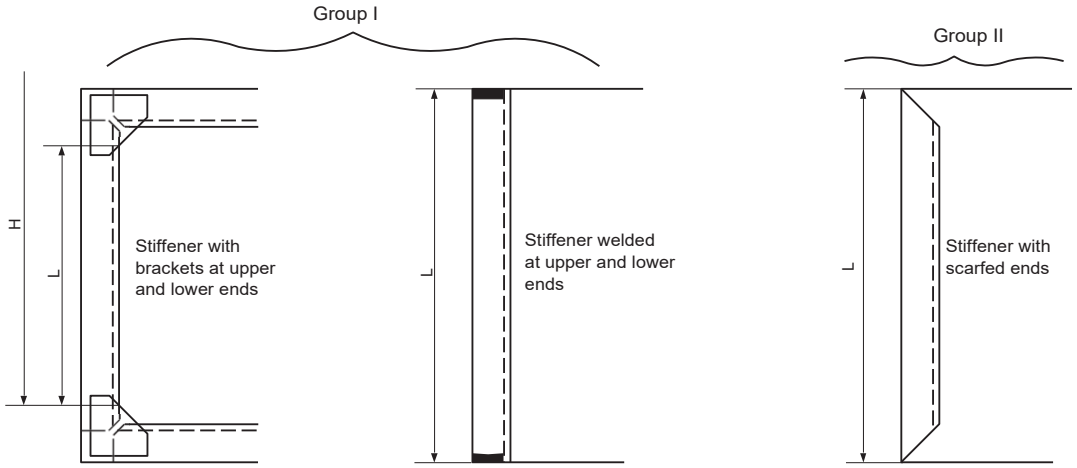


Table 2 : Values of w/b ratio for vertical stiffeners (cm³/m)

L (m)	end attachment	H, in m **(1)**											
		3,0	3,3	3,6	3,9	4,3	4,6	5,0	5,5	6,0	7,0	8,0	9,0	10,0
0,6	I	5,0	5,5	6,0	6,5	7,5	8,0	9,0	9,5	10,5	11,5	14,0	16,0	18,0
	II	8,0	9,0	10,0	11,0	12,0	12,5	13,0	15,0	16,0	19,0	22,0	25,0	28,0
0,8	I	8,5	9,5	10,5	11,5	13,0	14,0	15,0	16,5	18,0	22,0	25,0	28,0	31,5
	II	13,0	15,0	16,0	18,0	20,0	21,5	24,0	25,5	28,5	34,0	38,0	43,0	48,0
1,0	I		14,5	16,0	17,5	19,5	21,0	23,0	26,0	28,5	34,0	38,0	43,0	49,0
	II		22,0	24,0	27,0	30,0	32,5	36,0	39,0	43,0	51,0	58,0	67,0	75,0
1,2	I			22,5	24,5	28,0	30,0	33,0	37,0	40,5	48,0	55,0	63,0	71,0
	II			34,0	30,7	42,5	46,0	50,0	55,0	61,0	73,0	84,0	96,0	107
1,4	I			30,0	32,5	37,0	40,0	44,0	49,0	55,0	65,0	75,0	85,0	96,0
	II			45,0	49,0	56,0	61,0	67,0	74,0	82,0	98,0	113,0	129,0	144,0
1,6	I				47,0	53,0	57,0	64,0	71,0	79,0	94,0	110,0	125,0	140,0
	II				71,0	80,0	87,0	96,0	107,0	118,0	141,0	165,0	187,0	
1,8	I				58,0	65,0	71,0	79,0	88,0	98,0	117,0	136,0	156,0	175,0
	II				87,0	98,0	107,0	118,0	132,0	147,0	176,0	204,0		
(1) H is to be taken equal to the height of the tank top above the lower end of the stiffener, plus h.														

L (m)	end attachment	H, in m **(1)**												
		3,0	3,3	3,6	3,9	4,3	4,6	5,0	5,5	6,0	7,0	8,0	9,0	10,0
2,0	I II					78,0 118,0	85,0 129,0	95,0 142,0	107,0 160,0	119,0 178,0	142,0	166,0	190,0	
2,2	I II						100,0 151,0	112,0 168,0	126,0 190,0	140,0	170,0	198,0		
2,5	I II						124,0 187,0	139,0	158,0					

(1) H is to be taken equal to the height of the tank top above the lower end of the stiffener, plus h.

Table 3 : Values of w/b ratio for horizontal and top and bottom stiffeners (cm^3/m)

L (m)	end attach -ment	H, in m **(1)**															
		2,4	2,6	2,8	3,0	3,3	3,6	3,9	4,3	4,6	5,0	5,5	6,0	7,0	8,0	9,0	10,0
0,6	I II	4,5 7,0	5,0 8,0	5,5 8,5	6,0 9,0	6,5 10,0	7,0 11,0	7,5 11,5	8,5 12,5	9,0 13,5	10,0 15,0	11,0 16,0	12,0 17,5	13,5 21,0	15,0 24,0	17,0 27,0	19,0 30,0
0,8	I II	8,0 13,0	9,0 15,0	9,5 15,5	10,0 16,5	11,0 18,0	12,0 19,5	13,0 21,5	14,5 23,5	15,5 25,0	17,0 27,0	18,5 30,0	20,0 34,0	23,5 38,0	27,0 44,0	30,0 49,0	33,5 55,0
1,0	I II	13,0 20,0	15,0 22,0	15,5 23,5	16,5 25,0	18,0 28,0	19,5 30,0	21,5 33,0	23,5 36,0	25,0 39,0	27,0 42,0	30,0 46,0	34,0 50,0	38,0 59,0	44,0 67,0	49,0 75,0	55,0 84,0
1,2	I II	18,0 28,0	20,0 31,0	21,0 33,0	22,5 35,0	25,0 39,0	26,5 42,0	29,5 46,0	32,5 51,0	34,5 54,0	37,5 59,0	41,5 65,0	45,0 70,0	52,5 82,0	60,0 93,0	67,5 105	75,0 117
1,4	I II	26,0 39,0	28,0 43,0	30,5 45,5	32,5 49,0	36,0 54,0	39,0 58,5	42,5 63,5	46,5 70,0	50,0 75,0	54,5 81,0	59,5 89,0	65,0 97,0	76,0 113	87,0 130	97,0 146	108 162
1,6	I II	36,0 56,0	39,0 61,0	42,0 66,0	45,0 70,0	50,0 77,0	54,0 84,0	59,0 91,0	65,0 100	69,0 107	75,0 117	82,0 128	90,0 140	105 163	120 186	135	150
1,8	I II	46,0 70,0	50,0 76,0	54,0 82,0	58,0 88,0	63,0 96,0	69,0 105	75,0 113	82,0 125	88,0 134	95,0 146	105 160	115 175	134 204	153	172	191
2,0	I II	57,0 87,0	62,0 95,0	67,0 102	72,0 109	78,0 120	85,0 130	92,0 141	102 155	109 166	118 181	130 198	142	166	190		
2,2	I II	70,0 107	76,0 116	82,0 125	88,0 134	96,0 147	105 160	113 174	125 192	134 205	145	160	175	204			
2,5	I II	92,0 140	100 152	108 163	115 175	127 192	138	150	165	176	191						

(1) For horizontal stiffeners, H is to be measured from the horizontal stiffener immediately below the stiffener considered.
For top stiffeners, H = h.

APPENDIX 5 TYPE TEST PROCEDURE FOR CRANKCASE EXPLOSION RELIEF VALVES

1 General

1.1 Application

1.1.1 *(1/7/2008)*

This test procedure applies to type approved crankcase explosion relief valves intended to be fitted to diesel engines as required under Sec 2, [4.3.4].

Note 1: Engines are to be fitted with components and arrangements complying with this Appendix when:

- the engine is installed on existing ships (i.e. ships for which the date of contract for construction is before 1 July 2008) and the date of application for certification of the engine (i.e. the date of whatever document the Society requires/accepts as an application or request for certification of an individual engine) is on or after 1 July 2008; or
- the engine is installed on new ships (i.e. ships for which the date of contract for construction is on or after 1 July 2008).

1.1.2 *(1/1/2007)*

This test procedure is also applicable to explosion relief valves intended for gear cases.

1.1.3 *(1/1/2007)*

Standard repeatable test conditions have been established using methane gas and air mixture.

1.1.4 *(1/1/2007)*

The test procedure is only applicable to explosion relief valves fitted with flame arresters.

1.1.5 *(1/7/2007)*

Where internal oil wetting of a flame arrester is a design feature of an explosion relief valve, alternative test arrangements that demonstrate compliance with these requirements may be proposed by the Manufacturer. The alternative test arrangements are to be agreed by the Society.

1.2 Recognised Standards

1.2.1 *(1/7/2022)*

a) ISO 16852:2016

b) ISO/IEC 17025:2017

c) ISO 12100:2010

d) VDI 3673-1:2002

e) IMO MSC/Circ.677 as amended by MSC/Circ.1009 and MSC.1/Circ.1324.

1.3 Purpose

1.3.1 *(1/1/2007)*

The purpose of type testing crankcase explosion relief valves is fourfold:

a) To verify the effectiveness of the flame arrester.

b) To verify that the valve closes after an explosion.

c) To verify that the valve is gas/air tight after an explosion

d) To establish the level of overpressure protection provided by the valve.

2 Test houses

2.1 General

2.1.1 *(1/1/2007)*
The test houses for carrying out type testing of crankcase explosion relief valves are to meet the requirements given in [2.1.2] to [2.1.13].

2.1.2 *(1/7/2022)*
The test houses where test is carried out are to be accredited to a national or international standard, e.g. ISO/IEC 17025:2017.

2.1.3 *(1/1/2007)*
The test houses are to be acceptable to the Society.

2.1.4 *(1/1/2007)*
The test houses are to be equipped so that they can perform and record explosion testing in accordance with this procedure.

2.1.5 *(1/1/2007)*
The test houses are to have equipment for controlling and measuring a methane gas in air concentration within a test vessel to an accuracy of ± 0,1%.

2.1.6 *(1/1/2007)*
The test houses are to be capable of effective point located ignition of methane gas in air mixture.

2.1.7 *(1/7/2007)*
The pressure measuring equipment is to be capable of measuring the pressure in the test vessel in at least two positions: one at the valve and the other at the test vessel centre. The measuring arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognising the speed of events during an explosion. The result of each test is to be documented by video recording and by recording with a heat sensitive camera.

2.1.8 *(1/1/2008)*
The test vessel for explosion testing is to have documented dimensions. The dimensions are to be such that the vessel is not "pipe like" with the distance between dished ends being not more than 2,5 times its diameter. The internal volume of the test vessel is to include any standpipe arrangements.

2.1.9 *(1/1/2008)*
The test vessel is to be provided with a flange, located centrally at one end perpendicular to the vessel longitudinal axis for mounting the explosion relief valve. The test vessel is to be arranged in an orientation consistent with the way the valve will be installed in service, i.e. in the vertical plane or the horizontal plane.

2.1.10 *(1/7/2007)*
A circular plate is to be provided for fitting between the pressure vessel flange and valve to be tested with the following dimensions:

- Outside diameter of 2 times the outer diameter of the valve top cover.
- Internal bore having the same internal diameter as the valve to be tested.

2.1.11 *(1/1/2007)*
The test vessel is to have connections for measuring the methane in air mixture at the top and bottom.

2.1.12 *(1/1/2007)*
The test vessel is to be provided with a means of fitting an ignition source at a position as specified in [3.1.3].

2.1.13 *(1/1/2008)*
The test vessel volume is to be, as far as practicable, related to the size and capability of the relief valve to be tested. In general, the volume is to correspond to the requirement in Sec 2, [4.3.4] b) for the free area of explosion relief valve to be not less than 115cm^2/m^3 of crankcase gross volume.

This means that the testing of a valve having 1150 cm^2 of free area, would require a test vessel with a volume of 10m^3.

Where the free area of relief valves is greater than 115 cm^2/m^3 of the crankcase gross volume, the volume of the test vessel is to be consistent with the design ratio.

In no case the volume of the test vessel is to vary by more than +15% to -15% from the design cm^2/m^3 volume ratio.

3 Explosion tests, assessment and design series qualifications

3.1 Process

3.1.1 *(1/1/2008)*
All explosion tests to verify the functionality of crankcase explosion relief valves are to be carried out using an air and methane mixture with a volumetric methane concentration of 9,5% ±0,5%. The pressure in the test vessel is to be not less than atmospheric pressure and is not to exceed the opening pressure of the relief valve.

3.1.2 *(1/1/2007)*
The concentration of methane in the test vessel is to be measured at the top and bottom of the vessel and these concentrations are not to differ by more than 0,5%.

3.1.3 *(1/1/2008)*
The ignition of the methane and air mixture is to be made at the centreline of the test vessel at a position approximately one third of the height or length of the test vessel opposite to where the valve is mounted.

3.1.4 *(1/1/2008)*
The ignition is to be made using a maximum 100 joule explosive charge.

3.2 Valves to be tested

3.2.1 *(1/7/2009)*
The valves used for type testing (including the testing specified in item [3.2.3]) are to be selected from the Manufacturer's normal production line for such valves by the QSCS Classification Society (see Pt A, Ch 1, Sec 1, [1.2.1]) witnessing the tests.

3.2.2 *(1/1/2008)*
For approval of a specific valve size, three valves are to be tested in accordance with [3.2.3] and [3.3]. For a series of valves, refer to [3.5].

3.2.3 *(1/7/2007)*
The valves selected for type testing are to have been previously tested at the Manufacturer's works to demonstrate that the opening pressure is in accordance with the specification within a tolerance of ± 20% and that the valve is airtight at a pressure below the opening pressure for at least 30 seconds.

This test is to verify that the valve is airtight following assembly at the Manufacturer's works and that the valve begins to open at the required pressure demonstrating that the correct spring has been fitted.

3.2.4 *(1/1/2007)*
The type testing of valves is to recognise the orientation in which they are intended to be installed on the engine or gear case. Three valves of each size are to be tested for each intended installation orientation, i.e. in the vertical and /or horizontal positions.

3.3 Method

3.3.1 *(1/7/2009)*
The following requirements are to be satisfied at explosion testing:

a) The explosion testing is to be witnessed by a QSCS Classification Society Surveyor (see Pt A, Ch 1, Sec 1, [1.2.1]).

b) Where valves are to be installed on an engine or gear case with shielding arrangements to deflect the emission of explosion combustion products, the valves are to be tested with the shielding arrangements fitted.

c) Successive explosion tests to establish a valve's functionality are to be carried out as quickly as possible during stable weather conditions.

d) The pressure rise and decay during all explosion testing is to be recorded.

e) The external condition of the valves is to be monitored during each test for indication of any flame release by video and heat sensitive camera.

3.3.2 *(1/7/2007)*

The explosion testing is to be in three stages for each valve that is required to be approved as being type tested.

a) Stage 1:

Two explosion tests are to be carried out in the test vessel with the circular plate described in item [2.1.10] fitted and the opening in the plate covered by a 0,05mm thick polythene film. These tests establish a reference pressure level for determination of the capability of a relief valve in terms of pressure rise in the test vessel; see [3.4.1] f).

b) Stage 2:

1) Two explosion tests are to be carried out on three different valves of the same size. Each valve is to be mounted in the orientation for which approval is sought, i.e. in the vertical or horizontal position with the circular plate described in [2.1.10] located between the valve and pressure vessel mounting flange. The pressure rise is not to exceed the limit specified by the Manufacturer.

2) The first of the two tests on each valve is to be carried out with a 0,05 mm thick polythene bag enclosing the valve and circular plate; the bag is to have a minimum diameter of three times the diameter of the circular plate and volume not less than 30% of the test vessel. Before the explosion test is carried out, the polythene bag is to be empty of air. The polythene bag is required to provide a readily visible means of assessing whether there is flame transmission through the relief valve following an explosion consistent with the requirements of the standards identified in [1.2].

During the test, the explosion pressure will open the valve and some unburned methane/air mixture will be collected in the polythene bag. When the flame reaches the flame arrester and if there is flame transmission through the flame arrester, the methane/air mixture in the bag will be ignited and this will be visible.

3) Provided that the first explosion test successfully demonstrated that there was no indication of combustion outside the flame arrester and there are no visible signs of damage to the flame arrester or valve, a second explosion test without the polythene bag arrangement is to be carried out as soon as possible after the first test. During the second explosion test, the valve is to be visually monitored for any indication of combustion outside the flame arrester and video records are to be kept for subsequent analysis. The second test is required to demonstrate that the valve can still function in the event of a secondary crankcase explosion.

4) After each explosion, the test vessel is to be maintained in the closed condition for at least 10 seconds to enable the tightness of the valve to be ascertained. The tightness of the valve can be verified during the test from the pressure/time records or by a separate test after completing the second explosion test.

c) Stage 3:

Two further explosion tests are to be carried out as described in Stage 1. These further tests are required to provide an average baseline value for assessment of pressure rise recognising that the test vessel ambient conditions may have changed during the testing of the explosion relief valves in Stage 2.

3.4 Assessment and records

3.4.1 *(1/7/2009)*

For the purposes of verifying compliance with the requirements of this appendix, the assessment and records of the valves used for explosion testing are to address the following items a) to l).

a) The valves to be tested are to have evidence of design appraisal/approval by the QSCS Classification Society (see Pt A, Ch 1, Sec 1, [1.2.1]) witnessing the testing.

b) The designation, dimensions and characteristics of the valves to be tested are to be recorded. This is to include free area of the valve and the flame arrester and the amount of valve lift at 0,02 MPa.

c) The test vessel volume is to be determined and recorded.

d) For acceptance of the functioning of the flame arrester there is not to be any indication of flame or combustion outside the valve during an explosion test. This should be confirmed by the test laboratory taking into account measurements from the heat sensitive camera.

e) The pressure rise and decay during an explosion are to be recorded with indication of the pressure variation showing the maximum overpressure and steady under pressure in the test vessel during testing. The pressure variation is to be recorded at two points in the pressure vessel.

f) The effect of an explosion relief valve in terms of pressure rise following an explosion is ascertained from maximum pressures recorded at the centre of the test vessel during the three stages. The pressure rise within the test vessel due to the installation of a relief valve is the difference between the average pressure of the four explosions from Stages 1 and 3 and the average of the first tests on the three valves in Stage 2.

g) The valve tightness is to be ascertained by verifying from the records at the time of testing that an under pressure of at least 0,03 MPa is held by the test vessel for at least 10 seconds following an explosion.

This test is to verify that the valve has effectively closed and is reasonably gas-tight following dynamic operation during an explosion.

h) After each explosion test in Stage 2, the external condition of the flame arrester is to be examined for signs of seious damage and/or deformation that may affect the operation of the valve.

i) After completion of the explosion tests, the valves are to be dismantled and the condition of all components ascertained and documented. In particular, any indication of valve sticking or uneven opening that may affect the operation of the valve is to be noted. Photographic records of the valve condition are to be taken and included in the report.

3.5 Design series qualification

3.5.1 *(1/1/2007)*

The qualification of quenching devices to prevent the passage of flame can be evaluated for other similar devices where one device has been tested and found satisfactory.

3.5.2 *(1/1/2008)*

The quenching ability of a flame screen depends on the total mass of quenching lamellas/mesh. Provided the materials, thickness of materials, depth of lamellas/thickness of mesh layer and quenching gaps are the same, then the same quenching ability can be qualified for different size of flame screen. This is subject to the following relations being satisfied.

$$\frac{n_1}{n_2} = \sqrt{\frac{S_1}{S_2}}$$

$$\frac{A_1}{A_2} = \frac{S_1}{S_2}$$

where:

n_1 = total depth of flame arrester corresponding to the number of lamellas of size 1 quenching device for a valve with a relief area equal to S_1

n_2 = total depth of flame arrester corresponding to the number of lamellas of size 2 quenching device for a valve with a relief area equal to S_2

A_1 = free area of quenching device for a valve with a relief area equal to S_1

A_2 = free area of quenching device for a valve with a relief area equal to S_2

3.5.3 *(1/1/2008)*

The qualification of explosion relief valves of larger sizes than that which has been previously satisfactorily tested in accordance with [3.3] and [3.4] can be evaluated where valves are of identical type and have identical construction features, subject to the following items a) to c).

a) The free area of a larger valve does not exceed three times + 5% that of the valve that has been satisfactorily tested.

b) One valve of the largest size requiring qualification is subjected to satisfactory testing required by [3.2.3] and [3.3.2] b) except that a single valve will be accepted in [3.3.2] b)1) and the volume of the test vessel is not to be less than one third of the volume required by [2.1.13].

c) The assessment and records are to be in accordance with [3.4], noting that [3.4.1] f) will only be applicable to Stage 2 for a single valve.

3.5.4 *(1/7/2007)*

The qualification of explosion relief valves of smaller sizes than that which has been previously satisfactorily tested in accordance with [3.3] and [3.4] can be evaluated where valves are of identical type and have identical construction features, subject to the following items a) to c).

a) The free area of a smaller valve is not less than one third of the valve that has been satisfactorily tested.

b) One valve of each smaller size requiring qualification is subjected to satisfactory testing required by [3.2.3] and [3.3.2]b) except that a single valve will be accepted in [3.3.2]b)1) and the volume of the test vessel is not to be less than one third of the volume required by [2.1.13].

c) The assessment and records are to be in accordance with [3.4], noting that [3.4.1]f) will only be applicable to Stage 2 for a single valve.

4 Report and approval

4.1 The test report

4.1.1 *(1/7/2007)*

The test facility is to deliver a full report that includes the following information and documents:

a) Test specification

b) Details of test pressure vessel and valves tested

c) The orientation in which the valve was tested (vertical or horizontal position)

d) Methane in air concentration for each test

e) Ignition source

f) Pressure curves for each test

g) Video recordings of each valve test

h) The assessment and records stated in [3.4].

4.2 Approval

4.2.1 *(1/1/2007)*

The approval of an explosion relief valve is at the discretion of the Society based on the appraisal plans and particulars and on the test facilities' report of the results of type testing.

APPENDIX 6 TYPE TEST PROCEDURE FOR CRANKCASE OIL MIST DETECTION AND ALARM EQUIPMENT

1 General

1.1 Application

1.1.1 *(1/7/2007)*

This test procedure applies to type approved crankcase oil mist detection and alarm equipment as required under item Sec 2, [4.3.5].

1.1.2 *(1/7/2007)*

This test procedure is also applicable to oil mist detection and alarm equipment intended for gear cases.

1.1.3 *(1/1/2007)*

The provisions of Ch 3, Sec 8 apply as far as required in [3.1.1].

1.2 Purpose

1.2.1 *(1/7/2007)*

The purpose of type test crankcase oil mist detection and alarm equipment is sevenfold:

a) To verify the functionality of the system

b) To verify the effectiveness of oil mist detectors

c) To verify the accuracy of oil mist detectors

d) To verify the alarm set points

e) To verify time delays between oil mist leaving the source and alarm activation

f) To verify the operation of alarms indicating functional failure in the equipment and associated arrangements

g) To verify the influence of optical obscuration on detection.

2 Test houses

2.1 General

2.1.1 *(1/7/2016)*

Test houses carrying out type testing of crankcase oil mist detection and alarm equipment are to satisfy the following criteria:

a) A full range of facilities for carrying out the environmental and functionality tests required by this procedure are to be available and be acceptable to the Society.

b) The test house that verifies the functionality of the equipment is to be equipped so that it can control, measure and record oil mist concentration levels in terms of mg/l to an accuracy of ± 10% in accordance with this procedure.

c) When verifying the functionality, test houses are to consider the possible hazards associated with the generation of the oil mist required and take adequate precautions. The Society may accept the use of low toxicity, low hazard oils as used in other applications, provided it is demonstrated to have similar properties to SAE 40 monograde mineral oil specified in [3.4.2].

3 Tests

3.1 Equipment testing

3.1.1 *(1/7/2007)*

The range of tests is to include the following:

a) For the alarm/monitoring panel:
   1) Functional tests described in [3.2]
   2) Electrical power supply failure test
   3) Power supply variation test
   4) Dry heat test
   5) Damp heat test
   6) Vibration test
   7) EMC test
   8) Insulation resistance test
   9) High voltage test
   10) Static and dynamic inclinations.

b) For the detectors:
   1) Functional tests described in [3.2]
   2) Electrical power supply failure test
   3) Power supply variation test
   4) Dry heat test
   5) Damp heat test
   6) Vibration test
   7) Insulation resistance test
   8) High voltage test
   9) Static and dynamic inclinations.

3.2 Functional test process

3.2.1 *(1/7/2007)*

All tests to verify the functionality of crankcase oil mist detection and alarm equipment are to be carried out in accordance with [3.2.2] to [3.2.7] with an oil mist concentration in air, known in terms of mg/l to an accuracy of ±10%.

3.2.2 *(1/7/2007)*

The concentration of oil mist in the test chamber is to be measured in the top and bottom of the chamber and these concentrations are not to differ by more than 10% (see also item [3.4.1].

3.2.3 *(1/7/2016)*

The oil mist detector monitoring arrangements are to be capable of detecting oil mist in air concentrations of between 0 and 10% of the lower explosive limit (LEL) or between 0 and a percentage of weight of oil in air determined by the Manufacturer based on the sensor measurement method (e.g. obscuration or light scattering) that is acceptable to the Society taking into account the alarm level specified in [3.2.4].

The LEL corresponds to an oil mist concentration of approximately 50mg/l (about 4,1% weight of oil in air mixture).

3.2.4 *(1/7/2007)*

The alarm set point for oil mist concentration in air is to provide an alarm at a maximum level corresponding to not more than 5% of the LEL approximately 2,5 mg/l.

3.2.5 *(1/7/2007)*

Where alarm set points can be altered, the means of adjustment and indication of set points are to be verified against the equipment Manufacturer's instructions.

3.2.6 *(1/7/2016)*

The performance of the oil mist detector in mg/l is to be demonstrated. This is to include the following:

- range (oil mist detector)
- resolution (oil mist detector)
- sensitivity (oil mist detector).

Note 1: Sensitivity of a measuring system: quotient of the change in an indication of a measuring system and the corresponding change in a value of a quantity being measured.

Resolution: smallest change in a quantity being measured that causes a perceptible change in the corresponding indication.

3.2.7 *(1/7/2016)*

Where oil mist is drawn into a detector/monitor via piping arrangements, the time delay between the sample leaving the crankcase and operation of the alarm is to be determined for the longest and shortest lengths of pipes recommended by the Manufacturer. The pipe arrangements are to be in accordance with the Manufacturer's instructions/recommendations.

Piping is to be arranged to prevent pooling of oil condensate which may cause a blockage of the sampling pipe over time.

3.2.8 *(1/7/2016)*

It is to be demonstrated that the openings of detector equipment does not become occluded or blocked under continuous splash and spray of engine lubricating oil, as may occur in the crankcase atmosphere. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by the classification society. The temperature, quantity and angle of impact of the oil to be used is to be declared and their selection justified by the manufacturer.

3.2.9 *(1/7/2016)*

Detector equipment may be exposed to water vapour from the crankcase atmosphere which may affect its sensitivity and it is to be demonstrated that exposure to such conditions will not affect the functional operation of the detector equipment. Where exposure to water vapour and/or water condensation has been identified as a possible source of equipment malfunctioning, testing is to demonstrate that any mitigating arrangements, such as heating, are effective. Testing is to be in accordance with arrangements proposed by the Manufacturer and agreed by the Society.

This testing is in addition to that required by [3.1.1] b) 5) and is concerned with the effects of condensation caused by the detection equipment being at a lower temperature than the crankcase atmosphere.

3.2.10 *(1/7/2016)*

It is to be demonstrated that an indication is given where lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication as required in Sec 2, [4.3.5].

3.3 Detectors and alarm equipment to be tested

3.3.1 *(1/7/2009)*

The detectors and alarm equipment selected for the type testing are to be selected from the Manufacturer's normal production line by the QSCS Classification Society (see Pt A, Ch 1, Sec 1, [1.2.1]) witnessing the tests.

3.3.2 *(1/1/2007)*

Two detectors are to be tested. One is to be tested in clean condition and the other in a condition representing the maximum level of lens obscuration specified by the Manufacturer.

3.4 Method

3.4.1 *(1/1/2007)*

The following requirements are to be satisfied at type test.

3.4.2 *(1/7/2016)*

Oil mist generation is to satisfy the following items a) to e).

a) Oil mist is to be generated with suitable equipment using an SAE 40 monograde mineral oil or equivalent and supplied to a test chamber. The selection of the oil to be used is to take into consideration risks to health and safety, and the appropriate controls implemented. A low toxicity, low flammability oil of similar viscosity may be used as an alternative. The oil mist produced is to have an average (or arithmetic mean) droplet size not exceeding 5 μm. The

oil droplet size is to be checked using the sedimentation method or an equivalent method to a relevant international or national standard. If the sedimentation method is chosen, the test chamber is to have a minimum height of 1m and a volume of not less than 1 m^3.

Note 1: The calculated oil droplet size using the sedimentation method represents the average droplet size.

b) The oil mist concentrations used are to be ascertained by the gravimetric deterministic method or equivalent. Where an alternative technique is used its equivalence is to be demonstrated.

For this test, the gravimetric deterministic method is a process where the difference in weight of a 0,8 µm pore size membrane filter is ascertained from weighing the filter before and after drawing 1 litre of oil mist through the filter from the oil mist test chamber. The oil mist chamber is to be fitted with a recirculating fan.

c) Samples of oil mist are to be taken at regular intervals and the results plotted against the oil mist detector output. The oil mist detector is to be located adjacent to where the oil mist samples are drawn off.

d) The results of a gravimetric analysis are considered invalid and are to be rejected if the resultant calibration curve has an increasing gradient with respect to the oil mist detection reading. This situation occurs when insufficient time has been allowed for the oil mist to become homogeneous. Single results that are more than 10% below the calibration curve are to be rejected. This situation occurs when the integrity of the filter unit has been compromised and not all of the oil is collected on the filter paper.

e) The filters are required to be weighed to a precision of 0,1 mg and the volume of air/oil mist is to be sampled to 10 ml.

3.4.3 *(1/7/2016)*

For type approval the testing is to be witnessed by authorised personnel from the society.

3.4.4 *(1/7/2007)*

Oil mist detection equipment is to be tested in the orientation (vertical, horizontal or inclined) in which it is intended to be installed on an engine or gear case as specified by the equipment Manufacturer.

3.4.5 *(1/7/2016)*

Type testing is to be carried out for each type of oil mist detection and alarm equipment for which a Manufacturer seeks approval. Where sensitivity levels can be adjusted, testing is to be carried out at the extreme and mid-point level settings.

3.5 Assessment

3.5.1 *(1/7/2016)*

Assessment of oil mist detection equipment is to address the following points:

a) The equipment to be tested is to have evidence of design appraisal/approval by the QSCS Classification Society (see Pt A, Ch 1, Sec 1, [1.2.1]) witnessing the tests.

b) Details of the detection equipment to be tested are to be recorded and are to include:

- name of the Manufacturer
- type designation
- oil mist concentration assessment capability and alarm settings
- the maximum percentage level of lens obscuration used in [3.3.2].

c) After completion of the tests, the detection equipment is to be examined and the condition of all components ascertained and documented. Photographic records of the monitoring condition are to be taken and included in the report.

3.6 Design series qualification

3.6.1 *(1/1/2007)*

The approval of one detection/monitoring device may be used to qualify other devices having identical construction details. Proposals are to be submitted for consideration by the Society.

4 Report and approval

4.1 Report

4.1.1 *(1/7/2016)*

The test house is to provide a full report which includes the following information and documents:

a) test specification;

b) details of equipment tested;

c) results of tests.

The report is to include a declaration by the manufacturer of the oil mist detector of its:

- performance, in mg/L;
- accuracy, of oil mist concentration in air;
- precision, of oil mist concentration in air;
- range, of oil mist detector;
- resolution, of oil mist detector;
- response time, of oil mist detector;
- sensitivity, of oil mist detector;
- allowable obscuration of sensor detection, declared as percentage of obscuration. 0% totally clean, 100% totally obscure;
- detector failure alarm.

4.2 Approval

4.2.1 *(1/7/2007)*

Type approval of crankcase oil mist detection equipment is at the discretion of the Society based on the appraisal plans and particulars and on the test house report of the results of type testing.

4.2.2 *(1/7/2007)*

The following information is to be submitted to the Society for acceptance of oil mist detection and alarm arrangements:

a) Description of oil mist detection equipment and system including alarms.

b) Copy of the test house report identified in [4.1].

c) Schematic layout of engine oil mist detection arrangements showing location of detectors/sensors and piping arrangements and dimensions.

d) Maintenance and test manual, which is to include the following information:

   1) intended use of equipment and its operation

   2) functionality tests to demonstrate that the equipment is operational and that any faults can be identified and corrective actions communicated

   3) maintenance routines and spare parts recommendations

   4) limit setting and instructions for safe limit levels

   5) where necessary, details of configurations in which the equipment is and is not to be used.

APPENDIX 7 LNG FUELLED OR CNG FUELLED SHIPS

1 General

1.1 Application

1.1.1 *(1/1/2017)*

The provisions of this Appendix apply to the arrangement, installation, control and monitoring of machinery, equipment and systems of ships using low-flashpoint fuel other than ships covered by the IGC Code (hereinafter named 'gas-fuelled ships'). These ships are to comply with the requirements of the latest version of the International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels (IGF Code), as amended. In these Rules, reference to this Code and its amendments is made by the wording "IGF Code".

Consistently with the status of the IGF Code, the current version of this Appendix includes regulations to meet the functional requirements for natural gas fuel.

For other low-flashpoint fuels, compliance with the functional requirements of this Appendix is to be demonstrated through alternative design.

1.1.2 **Acceptance by the flag Administration** *(1/1/2017)*

The use of gas as fuel in ships requires additional acceptance by the Administration of the State whose flag the ship is entitled to fly.

1.1.3 **IGF Code requirements and the Society's rules** *(1/1/2017)*

a) For gas-fuelled ships, the IGF Code requirements are to be considered as rule requirements;

b) the requirements of this Appendix include additional mandatory class requirements, as well as the Society's interpretations of the IGF Code, which are also to be considered mandatory for Class;

c) in general, this Appendix applies to machinery, equipment and systems of gas-fuelled ships using low-flashpoint fuel and to the interfaces between these systems and the other parts of the ship, which are to comply with the applicable Sections of the hull and machinery Rules.

1.1.4 **IGF Code requirements and the Society's rules** *(1/1/2017)*

The following requirements of the IGF Code are not within the scope of classification:

- Chapter 11 - Fire Safety
- Chapter 17 - Drills and emergency exercises
- Chapter 18 - Operation
- Chapter 19 - Training.

These requirements are applied by the Society when acting on behalf of the flag Administration, within the scope of delegation (see [1.1.6]).

1.1.5 **Correspondence of the IGF Code with Part C Chapter 1, Appendix 7 ofthe Rules** *(1/1/2017)*

All the requirements of this Appendix are cross referenced to the applicable Chapters, Sections or paragraphs of the IGF Code, as appropriate.

1.1.6 **Certificate of Fitness** *(1/1/2017)*

The responsibility for interpretation of the IGF Code requirements for the purpose of issuing an International Certificate of Fitness for the Gas-fuelled Ships lies with the Administration of the state whose flag the ship is entitled to fly.

Whenever the Society is authorised by an Administration to issue on its behalf the "Certificate of Fitness for the Gas-Fuelled ships", or where the Society is authorised to carry out investigations and surveys on behalf of an Administration on the basis of which the "Certificate of Fitness for the Gas-Fuelled ships " will be issued by the Society, or where the Society is requested to certify compliance with the IGF Code, the full compliance with the requirements of the IGF Code, including the operative requirements mentioned in [1.1.4], is to be granted by the Administration.

1.2 Documentation to be submitted

1.2.1 *(1/1/2017)*

Tab 1 lists the plans, information, analysis, etc. which are to be submitted in addition to the information required in the other Parts of the Rules for the parts of the ship not affected by the cargo, as applicable.

Table 1 : Documents to be submitted *(1/1/2017)*

No.	I/A **(1)**	Document
1	I	Propulsion system general arrangement - Design philosophy including information on the machinery configuration, engine room arrangements, fuel arrangements, shutdown philosophy (if applicable), redundancy considerations etc. are to be submitted before other documentation
2	A	Fuel gas system Cause and effect diagram Test program for safety functions
3	A	Fuel gas system arrangement plan - including: • machinery and boiler spaces, accommodation, service and control station spaces • gas tanks and gas containment systems • gas pump and compressor rooms • gas bunkering pipes with shore connections • tank hatches, ventilation pipes and any other openings to gas tanks • ventilating pipes, doors and openings to gas pump rooms, compressor rooms and other hazardous areas • entrances, air inlets and openings to accommodation, service and control station spaces
4	I	Fuel gas system operational manual including procedures for: • bunkering • gas freeing and inerting • normal operation • emergency operation
5	A	Fuel gas tanks production process including: Drawings of: • tanks • supports and stays • secondary barriers • insulation • marking plates Fuel gas tank design analysis: • specification of design loads and structural analysis of gas tanks • complete stress analysis for independent tanks type B and type C. Fuel gas tank non-destructive testing (NDT) plan including: • information about strength and tightness testing • specification of stress relieving procedures for independent tanks type C (thermal or mechanical). Fuel gas tank welding procedures Fuel gas tank material specifications including connected pipes
6	A	Fuel gas tank safety relief valves and associated ventilation piping specification, detailed drawing and piping capacity analysis including back pressure
7	A	Fuel gas tank gas freeing and purging system piping diagram
8	A	Fuel gas tank control and monitoring system
9	A	Fuel gas piping system: Pipe routing sketch and thermal stress analysis when design temperature is below -110°C Piping diagram (including ventilation lines for safety relief valves or similar piping, and ducts for gas pipes)
(1) A = to be submitted for approval, in four copies I = to be submitted for information, in duplicate.		

No.	I/A **(1)**	Document
10	I	Fuel gas piping system - Specification of valves, flanges and fittings including offsets, loops, bends, expansion elements such as bellows and slip joints (only inside tanks). For valves intended for service with a design temperature below -55°C, documentation of leak test and functional test at design temperature (type test) is to be included
11	A	Fuel gas system drip trays - System arrangement plan - Hull protection beneath liquid piping where leakages may be anticipated, such as at shore connections and at pump seals. Including specification
12	I	Electrical bonding of piping - Specification
13	A	Cooling system - Piping diagram in connection with fuel gas system
14	A	Heating system - Piping diagram in connection with fuel gas system
15	A	Fuel gas compressor control and monitoring system
16	A	Fuel gas driven engines - Failure mode and effect analysis - Examination of all possible faults affecting the combustion process
17	A	Exhaust gas system - Piping diagram
18	A	Hazardous area classification drawing, including air-lock location, construction details and alarm equipment
19	A	Gastight bulkhead penetrations - Detailed drawing
20	A	Ventilation of gas fuel system spaces - Ducting diagram for spaces containing gas installations, such as gas pipe ducts led through enclosed spaces, and storage tanks below deck. Including capacity and location of fans and their motors
21	I	Explosion protection • System arrangement plan of electrical equipment in hazardous areas • Single line diagrams for all intrinsically safe circuits, for each circuit, including data for verification of the compatibility between the barrier and the field components • List of non-certified safe electrical equipment to be disconnected for ESD protected machinery spaces • Documentation to demonstrate the fulfilment of [4.3]
22	A	Fixed gas detection system arrangement plan Detectors, call points and alarm devices
23	A	Fire protection - Structural fire protection drawing in respect of gas installation arrangements
24	A	Fire protection - Fixed fire-extinguishing system for tank room
25	A	Fire protection - External surface protection water-spraying system
26	A	Fire protection - Bunkering station fire-fighting system
27	A	Fire detection and alarm system for storage tanks and ventilation trunks
28		FMEA of the whole gas-fuelled system
29	A	Test procedures of safety-critical items, in particular those related to the gas system as ascertained by the FMEA
30	I	Risk assessment required by paragraphs [5.10.5], [5.12.3], [6.4.1]a), [6.4.15].d)4)bullet2), [8.3.1]a), [12.4.1], [12.7] and [14.8.1] j) as well as by paragraphs [4.4] and [6.8] of the annex, as applicable
31	I	Documentation of alternative design as per [2], as applicable

(1) A = to be submitted for approval, in four copies
I = to be submitted for information, in duplicate.

1.3 Definitions

1.3.1 *(1/1/2017)*

IGF CODE REFERENCE: Ch. 2, 2.1

Unless otherwise stated below, definitions are as defined in SOLAS chapter II-2.

IGF CODE REFERENCE: Ch. 2, 2.2

1.3.2 *(1/1/2017)*

Accident means an uncontrolled event that may entail the loss of human life, personal injuries, environmental damage or the loss of assets and financial interests.

1.3.3 *(1/1/2017)*
Breadth (B) means the greatest moulded breadth of the ship at or below the deepest draught (summer load line draught) (refer to SOLAS regulation II-1/2.8).

1.3.4 *(1/1/2017)*
Bunkering means the transfer of liquid or gaseous fuel from land based or floating facilities into a ships' permanent tanks or connection of portable tanks to the fuel supply system.

1.3.5 *(1/1/2017)*
Certified safe type means electrical equipment that is certified safe by the relevant authorities recognized by the Society for operation in a flammable atmosphere based on a recognized standard.
Note 1: Refer to IEC 60079 series, Explosive atmospheres and IEC 60092-502:1999 Electrical Installations in Ships - Tankers - Special Features.

1.3.6 *(1/1/2017)*
CNG means compressed natural gas (see also [1.3.27]).

1.3.7 *(1/1/2017)*
Control station means those spaces defined in SOLAS chapter II-2 and additionally for this Appendix, the engine control room.

1.3.8 *(1/1/2017)*
Design temperature for selection of materials is the minimum temperature at which liquefied gas fuel may be loaded or transported in the liquefied gas fuel tanks.

1.3.9 *(1/1/2017)*
Design vapour pressure "P_0" is the maximum gauge pressure, at the top of the tank, to be used in the design of the tank.

1.3.10 *(1/1/2017)*
Double block and bleed valve means a set of two valves in series in a pipe and a third valve enabling the pressure release from the pipe between those two valves. The arrangement may also consist of a two-way valve and a closing valve instead of three separate valves.

1.3.11 *(1/1/2017)*
Dual fuel engines means engines that employ fuel covered by this Appendix (with pilot fuel) and oil fuel. Oil fuels may include distillate and residual fuels.

1.3.12 *(1/1/2017)*
Enclosed space means any space within which, in the absence of artificial ventilation, the ventilation will be limited and any explosive atmosphere will not be dispersed naturally.
Note 1: See also definition in IEC 60092-502:1999.

1.3.13 *(1/1/2017)*
ESD means emergency shutdown.

1.3.14 *(1/1/2017)*
Explosion means a deflagration event of uncontrolled combustion.

1.3.15 *(1/1/2017)*
Explosion pressure relief means measures provided to prevent the explosion pressure in a container or an enclosed space exceeding the maximum overpressure the container or space is designed for, by releasing the overpressure through designated openings.

1.3.16 *(1/1/2017)*
Fuel containment system is the arrangement for the storage of fuel including tank connections. It includes where fitted, a primary and secondary barrier, associated insulation and any intervening spaces, and adjacent structure if necessary for the support of these elements. If the secondary barrier is part of the hull structure it may be a boundary of the fuel storage hold space.
The spaces around the fuel tank are defined as follows:

a) fuel storage hold space is the space enclosed by the ship's structure in which a fuel containment system is situated. If tank connections are located in the fuel storage hold space, it will also be a tank connection space;

b) interbarrier space is the space between a primary and a secondary barrier, whether or not completely or partially occupied by insulation or other material; and

c) tank connection space is a space surrounding all tank connections and tank valves that is required for tanks with such connections in enclosed spaces.

1.3.17 *(1/1/2017)*
Filling limit (FL) means the maximum liquid volume in a fuel tank relative to the total tank volume when the liquid fuel has reached the reference temperature.

1.3.18 *(1/1/2017)*
Fuel preparation room means any space containing pumps, compressors and/or vaporizers for fuel preparation purposes.

1.3.19 *(1/1/2017)*
Gas means a fluid having a vapour pressure exceeding 0.28 MPa absolute at a temperature of 37.8°C.

1.3.20 *(1/1/2017)*
Gas consumer means any unit within the ship using gas as a fuel.

1.3.21 *(1/1/2017)*
Gas only engine means an engine capable of operating only on gas, and not able to switch over to operation on any other type of fuel.

1.3.22 *(1/1/2017)*
Hazardous area means an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment.

1.3.23 *(1/1/2017)*
High pressure means a maximum working pressure greater than 1.0 MPa.

1.3.24 *(1/1/2017)*
Independent tanks are self-supporting, do not form part of the ship's hull and are not essential to the hull strength.

1.3.25 *(1/1/2017)*
LEL means the lower explosive limit.

1.3.26 *(1/1/2017)*
Length (L) is the length as defined in the International Convention on Load Lines in force.

1.3.27 *(1/1/2017)*
LNG means liquefied natural gas.

1.3.28 *(1/1/2017)*
Loading limit (LL) means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded.

1.3.29 *(1/1/2017)*
Low-flashpoint fuel means gaseous or liquid fuel having a flashpoint lower than otherwise permitted under paragraph 2.1.1 of SOLAS regulation II-2/4.

1.3.30 *(1/1/2017)*
MARVS means the maximum allowable relief valve setting.

1.3.31 *(1/1/2017)*
MAWP means the maximum allowable working pressure of a system component or tank.

1.3.32 *(1/1/2017)*
Membrane tanks are non-self-supporting tanks that consist of a thin liquid and gas tight layer (membrane) supported through insulation by the adjacent hull structure.

1.3.33 *(1/1/2017)*
Multi-fuel engines means engines that can use two or more different fuels that are separate from each other.

1.3.34 *(1/1/2017)*

Non-hazardous area means an area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of equipment.

1.3.35 *(1/1/2017)*

Open deck means a deck having no significant fire risk that at least is open on both ends/sides, or is open on one end and is provided with adequate natural ventilation that is effective over the entire length of the deck through permanent openings distributed in the side plating or deckhead.

1.3.36 *(1/1/2017)*

Risk is an expression for the combination of the likelihood and the severity of the consequences.

1.3.37 *(1/1/2017)*

Reference temperature means the temperature corresponding to the vapour pressure of the fuel in a fuel tank at the set pressure of the pressure relief valves (PRVs).

1.3.38 *(1/1/2017)*

Secondary barrier is the liquid-resisting outer element of a fuel containment system designed to afford temporary containment of any envisaged leakage of liquid fuel through the primary barrier and to prevent the lowering of the temperature of the ship's structure to an unsafe level.

1.3.39 *(1/1/2017)*

Semi-enclosed space means a space where the natural conditions of ventilation are notably different from those on open deck due to the presence of structure such as roofs, windbreaks and bulkheads and which are so arranged that dispersion of gas may not occur.

Note 1: Refer also to IEC 60092-502:1999 Electrical Installations in Ships - Tankers - Special Features.

1.3.40 *(1/1/2017)*

Source of release means a point or location from which a gas, vapour, mist or liquid may be released into the atmosphere so that an explosive atmosphere could be formed.

1.3.41 *(1/1/2017)*

Unacceptable loss of power means that it is not possible to sustain or restore normal operation of the propulsion machinery in the event of one of the essential auxiliaries becoming inoperative, in accordance with SOLAS regulation II-1/26.3.

1.3.42 *(1/1/2017)*

Vapour pressure is the equilibrium pressure of the saturated vapour above the liquid, expressed in MPa absolute at a specified temperature.

2 Alternative design

IGF CODE REFERENCE: Ch. 2, 2.3

2.1 Deviation, equivalence and operational measures

2.1.1 *(1/1/2017)*

Fuels, appliances and arrangements of low-flashpoint fuel systems may either:

a) deviate from those set out in this Appendix, or

b) be designed for use of a fuel not specifically addressed in this Appendix.

Such fuels, appliances and arrangements can be used provided that these meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant paragraphs.

2.1.2 *(1/1/2017)*

The equivalence of the alternative design is to be demonstrated as specified in SOLAS regulation II-1/55, and approved by the Administration. Operational methods or procedures will not be allowed as an alternative to a particular fitting, material, appliance, apparatus, item of equipment, or type thereof which is prescribed by this Appendix.

3 Goal and functional requirements

IGF CODE REFERENCE: Ch. 3

3.1 Goal

3.1.1 *(1/1/2017)*
The goal of this Appendix is to provide for safe and environmentally-friendly design, construction and operation of ships and in particular their installations of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery using gas or low-flashpoint fuel as fuel.

3.2 Functional requirements

3.2.1 *(1/1/2017)*
The safety, reliability and dependability of the systems is to be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery. A FMEA consistent with the "TASNEEF Guide for FMEA" is to be carried out for the whole gas-fuelled system, including process system, electrical power supplies and control system, to check the potential existence of failure modes that can jeopardize the ship's safety. The results of the FMEA are then to be used to establish a trial program.

3.2.2 *(1/1/2017)*
The probability and consequences of fuel-related hazards are to be limited to a minimum through arrangement and system design, such as ventilation, detection and safety actions. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions are to be initiated.

3.2.3 *(1/1/2017)*
The design philosophy is to ensure that risk reducing measures and safety actions for the gas fuel installation do not lead to an unacceptable loss of power.

3.2.4 *(1/1/2017)*
Hazardous areas are to be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment.

3.2.5 *(1/1/2017)*
Equipment installed in hazardous areas are to be minimized to that required for operational purposes and are to be suitably and appropriately certified.

3.2.6 *(1/1/2017)*
Unintended accumulation of explosive, flammable or toxic gas concentrations are to be prevented.

3.2.7 *(1/1/2017)*
System components are to be protected against external damages.

3.2.8 *(1/1/2017)*
Sources of ignition in hazardous areas are to be minimized to reduce the probability of explosions.

3.2.9 *(1/1/2017)*
It is to be arranged for safe and suitable fuel supply, storage and bunkering arrangements capable of receiving and containing the fuel in the required state without leakage. Other than when necessary for safety reasons, the system is to be designed to prevent venting under all normal operating conditions including idle periods.

3.2.10 *(1/1/2017)*
Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application are to be provided.

3.2.11 *(1/1/2017)*
Machinery, systems and components are to be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.

3.2.12 *(1/1/2017)*
Fuel containment system and machinery spaces containing source that might release gas into the space are to be arranged and located such that a fire or explosion in either will not lead to an unacceptable loss of power or render equipment in other compartments inoperable.

3.2.13 *(1/1/2017)*
Suitable control, alarm, monitoring and shutdown systems are to be provided to ensure safe and reliable operation.

3.2.14 *(1/1/2017)*

Fixed gas detection suitable for all spaces and areas concerned are to be arranged.

3.2.15 *(1/1/2017)*

Fire detection, protection and extinction measures appropriate to the hazards concerned are to be provided.

3.2.16 *(1/1/2017)*

Commissioning, trials and maintenance of fuel systems and gas utilization machinery are to satisfy the goal in terms of safety, availability and reliability.

3.2.17 *(1/1/2017)*

The technical documentation is to permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.

3.2.18 *(1/1/2017)*

A single failure in a technical system or component is not to lead to an unsafe or unreliable situation.

4 General requirements

IGF CODE REFERENCE: Ch. 4, 4.1

4.1 Goal

4.1.1 *(1/1/2017)*

The goal of this paragraph is to ensure that the necessary assessments of the risks involved are carried out in order to eliminate or mitigate any adverse effect to the persons on board, the environment or the ship.

4.2 Risk assessment

IGF CODE REFERENCE: Ch. 4, 4.2

4.2.1 *(1/1/2017)*

A risk assessment is to be conducted to ensure that risks arising from the use of low-flashpoint fuels affecting persons on board, the environment, the structural strength or the integrity of the ship are addressed. Consideration are to be given to the hazards associated with physical layout, operation and maintenance, following any reasonably foreseeable failure.

4.2.2 *(1/1/2025)*

For ships to which this Appendix applies, the risk assessment required by [4.2.1] *need only be conducted where explicitly required by paragraphs [*5.11.5], [5.13.3], [6.4.1], [8.3.1] a), [12.4.1], [12.7] and [14.8.1] j) *as well as by paragraphs* [4.4] and [6.8] *of this Appendix.*

4.2.3 *(1/1/2017)*

The risks are to be analysed using acceptable and recognized risk analysis techniques, and loss of function, component damage, fire, explosion and electric shock are as a minimum to be considered. The analysis is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as necessary. Details of risks, and the means by which they are mitigated, are to be documented to the satisfaction of the Society. Guidance on risk analysis techniques can be found in the "TASNEEF Guide on Risk Analysis".

4.2.4 *(1/1/2017)*

The assumptions for the risk assessment are to be agreed by a design team acceptable to the Administration. It may include a representative of Class, owner, builder or designer, and expert(s) having the necessary knowledge and experience in safety, design and/or operation as necessary for the specific evaluation at hand. Other members may include marine surveyors, ship operators, safety engineers, equipment manufacturers, human factors experts, naval architects and marine engineers, according to the problem under scope.

4.3 Limitation of explosion consequences

IGF CODE REFERENCE: Ch. 4, 4.3

4.3.1 *(1/1/2017)*

The preferred safety policy is to be the elimination of either any source of release or any source of ignition, or both. Only in case this is demonstrated not to be feasible, the following applies.

An explosion in any space containing any potential sources of release (note 1) and potential ignition sources is not to:

a) cause damage to or disrupt the proper functioning of equipment/systems located in any space other than that in which the incident occurs;

b) damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur;

c) damage work areas or accommodation in such a way that persons who stay in such areas under normal operating conditions are injured;

d) disrupt the proper functioning of control stations and switchboard rooms necessary for power distribution;

e) damage life-saving equipment or associated launching arrangements;

f) disrupt the proper functioning of fire-fighting equipment located outside the explosion-damaged space;

g) affect other areas of the ship in such a way that chain reactions involving, inter alia, cargo, gas and bunker oil may arise; or

h) prevent persons access to life-saving appliances or impede escape routes.

The aforesaid points are to be demonstrated in a way acceptable to the Society.

Note 1: Double wall fuel pipes are not considered as potential sources of release.

5 Ship design and arrangement

IGF CODE REFERENCE: Part A-1: Specific requirements for ships using natural gas as fuel

5.1 Intended fuel

5.1.1 *(1/1/2017)*

Fuel in the context of the regulations in this part means natural gas, either in its liquefied or gaseous state.

It should be recognized that the composition of natural gas may vary depending on the source of natural gas and the processing of the gas.

5.2 Goal

IGF CODE REFERENCE: Ch. 5, 5.1

5.2.1 *(1/1/2017)*

The goal of this paragraph [5.2] is to provide for safe location, space arrangements and mechanical protection of power generation equipment, fuel storage systems, fuel supply equipment and refuelling systems.

5.3 Functional requirements

IGF CODE REFERENCE: Ch. 5, 5.2

5.3.1 *(1/1/2017)*

This paragraph [5.3] is related to functional requirements in [3.2.1] to [3.2.3], [3.2.5], [3.2.6], [3.2.8], [3.2.12] to [3.2.15] and [3.2.17]. In particular the following apply:

a) the fuel tank(s) are to be located in such a way that the probability for the tank(s) to be damaged following a collision or grounding is reduced to a minimum taking into account the safe operation of the ship and other hazards that may be relevant to the ship;

b) fuel containment systems, fuel piping and other fuel sources of release are to be so located and arranged that released gas is lead to a safe location in the open air;

c) the access or other openings to spaces containing fuel sources of release are to be so arranged that flammable, asphyxiating or toxic gas cannot escape to spaces that are not designed for the presence of such gases;

d) fuel piping is to be protected against mechanical damage;

e) the propulsion and fuel supply system are to be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power; and

f) the probability of a gas explosion in a machinery space with gas or low-flashpoint fuelled machinery is to be minimized.

5.4 Regulations - General

IGF CODE REFERENCE: Ch. 5, 5.3

5.4.1 *(1/1/2017)*

Fuel storage tanks are to be protected against mechanical damage.

5.4.2 *(1/1/2017)*

Fuel storage tanks and/or equipment located on open deck are to be located to ensure sufficient natural ventilation, so as to prevent accumulation of escaped gas.

5.4.3 *(1/1/2017)*

The fuel tank(s) shall be protected from external damage caused by collision or grounding in the following way:

a) *The fuel tanks shall be located at a minimum distance of B/5 or 11.5 m, whichever is less, measured inboard from the ship side at right angles to the centreline at the level of the summer load line draught; where:*

   B is the greatest moulded breadth of the ship at or below the deepest draught (summer load line draught) (refer to SOLAS regulation II-1/2.8).

b) *The boundaries of each fuel tank shall be taken as the extreme outer longitudinal, transverse and vertical limits of the tank structure including its tank valves.*

c) *For independent tanks the protective distance shall be measured to the tank shell (the primary barrier of the tank containment system). For membrane tanks the distance shall be measured to the bulkheads surrounding the tank insulation.*

d) *In no case shall the boundary of the fuel tank be located closer to the shell plating or aft terminal of the ship than as follows:*

   1) *For passenger ships: B/10 but in no case less than 0.8 m. However, this distance need not be greater than B/15 or 2 m whichever is less where the shell plating is located inboard of B/5 or 11.5 m, whichever is less, as required by a).*

   2) *For cargo ships:*

      - *for V_c below or equal 1,000 m^3, 0.8 m;*
      - *for 1,000 m^3 < Vc < 5,000 m^3, 0.75 + V_c x 0.2/4,000 m;*
      - *for 5,000 m^3 $\leq V_c$ < 30,000 m^3, 0.8 + V_c/25,000 m; and*
      - *for $V_c \leq$ 30,000 m^3, 2 m,*

      where:

      V_c corresponds to 100% of the gross design volume of the individual fuel tank at 20°C, including domes and appendages.

e) *The lowermost boundary of the fuel tank(s) shall be located above the minimum distance of B/15 or 2.0 m, whichever is less, measured from the moulded line of the bottom shell plating at the centreline.*

f) *For multihull ships the value of B may be specially considered.*

g) *The fuel tank(s) shall be abaft a transverse plane at 0.08L measured from the forward perpendicular in accordance with SOLAS regulation II-1/8.1 for passenger ships, and abaft the collision bulkhead for cargo ships.*

   Where:

   L is the length as defined in the International Convention on Load Lines (refer to SOLAS regulation II-1/2.5).

h) *For ships with a hull structure providing higher collision and/or grounding resistance, fuel tank location regulations may be specially considered in accordance with section 2.3.*

5.4.4 *(1/1/2017)*

As an alternative to [5.4.3] a) above, the following calculation method may be used to determine the acceptable location of the fuel tanks:

a) *the value f_{CN} calculated as described in the following shall be less than 0,02 for passenger ships and 0,04 for cargo ships (see Note 1);*

b) *the f_{CN} is calculated by the following formulation:*

   $f_{CN} = f_l \times f_t \times f_v$

   where:

f_l is calculated by use of the formulations for factor p contained in SOLAS regulation II-1/7-1.1.1.1. The value of x1 shall correspond to the distance from the aft terminal to the aftmost boundary of the fuel tank and the value of x 2 shall correspond to the distance from the aft terminal to the foremost boundary of the fuel tank.

f_t is calculated by use of the formulations for factor r contained in SOLAS regulation II-1/7-1.1.2, and reflects the probability that the damage penetrates beyond the outer boundary of the fuel tank. The formulation is:

$f_t = 1 - r (x_1, x_2, b)$ see Note 2

f_v is calculated by use of the formulations for factor v contained in SOLAS regulation II-1/7-2.6.1.1 and reflects the probability that the damage is not extending vertically above the lowermost boundary of the fuel tank. The formulations to be used are:

$f_v = 1,0 − 0,8· ((H−d) / 7,8)$, if (H−d) is less than or equal to 7,8 m. f_v shall not be taken greater than 1.

$f_v = 0,2 − (0,2 · ((H−d)−7,8)/4,7)$, in all other cases f_v shall not be taken less than 0.

where:

H is the distance from baseline, in metres, to the lowermost boundary of the fuel tank; and

d is the deepest draught (summer load line draught).

Note 1: The value f_{CN} accounts for collision damages that may occur within a zone limited by the longitudinal projected boundaries of the fuel tank only, and cannot be considered or used as the probability for the fuel tank to become damaged given a collision. The real probability will be higher when accounting for longer damages that include zones forward and aft of the fuel tank.

Note 2: When the outermost boundary of the fuel tank is outside the boundary given by the deepest subdivision waterline the value of b should be taken as 0.

c) The boundaries of each fuel tank shall be taken as the extreme outer longitudinal, transverse and vertical limits of the tank structure including its tank valves.

d) For independent tanks the protective distance shall be measured to the tank shell (the primary barrier of the tank containment system). For membrane tanks the distance shall be measured to the bulkheads surrounding the tank insulation.

e) In no case shall the boundary of the fuel tank be located closer to the shell plating or aft terminal of the ship than as follows:

1) For passenger ships: B/10 but in no case less than 0,8 m. However, this distance need not be greater than B/15 or 2 m whichever is less where the shell plating is located inboard of B/5 or 11.5 m, whichever is less, as required by [5.4.3] a).

2) For cargo ships:

- *for V_c below or equal 1,000 m^3, 0.8 m;*
- *for 1000 m^3 < V_c < 5000 m^3, 0,75 + V_c x 0,2/4000 m;*
- *for 5000 m^3 ≤ V_c < 30000 m^3, 0,8 + V_c/25000 m; and*
- *for V_c ≤ 30000 m^3, 2 m,*

where:

V_c corresponds to 100% of the gross design volume of the individual fuel tank at 20°C, including domes and appendages.

f) In case of more than one non-overlapping fuel tank located in the longitudinal direction, f_{CN} shall be calculated in accordance with paragraph item b) for each fuel tank separately. The value used for the complete fuel tank arrangement is the sum of all values for f_{CN} obtained for each separate tank.

g) In case the fuel tank arrangement is unsymmetrical about the centreline of the ship, the calculations of f_{CN} shall be calculated on both starboard and port side and the average value shall be used for the assessment. The minimum distance as set forth in paragraph item e) shall be met on both sides.

h) For ships with a hull structure providing higher collision and/or grounding resistance, fuel tank location regulations may be specially considered in accordance with section 2.3.

5.4.5 *(1/1/2017)*

When fuel is carried in a fuel containment system requiring a complete or partial secondary barrier:

a) fuel storage hold spaces shall be segregated from the sea by a double bottom; and

b) the ship shall also have a longitudinal bulkhead forming side tanks.

5.5 Machinery space concepts

IGF CODE REFERENCE: Ch. 5, 5.4

5.5.1 *(1/1/2017)*

In order to minimize the probability of a gas explosion in a machinery space with gas-fuelled machinery one of these two alternative concepts may be applied:

a) Gas safe machinery spaces: Arrangements in machinery spaces are such that the spaces are considered gas safe under all conditions, normal as well as abnormal conditions, i.e. inherently gas safe.

In a gas safe machinery space a single failure cannot lead to release of fuel gas into the machinery space.

b) ESD-protected machinery spaces: Arrangements in machinery spaces are such that the spaces are considered non-hazardous under normal conditions, but under certain abnormal conditions may have the potential to become hazardous. In the event of abnormal conditions involving gas hazards, emergency shutdown (ESD) of non-safe equipment (ignition sources) and machinery is to be automatically executed while equipment or machinery in use or active during these conditions is to be of a certified safe type.

In an ESD protected machinery space a single failure may result in a gas release into the space. Venting is designed to accommodate a probable maximum leakage scenario due to technical failures.

Failures leading to dangerous gas concentrations, e.g. gas pipe ruptures or blow out of gaskets are covered by explosion pressure relief devices and ESD arrangements.

5.5.2 *(1/1/2017)*

Fuel storage tanks and/or equipment located on open deck are to be located to ensure sufficient natural ventilation, so as to prevent accumulation of escaped gas.

5.6 Regulations for gas safe machinery space

IGF CODE REFERENCE: Ch. 5, 5.5

5.6.1 *(1/1/2017)*

A single failure within the fuel system is not to lead to a gas release into the machinery space.

5.6.2 *(1/1/2017)*

All fuel piping within machinery space boundaries is to be enclosed in a gas tight enclosure in accordance with [9.6].

5.7 Regulations for ESD-protected machinery spaces

IGF CODE REFERENCE: Ch. 5, 5.6

5.7.1 *(1/1/2017)*

ESD protection is to be limited to machinery spaces that are certified for periodically unattended operation.

5.7.2 *(1/1/2017)*

Measures are to be applied to protect against explosion, damage of areas outside of the machinery space and ensure redundancy of power supply. The following arrangement is to be provided but may not be limited to:

a) gas detector;

b) shutoff valve;

c) redundancy; and

d) efficient ventilation

5.7.3 *(1/1/2017)*

IGF CODE REFERENCE: Ch. 5, 5.6.3

Gas supply piping within machinery spaces may be accepted without a gastight external enclosure on the following conditions:

a) engines for generating propulsion power and electric power are to be located in two or more machinery spaces not having any common boundaries unless it can be documented that a single casualty will not affect both spaces;

b) the gas machinery space is to contain only a minimum of such necessary equipment, components and systems as are required to ensure that the gas machinery maintains its function;

c) a fixed gas detection system arranged to automatically shutdown the gas supply, and disconnect all electrical equipment or installations not of a certified safe type, is to be fitted.

5.7.4 *(1/1/2017)*

IGF CODE REFERENCE: Ch. 5, 5.6.4

Distribution of engines between the different machinery spaces is to be such that shutdown of fuel supply to any one machinery space does not lead to an unacceptable loss of power.

5.7.5 *(1/1/2017)*

IGF CODE REFERENCE: Ch. 5, 5.6.5

ESD protected machinery spaces separated by a single bulkhead is to have sufficient strength to withstand the effects of a local gas explosion in either space, without affecting the integrity of the adjacent space and equipment within that space.

5.7.6 *(1/1/2017)*

IGF CODE REFERENCE: Ch. 5, 5.6.6

ESD protected machinery spaces is to be designed to provide a geometrical shape that will minimize the accumulation of gases or formation of gas pockets.

5.7.7 *(1/1/2017)*

IGF CODE REFERENCE: Ch. 5, 5.6.7

The ventilation system of ESD-protected machinery spaces is to be arranged in accordance with [12.5].

5.8 Regulations for location and protection of fuel piping

IGF CODE REFERENCE: Ch. 5, 5.7

5.8.1 *(1/1/2017)*

Fuel pipes are not to be located less than 800 mm from the ship's side.

5.8.2 *(1/1/2017)*

Fuel piping is not to be led directly through accommodation spaces, service spaces, electrical equipment rooms or control stations as defined in the SOLAS Convention.

5.8.3 *(1/1/2017)*

Fuel pipes led through ro-ro spaces, special category spaces and on open decks are to be protected against mechanical damage.

5.8.4 *(1/1/2017)*

Gas fuel piping in ESD protected machinery spaces are to be located as far as practicable from the electrical installations and tanks containing flammable liquids.

5.8.5 *(1/1/2017)*

Gas fuel piping in ESD protected machinery spaces are to be protected against mechanical damage.

5.9 Regulations for fuel preparation room design

IGF CODE REFERENCE: Ch. 5, 5.8

5.9.1 *(1/1/2017)*

Fuel preparation rooms are to be located on an open deck, unless those rooms are arranged and fitted in accordance with the rrequirements of this Appendix for tank connection spaces.

5.10 Regulations for bilge systems

IGF CODE REFERENCE: Ch. 5, 5.9

5.10.1 *(1/1/2017)*

Bilge systems installed in areas where fuel covered by this Appendix can be present are to be segregated from the bilge system of spaces where fuel cannot be present.

5.10.2 *(1/1/2017)*

Where fuel is carried in a fuel containment system requiring a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through the adjacent ship structure are to be provided. The bilge system is not to lead to pumps in safe spaces. Means of detecting such leakage are to be provided.

5.10.3 *(1/1/2017)*

The hold or interbarrier spaces of type A independent tanks for liquid gas are to be provided with a drainage system suitable for handling liquid fuel in the event of fuel tank leakage or rupture.

5.11 Regulations for drip trays

IGF CODE REFERENCE: Ch. 5, 5.10

5.11.1 *(1/1/2017)*

Drip trays are to be fitted where leakage may occur which can cause damage to the ship structure or where limitation of the area which is effected from a spill is necessary.

5.11.2 *(1/1/2017)*

Drip trays are to be made of suitable material.

5.11.3 *(1/1/2017)*

The drip tray are to be thermally insulated from the ship's structure so that the surrounding hull or deck structures are not exposed to unacceptable cooling, in case of leakage of liquid fuel.

5.11.4 *(1/1/2017)*

Each tray is to be fitted with a drain valve to enable rain water to be drained over the ship's side.

5.11.5 *(1/1/2017)*

Each tray is to have a sufficient capacity to ensure that the maximum amount of spill according to the risk assessment can be handled.

5.11.6 *(1/1/2017)*

The risk assessment is to follow the steps outlined below.

a) The design team is to conduct a Hazard Identification (HAZID) to agree on the scenarios to be subjected to the risk analysis, and on the assumptions regarding the most critical events (typically, connection failures causing an LNG spill).

b) Reasonable assumptions on the extent of connection failures or other selected events and the process parameters of the LNG are to be made by the design team, preferably on the basis of statistics available in the public domain or provided and documented by stakeholders.

c) Reasonable assumptions on the operation of ventilation system are to be made according to layout and procedures of the affected space.

d) In order to verify the drip tray capacity, a specific simulation is to be set up, aimed at evaluating the maximum amount of LNG spilled onto the drip tray, the evaporation rate, and the possibility to fully accommodate the LNG in the drip tray. The dispersion of methane resulting from LNG evaporation in the affected space is also to be ascertained.

e) The simulation is to be conducted by commercially available and validated tools (typically, by CFD tools). It is to focus on the calculation of the amount of LNG spilled before the stop of LNG flow.

f) For the sake of conservatism, in order to maximize the accumulation of LNG onto the drip tray, LNG release is to be directed downward, impinging on the drip tray, and ambient temperature is to be set to the minimum credible winter temperature. Equipment and space surfaces and drip tray are to be considered adiabatic, to conservatively minimize the heat exchange with the LNG droplets, and to increase the amount of liquid accumulated in the drip tray.

g) Reasonable assumptions are to be made by the design team regarding detection time, LNG flow stop time and human reaction time, in case operators are credited in the emergency

If the simulation demonstrates that the drip tray cannot accommodate the LNG spill, mitigating measures are to be provided and subjected to the same simulation process, to appreciate the risk reduction.

5.12 Regulations for arrangement of entrances and other openings in enclosed spaces

IGF CODE REFERENCE: Ch. 5, 5.11

5.12.1 *(1/1/2017)*

Direct access is not to be permitted from a non-hazardous area to a hazardous area. Where such openings are necessary for operational reasons, an airlock which complies with [5.13] is to be provided.

5.12.2 *(1/1/2017)*

If the fuel preparation room is approved located below deck, the room is, as far as practicable, to have an independent access direct from the open deck. Where a separate access from deck is not practicable, an airlock which complies with [5.13] is to be provided.

5.12.3 *(1/1/2017)*

Unless access to the tank connection space is independent and direct from open deck it is to be arranged as a bolted hatch. The space containing the bolted hatch will be a hazardous space.

5.12.4 *(1/1/2017)*

If the access to an ESD-protected machinery space is from another enclosed space in the ship, the entrances are to be arranged with an airlock which complies with [5.13].

5.12.5 *(1/1/2017)*

For inerted spaces access arrangements are to be such that unintended entry by personnel are to be prevented. If access to such spaces is not from an open deck, sealing arrangements are to ensure that leakages of inert gas to adjacent spaces are prevented.

5.13 Regulations for airlocks

IGF CODE REFERENCE: Ch. 5, 5.12

5.13.1 *(1/1/2017)*

An airlock is a space enclosed by gastight bulkheads with two substantially gastight doors spaced at least 1,5 m and not more than 2,5 m apart. Unless subject to the requirements of the International Convention on Load Lines, the door sill is not be less than 300 mm in height. The doors are not to be self-closing without any holding back arrangements.

5.13.2 *(1/1/2017)*

Airlocks are to be mechanically ventilated at an overpressure relative to the adjacent hazardous area or space.

5.13.3 *(1/1/2017)*

The airlocks are to be designed in a way that no gas can be released to safe spaces in case of the most critical event in the gas dangerous space separated by the airlock. The events are to be evaluated in the risk analysis according to [4.2].

For this purpose, the design team is to conduct a Hazard Identification (HAZID) to agree on the airlocks to be subjected to the risk analysis, and on the assumptions regarding the most critical events.

In order to assess the structural integrity of the room and the suitability of the designed airlock, the maximum pressure within the spaces identified by the HAZID has to be evaluated, considering the effectiveness of the ventilation system. This calls for a simulation by means of the tools mentioned in [5.11.6]. The following steps, as a minimum, are to be performed.

a) Representative accidental scenarios of loss of LNG from failures in process or containment systems are to be selected by the design team in the identified spaces. The simulation is to focus on the calculation of the amount of LNG spilled before the stop of the LNG flow

b) Reasonable assumptions on the extent of containment failure and the process parameters of the LNG are to be made by the design team, preferably on the basis of statistics available in the public domain or provided and documented by stakeholders.

c) Reasonable assumptions on the operation of ventilation system are to be made according to layout and procedures of the selected spaces.

d) For the sake of conservatism, in order to maximize the accumulation of LNG onto the space floor, LNG release is to be directed downward, impinging on the floor, and ambient temperature is to be set to the maximum credible summer temperature in the space. The surfaces are to be considered isothermal at ambient temperature, to conservatively increase the evaporation rate and, consequently, the pressure buildup.

e) Reasonable assumptions are to be made by the design team regarding detection time, LNG flow stop time and human reaction time, in case operators are credited in the emergency.

If the simulation demonstrates that the analysed airlocks cannot prevent gas release in safe space, mitigating measures are to be provided and subjected to the same simulation process, to appreciate the risk reduction.

5.13.4 *(1/1/2017)*
Airlocks are to have a simple geometrical form. They are to provide free and easy passage, and are to have a deck area not less than 1,5 m^2. Airlocks are not to be used for other purposes, for instance as store rooms.

5.13.5 *(1/1/2017)*
An audible and visual alarm system to give a warning on both sides of the airlock is to be provided to indicate if more than one door is moved from the closed position.

5.13.6 *(1/1/2017)*
For non-hazardous spaces with access from hazardous spaces below deck where the access is protected by an airlock, upon loss of underpressure in the hazardous space access to the space is to be restricted until the ventilation has been reinstated. Audible and visual alarms are to be given at a manned location to indicate both loss of pressure and opening of the airlock doors when pressure is lost.

5.13.7 *(1/1/2017)*
Essential equipment required for safety is not to be de-energized and is to be of a certified safe type. This may include lighting, fire detection, public address, general alarms systems.

6 Fuel containment system

IGF CODE REFERENCE: Ch. 6

6.1 Goal

6.1.1 *(1/1/2017)*
The goal of this paragraph [6] is to provide that gas storage is adequate so as to minimize the risk to personnel, the ship and the environment to a level that is equivalent to a conventional oil fuelled ship.

6.2 Functional requirements

6.2.1 *(1/1/2017)*
This *paragraph [6.2]* relates to functional requirements in [3.2.1], [3.2.2], [3.2.5] and [3.2.8] to [3.2.17]. In particular the following apply:

a) the fuel containment system is to be so designed that a leak from the tank or its connections does not endanger the ship, persons on board or the environment. Potential dangers to be avoided include:
   1) exposure of ship materials to temperatures below acceptable limits;
   2) flammable fuels spreading to locations with ignition sources;
   3) toxicity potential and risk of oxygen deficiency due to fuels and inert gases;
   4) restriction of access to muster stations, escape routes and life-saving appliances (LSA); and
   5) reduction in availability of LSA.

b) the pressure and temperature in the fuel tank are to be kept within the design limits of the containment system and possible carriage requirements of the fuel;

c) the fuel containment arrangement is to be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power; and

d) if portable tanks are used for fuel storage, the design of the fuel containment system is to be equivalent to permanent installed tanks as described in this paragraph.

6.3 Regulations - General

6.3.1 *(1/1/2025)*
The requirements in IGF Code 6.3 apply.

6.4 Regulations for liquefied gas fuel containment

6.4.1 General *(1/1/2025)*
The requirements in IGF Code 6.4 apply.

The risk assessment required in [4.2] is to include evaluation of the ship's liquefied gas fuel containment system, and may lead to additional safety measures for integration into the overall vessel design.

6.4.2 Guidelines for risk assessment *(1/1/2025)*

For the purpose of implementing [6.4.1], the design team is to conduct a Hazard Identification (HAZID) to agree on the scenarios to be subjected to the risk analysis, and on the assumptions regarding the most critical events. If such scenarios are liquid spills or gas releases, their effects in the affected spaces (in particular, pressure buildup and low temperature effects) are to be simulated by means of the tools mentioned in [5.11.6]. The following steps, as a minimum, are to be performed.

a) Representative accidental scenarios of loss of LNG or methane from failures in process or containment systems are to be selected by the design team in the identified spaces.

b) Reasonable assumptions on the extent of containment failure and the process parameters of the LNG or methane are to be made by the design team, preferably on the basis of statistics available in the public domain or provided and documented by stakeholders.

c) Reasonable assumptions on the operation of ventilation system are to be made according to layout and procedures of the selected spaces.

d) For the sake of conservatism, in order to maximize the accumulation of LNG onto the space floor, LNG release is to be directed downward, impinging on the floor, and ambient temperature is to be set to the maximum credible summer temperature in the space. The surfaces are to be considered isothermal at ambient temperature, to conservatively increase the evaporation rate and, consequently, the pressure buildup.

e) Reasonable assumptions are to be made by the design team regarding detection time, LNG flow stop time, flow through relief valves and human reaction time, in case operators are credited in the emergency.

If the simulation demonstrates that an analysed scenario may cause the failure of the containment, mitigating measures are to be provided and subjected to the same simulation process, to appreciate the risk reduction.

6.4.3 *(1/1/2025)*

The requirements in IGF Code 6.4.1.2 to 6.4.16.4 apply taking into account the provisions in [6.4.4] to [6.4.11].

6.4.4 **Loads due to ship motions** *(1/1/2025)*

IGF CODE REFERENCE: Ch. 6, 6.4.9.4.1.1

Dynamic loads acting on tanks are to take into account the long-term distribution of ship accelerations in irregular seas according to Pt B, Ch 5, Sec 1, [2.1.4].

6.4.5 **Sloshing loads** *(1/1/2025)*

IGF CODE REFERENCE: Ch. 6, 6.4.9.4.1.3

Sloshing loads are to be evaluated according to Pt B, Ch 5, Sec 6, [2] including the possibility of alternative methods (see Pt B, Ch 5, Sec 6, [2.2.8]).

6.4.6 **Fatigue Design Condition** *(1/1/2025)*

IGF CODE REFERENCE: Ch. 6, 6.4.12.2

The C_w parameter, maximum allowable cumulative fatigue damage ratio, needs not to be taken lower than the maximum value prescribed in the IGF Code reference i.e. either 0,5 or 0,1 according to the different types of failures considered.

Pt E, Ch 9, Sec 4, [7.3.4] can be used as simplified dynamic loading spectra cited in IGF Code 6.4.12.2.5.

Pt E, Ch 9, Sec 4, [7.4.3] can be used as simplified stress distribution for the crack propagation analysis cited in IGF Code 6.4.12.2.7.

6.4.7 **Type A independent tanks** *(1/1/2025)*

IGF CODE REFERENCE: Ch. 6, 6.4.15.1

Type A independent tanks are tanks primarily designed using classical ship-structural analysis procedures in accordance with the requirements of the Society.

To this purpose, the requirements in Pt E, Ch 9, Sec 4, [2.1.1], and [6] are to be applied.

6.4.8 **Type B independent tanks** *(1/1/2025)*

IGF CODE REFERENCE: Ch. 6, 6.4.15.2

Type B independent tanks are tanks designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics.

To this purpose, the requirements in Pt E, Ch 9, Sec 4, [2.2], and [7] except [7.2.5], [7.3.6] are to be applied.

When applying Pt E, Ch 9, Sec 4, [2.2] and [7], the accelerations according to [6.4.4] are to be used instead of those according to IGC Code 4.28.2.

In lieu of Pt E, Ch 9, Sec 4, [7.2.5] which is not applicable, the stress checks according to IGF Code 6.4.15.2.3.1 is to be applied.

In lieu of Pt E, Ch 9, Sec 4, [7.3.6] which is not applicable, the provisions in [6.4.6] are to be used.

6.4.9 Type C independent tanks *(1/1/2025)*

IGF CODE REFERENCE: Ch. 6, 6.4.15.3

The design basis for type C independent tanks is based on pressure vessel criteria modified to include fracture mechanics and crack propagation criteria.

The additional requirements in Pt E, Ch 9, Sec 4, [8], are to be applied.

To detail the pressure vessel criteria the tank designer most often choses to use an international pressure vessel design code such as ASME VIII Div. 1, AD Merkblatter, ISO 16528 or other equivalent.

In case the pressure vessel design code was not specified by the tank designer, the different surface of revolution shells scantlings may be verified using the formulae in Sec 3.

The allowable stresses to be applied to the pressure vessel checks are those in IGF Code 6.4.15.3.3.1.

6.4.10 Membrane tanks *(1/1/2025)*

IGF CODE REFERENCE: Ch. 6, 6.4.15.4

The additional requirements in Pt E, Ch 9, Sec 4, [5], are to be applied.

6.4.11 Supporting arrangements *(1/1/2025)*

IGF CODE REFERENCE: Ch. 6, 6.4.6

The additional requirements in Pt E, Ch 9, Sec 4, [9], are to be applied.

6.5 Regulations for portable liquefied gas fuel tanks

6.5.1 *(1/1/2025)*

The requirements in IGF Code 6.5 apply.

6.6 Regulations for CNG fuel containment

6.6.1 *(1/1/2025)*

The requirements in IGF Code 6.6 apply.

6.7 Regulations for pressure relief system

6.7.1 General *(1/1/2017)*

a) *All fuel storage tanks are to be provided with a pressure relief system appropriate to the design of the fuel containment system and the fuel being carried. Fuel storage hold spaces, interbarrier spaces, tank connection spaces and tank cofferdams, which may be subject to pressures beyond their design capabilities, are also to be provided with a suitable pressure relief system. Pressure control systems specified in [6.9] are to be independent of the pressure relief systems.*

b) *Fuel storage tanks which may be subject to external pressures above their design pressure are to be fitted with vacuum protection systems.*

6.7.2 Pressure relief systems for liquefied gas fuel tanks *(1/1/2017)*

a) *If fuel release into the vacuum space of a vacuum insulated tank cannot be excluded, the vacuum space is to be protected by a pressure relief device which is to be connected to a vent system if the tanks are located below deck. On open deck a direct release into the atmosphere may be accepted by the Society for tanks not exceeding the size of a 40 ft container if the released gas cannot enter safe areas.*

b) *Liquefied gas fuel tanks are to be fitted with a minimum of 2 pressure relief valves (PRVs) allowing for disconnection of one PRV in case of malfunction or leakage.*

c) *Interbarrier spaces are to be provided with pressure relief devices. For membrane systems, the designer is to demonstrate adequate sizing of interbarrier space PRVs.*

d) *The setting of the PRVs is not to be higher than the vapour pressure that has been used in the design of the tank. Valves comprising not more than 50% of the total relieving capacity may be set at a pressure up to 5% above MARVS to allow sequential lifting, minimizing unnecessary release of vapour.*

e) *The following temperature regulations apply to PRVs fitted to pressure relief systems:*

1) *PRVs on fuel tanks with a design temperature below 0oC are to be designed and arranged to prevent their becoming inoperative due to ice formation;*

2) *the effects of ice formation due to ambient temperatures are to be considered in the construction and arrangement of PRVs;*

3) *PRVs are to be constructed of materials with a melting point above 925°C. Lower melting point materials for internal parts and seals may be accepted provided that fail-safe operation of the PRV is not compromised; and*

4) *sensing and exhaust lines on pilot operated relief valves are to be of suitably robust construction to prevent damage.*

f) *In the event of a failure of a fuel tank PRV a safe means of emergency isolation is to be available.*

1) *procedures are to be provided and included in the operation manual ;*

2) *the procedures are to allow only one of the installed PRVs for the liquefied gas fuel tanks to be isolated, physical interlocks are to be included to this effect; and*

3) *isolation of the PRV is to be carried out under the supervision of the master. This action is to be recorded in the ship's log, and at the PRV.*

g) *Each pressure relief valve installed on a liquefied gas fuel tank is to be connected to a venting system, which is to be:*

1) *so constructed that the discharge will be unimpeded and normally be directed vertically upwards at the exit;*

2) *arranged to minimize the possibility of water or snow entering the vent system; and*

3) *arranged such that the height of vent exits are normally not to be less than B/3 or 6 m, whichever is the greater, above the weather deck and 6 m above working areas and walkways. However, vent mast height could be limited to lower value according to special consideration by the Society.*

h) *The outlet from the pressure relief valves is normally to be located at least 10 m from the nearest:*

1) *air intake, air outlet or opening to accommodation, service and control spaces, or other non-hazardous area; and*

2) *exhaust outlet from machinery installations.*

i) *All other fuel gas vent outlets are also to be arranged in accordance with [6.7.2] g) and [6.7.2] h). Means are to be provided to prevent liquid overflow from gas vent outlets, due to hydrostatic pressure from spaces to which they are connected.*

j) *In the vent piping system, means for draining liquid from places where it may accumulate are to be provided. The PRVs and piping are to be arranged so that liquid can, under no circumstances, accumulate in or near the PRVs.*

k) *Suitable protection screens of not more than 13 mm square mesh are to be fitted on vent outlets to prevent the ingress of foreign objects without adversely affecting the flow.*

l) *All vent piping is to be designed and arranged not to be damaged by the temperature variations to which it may be exposed, forces due to flow or the ship's motions.*

m) *PRVs are to be connected to the highest part of the fuel tank. PRVs are to be positioned on the fuel tank so that they will remain in the vapour phase at the filling limit (FL) as given in 6.8, under conditions of 15° list and 0.015L trim, where L is defined in [2.2.25].*

6.7.3 Sizing of pressure relieving system *(1/1/2017)*

a) *Sizing of pressure relief valves*

1) *PRVs are to have a combined relieving capacity for each liquefied gas fuel tank to discharge the greater of the following, with not more than a 20% rise in liquefied gas fuel tank pressure above the MARVS:*

- *the maximum capacity of the liquefied gas fuel tank inerting system if the maximum attainable working pressure of the liquefied gas fuel tank inerting system exceeds the MARVS of the liquefied gas fuel tanks; or*
- *vapours generated under fire exposure computed using the following formula:*

$Q = FGA^{0,82}$ (m^3/s)

where:

Q : minimum required rate of discharge of air at standard conditions of 273,15 Kelvin (K) and 0,1013 MPa

F : fire exposure factor for different liquefied gas fuel types:

F : 1,0 for tanks without insulation located on deck;

F : 0,5 for tanks above the deck when insulation is approved by the Society. (Approval will be based on the use of a fireproofing material, the thermal conductance of insulation, and its stability under fire exposure);

F : 0,5 for uninsulated independent tanks installed in holds;

F : 0,2 for insulated independent tanks in holds (or uninsulated independent tanks in insulated holds);

F : 0,1 for insulated independent tanks in inerted holds (or uninsulated independent tanks in inerted, insulated holds); and

F : 0,1 for membrane tanks.

For independent tanks partly protruding through the weather decks, the fire exposure factor is to be determined on the basis of the surface areas above and below deck.

G : gas factor according to formula:

$$G = \frac{12,4}{LD}\sqrt{\frac{ZT}{M}}$$

where:

T : temperature in Kelvin at relieving conditions, i.e. 120% of the pressure at which the pressure relief valve is set;

L : latent heat of the material being vaporized at relieving conditions, in kJ/kg;

D : a constant based on relation of specific heats k and is calculated as follows:

$$D = \sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

where:

k : ratio of specific heats at relieving conditions, and the value of which is between 1.0 and 2.2. If k is not known, D = 0.606 is to be used;

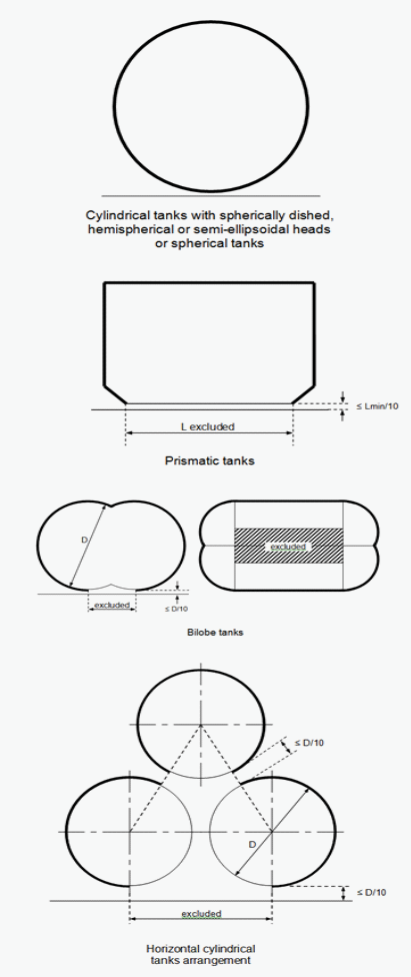
Z : compressibility factor of the gas at relieving conditions; if not known, Z = 1.0 is to be used;

M : molecular mass of the product.

The gas factor of each liquefied gas fuel to be carried is to be determined and the highest value is to be used for PRV sizing.

A : external surface area of the tank (m^2), as for different tank types, as shown in Fig 1.

Figure 1



2) *For vacuum insulated tanks in fuel storage hold spaces and for tanks in fuel storage hold spaces separated from potential fire loads by coffer dams or surrounded by ship spaces with no fire load the following applies:*
   - *If the pressure relief valves have to be sized for fire loads the fire factors according may be reduced to the following values:*

     F = 0,5 to F = 0,25

     F = 0,2 to F = 0,1

     The minimum fire factor is F = 0,1

3) *The required mass flow of air at relieving conditions is given by:*

   $M_{air} = Q * \rho_{air}$ *(kg/s)*

   where density of air (ρ_{air}) *= 1,293 kg/m³ (air at 273,15 K, 0,1013 MPa).*

b) *Sizing of vent pipe system*

1) *Pressure losses upstream and downstream of the PRVs, are to be taken into account when determining their size to ensure the flow capacity required by [6.7.3] a).*

2) *Upstream pressure losses*
   - *the pressure drop in the vent line from the tank to the PRV inlet is not to exceed 3% of the valve set pressure at the calculated flow rate, in accordance with [6.7.3] a);*
   - *pilot-operated PRVs are to be unaffected by inlet pipe pressure losses when the pilot senses directly from the tank dome; and*
   - *pressure losses in remotely sensed pilot lines are to be considered for flowing type pilots.*

3) *Downstream pressure losses*
   - *Where common vent headers and vent masts are fitted, calculations are to include flow from all attached PRVs.*

- *The built-up back pressure in the vent piping from the PRV outlet to the location of discharge to the atmosphere, and including any vent pipe interconnections that join other tanks, is not to exceed the following values:*
  - *for unbalanced PRVs: 10% of MARVS;*
  - *for balanced PRVs: 30% of MARVS; and*
  - *for pilot operated PRVs: 50% of MARVS.*

  Alternative values provided by the PRV manufacturer may be accepted.

4) *To ensure stable PRV operation, the blow-down is not to be less than the sum of the inlet pressure loss and 0.02 MARVS at the rated capacity.*

6.8 Regulations on loading limit for liquefied gas fuel tanks

6.8.1 *(1/1/2017)*

Storage tanks for liquefied gas are not to be filled to more than a volume equivalent to 98% full at the reference temperature as defined in [2.2.36].

A loading limit curve for actual fuel loading temperatures is to be prepared from the following formula:

$LL = FL_{\rho R/\rho L}$

where:

LL : loading limit as defined in [2.2.27], expressed in per cent;

FL : filling limit as defined in [2.2.16] expressed in per cent, here 98%;

ρR *: relative density of fuel at the reference temperature; and*

ρL *: relative density of fuel at the loading temperature.*

6.8.2 *(1/1/2017)*

In cases where the tank insulation and tank location make the probability very small for the tank contents to be heated up due to an external fire, special considerations may be made to allow a higher loading limit than calculated using the reference temperature, but never above 95%. This also applies in cases where a second system for pressure maintenance is installed, (refer to [6.9]). However, if the pressure can only be maintained / controlled by fuel consumers, the loading limit as calculated in [6.8.1] is to be used.

6.9 Regulations for the maintaining of fuel storage condition

6.9.1 **Control of tank pressure and temperature** *(1/1/2017)*

a) *With the exception of liquefied gas fuel tanks designed to withstand the full gauge vapour pressure of the fuel under conditions of the upper ambient design temperature, liquefied gas fuel tanks' pressure and temperature are to be maintained at all times within their design range by means acceptable to the Society, e.g. by one of the following methods:*

   1) *reliquefaction of vapours;*
   2) *thermal oxidation of vapours;*
   3) *pressure accumulation; or*
   4) *liquefied gas fuel cooling.*

   The method chosen is to be capable of maintaining tank pressure below the set pressure of the tank pressure relief valves for a period of 15 days assuming full tank at normal service pressure and the ship in idle condition, i.e. only power for domestic load is generated.

b) *Venting of fuel vapour for control of the tank pressure is not acceptable except in emergency situations.*

6.9.2 **Design of systems** *(1/1/2017)*

a) *For worldwide service, the upper ambient design temperature is to be sea 32°C and air 45°C. For service in particularly hot or cold zones, these design temperatures are to be increased or decreased, to the satisfaction of the Society.*

b) *The overall capacity of the system is to be such that it can control the pressure within the design conditions without venting to atmosphere.*

6.9.3 **Reliquefaction systems** *(1/1/2017)*

a) *The reliquefaction system is to be designed and calculated according to [6.9.3] b). The system is to be sized in a sufficient way also in case of no or low consumption.*

b) The reliquefaction system is to be arranged in one of the following ways:

1) a direct system where evaporated fuel is compressed, condensed and returned to the fuel tanks;

2) an indirect system where fuel or evaporated fuel is cooled or condensed by refrigerant without being compressed;

3) a combined system where evaporated fuel is compressed and condensed in a fuel/refrigerant heat exchanger and returned to the fuel tanks; or

4) if the reliquefaction system produces a waste stream containing methane during pressure control operations within the design conditions, these waste gases are, as far as reasonably practicable, to be disposed of without venting to atmosphere.

6.9.4 **Thermal oxidation systems** *(1/1/2017)*

Thermal oxidation can be done by either consumption of the vapours according to the regulations for consumers described in this Appendix or in a dedicated gas combustion unit (GCU). It is to be demonstrated that the capacity of the oxidation system is sufficient to consume the required quantity of vapours. In this regard, periods of slow steaming and/or no consumption from propulsion or other services of the ship are to be considered.

6.9.5 **Compatibility** *(1/1/2017)*

Refrigerants or auxiliary agents used for refrigeration or cooling of fuel are to be compatible with the fuel they may come in contact with (not causing any hazardous reaction or excessively corrosive products). In addition, when several refrigerants or agents are used, these are to be compatible with each other.

6.9.6 **Availability of systems** *(1/1/2017)*

a) The availability of the system and its supporting auxiliary services is to be such that in case of a single failure (of mechanical non-static component or a component of the control systems) the fuel tank pressure and temperature can be maintained by another service/system.

b) Heat exchangers that are solely necessary for maintaining the pressure and temperature of the fuel tanks within their design ranges are to have a standby heat exchanger unless they have a capacity in excess of 25% of the largest required capacity for pressure control and they can be repaired on board without external sources.

6.10 Regulations on atmospheric control within the fuel containment system

6.10.1 *(1/1/2017)*

A piping system is to be arranged to enable each fuel tank to be safely gas-freed, and to be safely filled with fuel from a gas-free condition. The system is to be arranged to minimize the possibility of pockets of gas or air remaining after changing the atmosphere.

6.10.2 *(1/1/2017)*

The system is to be designed to eliminate the possibility of a flammable mixture existing in the fuel tank during any part of the atmosphere change operation by utilizing an inerting medium as an intermediate step.

6.10.3 *(1/1/2017)*

Gas sampling points are to be provided for each fuel tank to monitor the progress of atmosphere change.

6.10.4 *(1/1/2017)*

Inert gas utilized for gas freeing of fuel tanks may be provided externally to the ship.

6.11 Regulations on atmosphere control within fuel storage hold spaces (Fuel containment systems other than type C independent tanks)

6.11.1 *(1/1/2017)*

Interbarrier and fuel storage hold spaces associated with liquefied gas fuel containment systems requiring full or partial secondary barriers are to be inerted with a suitable dry inert gas and kept inerted with make-up gas provided by a shipboard inert gas generation system, or by shipboard storage, which is to be sufficient for normal consumption for at least 30 days. Shorter periods may be considered by the Society depending on the ship's service.

6.11.2 *(1/1/2017)*

Alternatively, the spaces referred to in [6.11.1] requiring only a partial secondary barrier may be filled with dry air provided that the ship maintains a stored charge of inert gas or is fitted with an inert gas generation system sufficient to inert the largest of these spaces, and provided that the configuration of the spaces and the relevant vapour detection systems, together with the capability of the inerting arrangements, ensures that any leakage from the liquefied gas fuel

tanks will be rapidly detected and inerting effected before a dangerous condition can develop. Equipment for the provision of sufficient dry air of suitable quality to satisfy the expected demand is to be provided.

6.12 Regulations on environmental control of spaces surrounding type C independent tanks

6.12.1 *(1/1/2017)*

Spaces surrounding liquefied gas fuel tanks are to be filled with suitable dry air and be maintained in this condition with dry air provided by suitable air drying equipment. This is only applicable for liquefied gas fuel tanks where condensation and icing due to cold surfaces is an issue.

6.13 Regulations on inerting

6.13.1 *(1/1/2017)*

Arrangements to prevent back-flow of fuel vapour into the inert gas system are to be provided as specified below.

6.13.2 *(1/1/2017)*

To prevent the return of flammable gas to any non-hazardous spaces, the inert gas supply line is to be fitted with two shutoff valves in series with a venting valve in between (double block and bleed valves). In addition, a closable non-return valve is to be installed between the double block and bleed arrangement and the fuel system. These valves are to be located outside non-hazardous spaces.

6.13.3 *(1/1/2017)*

Where the connections to the fuel piping systems are non-permanent, two non-return valves may be substituted for the valves required in [6.13.2].

6.13.4 *(1/1/2017)*

The arrangements are to be such that each space being inerted can be isolated and the necessary controls and relief valves, etc. are to be provided for controlling pressure in these spaces.

6.13.5 *(1/1/2017)*

Where insulation spaces are continually supplied with an inert gas as part of a leak detection system, means are to be provided to monitor the quantity of gas being supplied to individual spaces

6.14 Regulations on inert gas production and storage on board

6.14.1 *(1/1/2017)*

The equipment is to be capable of producing inert gas with oxygen content at no time greater than 5% by volume. A continuous-reading oxygen content meter is to be fitted to the inert gas supply from the equipment and is to be fitted with an alarm set at a maximum of 5% oxygen content by volume.

6.14.2 *(1/1/2017)*

An inert gas system is to have pressure controls and monitoring arrangements appropriate to the fuel containment system.

6.14.3 *(1/1/2017)*

Where a nitrogen generator or nitrogen storage facilities are installed in a separate compartment outside of the engine-room, the separate compartment is to be fitted with an independent mechanical extraction ventilation system, providing a minimum of 6 air changes per hour. A low oxygen alarm is to be fitted.

6.14.4 *(1/1/2017)*

Nitrogen pipes are only to be led through well ventilated spaces. Nitrogen pipes in enclosed spaces are to:

- *be fully welded;*
- *have only a minimum of flange connections as needed for fitting of valves; and*
- *be as short as possible.*

7 Material and general pipe design

IGF CODE REFERENCE: Ch. 7

7.1 Goal

7.1.1 *(1/1/2017)*

The goal of this paragraph is to ensure the safe handling of fuel, under all operating conditions, to minimize the risk to the ship, personnel and to the environment, having regard to the nature of the products involved.

7.2 Functional requirements

7.2.1 *(1/1/2017)*

This paragraph [7] relates to functional requirements in [3.2.1], [3.2.5], [3.2.6], [3.2.8], [3.2.9] and [3.2.10]. In particular the following apply:

a) *Fuel piping is to be capable of absorbing thermal expansion or contraction caused by extreme temperatures of the fuel without developing substantial stresses.*

b) *Provision is to be made to protect the piping, piping system and components and fuel tanks from excessive stresses due to thermal movement and from movements of the fuel tank and hull structure.*

c) *If the fuel gas contains heavier constituents that may condense in the system, means for safely removing the liquid are to be fitted.*

d) *Low temperature piping is to be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material.*

7.3 Regulations for general pipe design

7.3.1 General *(1/1/2017)*

a) *Fuel pipes and all the other piping needed for a safe and reliable operation and maintenance are to be colour marked in accordance with a standard at least equivalent to those acceptable to the Organization*

b) *Where tanks or piping are separated from the ship's structure by thermal isolation, provision is to be made for electrically bonding to the ship's structure both the piping and the tanks. All gasketed pipe joints and hose connections are to be electrically bonded.*

c) *All pipelines or components which may be isolated in a liquid full condition are to be provided with relief valves.*

d) *Pipework, which may contain low temperature fuel, is to be thermally insulated to an extent which will minimize condensation of moisture.*

e) *Piping other than fuel supply piping and cabling may be arranged in the double wall piping or duct provided that they do not create a source of ignition or compromise the integrity of the double pipe or duct. The double wall piping or duct is to contain only piping or cabling necessary for operational purposes.*

7.3.2 **Wall thickness** *(1/1/2017)*

a) *The minimum wall thickness is to be calculated as follows:*

$t = (t_0 + b + c) / (1 - a/100)$ (mm)

where:

t_0 : theoretical thickness

t_0 : $PD / (2{,}0Ke + P)$ (mm)

whit:

P : design pressure (MPa) referred to in [7.3.3]

D : outside diameter (mm);

K : allowable stress (N/mm^2) referred to in [7.3.4]; and

e : efficiency factor equal to 1.0 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, that are considered equivalent to seamless pipes when non-destructive testing on welds is carried out in accordance with recognized standards. In other cases an efficiency factor of less than 1,0, in accordance with recognized standards, may be required depending on the manufacturing process;

h : allowance for bending (mm). The value of b is to be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, b is to be:

$b = D\, t_0 / 2{,}5r$ (mm)

with

r : mean radius of the bend (mm);

c : corrosion allowance (mm). If corrosion or erosion is expected the wall thickness of the piping is to be increased over that required by other design regulations. This allowance is to be consistent with the expected life of the piping; and

a : negative manufacturing tolerance for thickness (%).

b) The absolute minimum wall thickness is to be in accordance with a standard acceptable to the Society.

7.3.3 Design condition *(1/1/2017)*

a) The greater of the following design conditions is to be used for piping, piping system and components as appropriate:

1) for systems or components which may be separated from their relief valves and which contain only vapour at all times, vapour pressure at 45°C assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or

2) the MARVS of the fuel tanks and fuel processing systems; or

3) the pressure setting of the associated pump or compressor discharge relief valve; or

4) the maximum total discharge or loading head of the fuel piping system; or

5) the relief valve setting on a pipeline system.

b) Piping, piping systems and components are to have a minimum design pressure of 1.0 MPa except for open ended lines where it is not to be less than 0.5 MPa.

7.3.4 Allowable stress *(1/1/2017)*

a) For pipes made of steel including stainless steel, the allowable stress to be considered in the formula of the strength thickness in [7.3.2] a) is to be the lower of the following values:

R_m/2,7 or R_e/1,8

R_m : specified minimum tensile strength at room temperature (N/mm^2); and

R_e : specified minimum yield stress at room temperature (N/mm^2). If the stress strain curve does not show a defined yield stress, the 0.2% proof stress applies.

b) Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to superimposed loads, the wall thickness is to be increased over that required by [7.3.2] or, if this is impracticable or would cause excessive local stresses, these loads are to be reduced, protected against or eliminated by other design methods. Such superimposed loads may be due to; supports, ship deflections, liquid pressure surge during transfer operations, the weight of suspended valves, reaction to loading arm connections, or otherwise.

c) For pipes made of materials other than steel, the allowable stress is to be considered by the Society.

d) High pressure fuel piping systems is to have sufficient constructive strength. This is to be confirmed by carrying out stress analysis and taking into account:

1) stresses due to the weight of the piping system;

2) acceleration loads when significant; and

3) internal pressure and loads induced by hog and sag of the ship.

e) When the design temperature is minus 110°C or colder, a complete stress analysis, taking into account all the stresses due to weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hog and sag of the ship is to be carried out for each branch of the piping system.

7.3.5 Flexibility of piping *(1/1/2017)*

The arrangement and installation of fuel piping is to provide the necessary flexibility to maintain the integrity of the piping system in the actual service situations, taking potential for fatigue into account.

7.3.6 Piping fabrication and joining details *(1/1/2017)*

a) Flanges, valves and other fittings is to comply with a standard acceptable to the Society, taking into account the design pressure defined in [7.3.3] a). For bellows and expansion joints used in vapour service, a lower minimum design pressure than defined in [7.3.3] a) may be accepted.

b) All valves and expansion joints used in high pressure fuel piping systems are to be approved according to a standard acceptable to the Society.

c) The piping system is to be joined by welding with a minimum of flange connections. Gaskets are to be protected against blow-out.

d) Piping fabrication and joining details are to comply with the following:

1) Direct connections

- *Butt-welded joints with complete penetration at the root may be used in all applications. For design temperatures colder than minus 10°C, butt welds are to be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back-up on the first pass. For design pressures in excess of 1.0 MPa and design temperatures of minus 10°C or colder, backing rings are to be removed.*
- *Slip-on welded joints with sleeves and related welding, having dimensions in accordance with recognized standards, are only to be used for instrument lines and open-ended lines with an external diameter of 50 mm or less and design temperatures not colder than minus 55°C.*
- *Screwed couplings complying with recognized standards are only to be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.*

2) Flanged connections

- *Flanges in flange connections are to be of the welded neck, slip-on or socket welded type; and*
- *For all piping except open ended, the following restrictions apply:*
  - *For design temperatures colder than minus 55°C, only welded neck flanges are to be used; and*
  - *For design temperatures colder than minus 10°C, slip-on flanges are not to be used in nominal sizes above 100 mm and socket welded flanges are not to be used in nominal sizes above 50 mm.*

3) Expansion joints

Where bellows and expansion joints are provided in accordance with [7.3.6] a) the following apply:

- *if necessary, bellows are to be protected against icing;*
- *slip joints are not to be used except within the liquefied gas fuel storage tanks; and*
- *bellows are normally not to be arranged in enclosed spaces.*

4) Other connections

Piping connections are to be joined in accordance with [7.3.6] d)1) to [7.3.6] d)3) but for other exceptional cases the Society may consider alternative arrangements.

7.4 Regulations for materials

7.4.1 Metallic materials *(1/1/2025)*

The requirements in IGF Code 7.4 apply.

The requirements in Pt D, Ch 2, App 7 apply in addition.

7.4.2 Insulation materials *(1/1/2025)*

The requirements in Pt E, Ch 9, Sec 4, [12.1] apply.

8 Bunkering

IGF CODE REFERENCE: Ch. 8

8.1 Goal

8.1.1 *(1/1/2017)*

The goal of this paragraph is to provide for suitable systems on board the ship to ensure that bunkering can be conducted without causing danger to persons, the environment or the ship.

8.2 Functional requirements

8.2.1 *(1/1/2017)*

This paragraph relates to functional requirements in [3.2.1] to [3.2.11] and [3.2.13] to [3.2.17]. In particular the following apply.

The piping system for transfer of fuel to the storage tank is to be designed such that any leakage from the piping system cannot cause danger to personnel, the environment or the ship.

8.3 Regulations for bunkering station

8.3.1 General *(1/1/2017)*

a) The bunkering station is to be located on open deck so that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations are to be subject to special consideration within the risk assessment.

The risk assessment is to follow the steps outlined below.

1) The design team is to conduct a Hazard Identification (HAZID) to agree on the scenarios to be subjected to the risk analysis, and on the assumptions regarding the most critical events (typically, connection failures causing an LNG spill). The effects in the bunker station and above it are to be simulated by means of the tools mentioned in [5.10.6].
2) As a minimum, a scenario to be assumed is the failure of the presentation flange on the liquid bunkering line. The simulation is to focus on the calculation of the amount of LNG spilled before the intervention of ESD and the stop of the bunkering pumps. After the stop of the pumps, the amount of the discharge of the residual inventory of the hose or loading arm is to be calculated according to the bunkering configuration, to estimate whether it is significant; in this case, it is to be taken into account in the simulation.
3) Reasonable assumptions on the extent of connection failures or other selected events and the parameters of the LNG process are to be made by the design team, preferably on the basis of statistics available in the public domain or provided and documented by stakeholders.
4) Reasonable assumptions on the operation of ventilation system are to be made according to layout and procedures of the bunker station.
5) In order to verify the drip tray capacity, a specific simulation is to be set up, aimed at evaluating the maximum amount of LNG spilled onto the drip tray, the evaporation rate, and the possibility to fully accommodate the LNG in the drip tray avoiding any overboard disposal.
6) In particular, the dispersion of methane resulting from LNG evaporation in the bunker station and from the bunker station to the upper decks, if realistically possible, is to be simulated.
7) For the sake of conservatism, in order to maximize the accumulation of LNG onto the drip tray, LNG release is to be directed downward, impinging on the drip tray, and ambient temperature is to be set to the minimum credible winter temperature. Equipment, bunker station floor and surfaces and drip tray are to be considered adiabatic, to conservatively increase the amount of liquid accumulated in the drip tray.
8) Reasonable assumptions are to be made by the design team regarding detection time, LNG flow stop time and human reaction time, in case operators are credited in the emergency.

If the simulation demonstrates that the drip tray cannot accommodate the LNG spill, or the dispersion of evaporated methane reaches hazardous areas, mitigating measures are to be provided and subjected to the same simulation process, to appreciate the risk reduction.

b) Connections and piping are to be so positioned and arranged that any damage to the fuel piping does not cause damage to the ship's fuel containment system resulting in an uncontrolled gas discharge.

c) Arrangements are to be made for safe management of any spilled fuel.

d) Suitable means are to be provided to relieve the pressure and remove liquid contents from pump suctions and bunker lines. Liquid is to be discharged to the liquefied gas fuel tanks or other suitable location.

e) The surrounding hull or deck structures are not to be exposed to unacceptable cooling, in case of leakage of fuel

f) For CNG bunkering stations, low temperature steel shielding is to be considered to determine if the escape of cold jets impinging on surrounding hull structure is possible.

8.3.2 Ships' fuel hoses *(1/1/2017)*

a) Liquid and vapour hoses used for fuel transfer are to be compatible with the fuel and suitable for the fuel temperature.

b) Hoses subject to tank pressure, or the discharge pressure of pumps or vapour compressors, are to be designed for a bursting pressure not less than five times the maximum pressure the hose can be subjected to during bunkering.

8.4 Regulations for manifold

8.4.1 *(1/1/2017)*

The bunkering manifold is to be designed to withstand the external loads during bunkering. The connections at the bunkering station are to be of dry-disconnect type equipped with additional safety dry break-away coupling/ self-sealing quick release. The couplings are to be of a standard type.

8.5 Regulations for bunkering system

8.5.1 *(1/1/2017)*
An arrangement for purging fuel bunkering lines with inert gas is to be provided.

8.5.2 *(1/1/2017)*
The bunkering system is to be so arranged that no gas is discharged to the atmosphere during filling of storage tanks.

8.5.3 *(1/1/2017)*
A manually operated stop valve and a remote operated shutdown valve in series, or a combined manually operated and remote valve is to be fitted in every bunkering line close to the connecting point. It is to be possible to operate the remote valve in the control location for bunkering operations and/or from another safe location.

8.5.4 *(1/1/2017)*
Means are to be provided for draining any fuel from the bunkering pipes upon completion of operation.

8.5.5 *(1/1/2017)*
Bunkering lines are to be arranged for inerting and gas freeing. When not engaged in bunkering, the bunkering pipes are to be free of gas, unless the consequences of not gas freeing are evaluated and approved.

8.5.6 *(1/1/2017)*
In case bunkering lines are arranged with a cross-over it is to be ensured by suitable isolation arrangements that no fuel is transferred inadvertently to the ship side not in use for bunkering.

8.5.7 *(1/1/2017)*
A ship-shore link (SSL) or an equivalent means for automatic and manual ESD communication to the bunkering source is to be fitted.

8.5.8 *(1/1/2017)*
If not demonstrated to be required at a higher value due to pressure surge considerations a default time as calculated in accordance with [16.7.3] g) from the trigger of the alarm to full closure of the remote operated valve required by [8.5.3] is to be adjusted.

9 Fuel supply to consumers

IGF CODE REFERENCE: Ch. 9

9.1 Goal

9.1.1 *(1/1/2017)*
The goal of this paragraph is to ensure safe and reliable distribution of fuel to the consumers.

9.2 Functional requirements

9.2.1 *(1/1/2017)*
This paragraph is related to functional requirements in [3.2.1] to [3.2.6], [3.2.8] to [3.2.11] and [3.2.13] to [3.2.17]. In particular the following apply:

a) the fuel supply system is to be so arranged that the consequences of any release of fuel will be minimized, while providing safe access for operation and inspection;

b) the piping system for fuel transfer to the consumers is to be designed in a way that a failure of one barrier cannot lead to a leak from the piping system into the surrounding area causing danger to the persons on board, the environment or the ship; and

c) fuel lines outside the machinery spaces are to be installed and protected so as to minimize the risk of injury to personnel and damage to the ship in case of leakage.

9.3 Regulations on redundancy of fuel supply

9.3.1 *(1/1/2017)*
For single fuel installations the fuel supply system is to be arranged with full redundancy and segregation all the way from the fuel tanks to the consumer, so that a leakage in one system does not lead to an unacceptable loss of power.

9.3.2 *(1/1/2017)*
For single fuel installations, the fuel storage is to be divided between two or more tanks. The tanks are to be located in separate compartments.

9.3.3 *(1/1/2017)*
For type C tank only, one tank may be accepted if two completely separate tank connection spaces are installed for the one tank.

9.4 Regulations on safety functions of gas supply system

9.4.1 *(1/1/2017)*
Fuel storage tank inlets and outlets are to be provided with valves located as close to the tank as possible. Valves required to be operated during normal operation16 which are not accessible are to be remotely operated. Tank valves whether accessible or not are to be automatically operated when the safety system required in [14.2]b) is activated.

9.4.2 *(1/1/2017)*
The main gas supply line to each gas consumer or set of consumers is to be equipped with a manually operated stop valve and an automatically operated "master gas fuel valve" coupled in series or a combined manually and automatically operated valve. The valves are to be situated in the part of the piping that is outside the machinery space containing gas consumers, and placed as near as possible to the installation for heating the gas, if fitted. The master gas fuel valve is to automatically cut off the gas supply when activated by the safety system required in[14.2]b).

9.4.3 *(1/1/2017)*
The automatic master gas fuel valve is to be operable from safe locations on escape routes inside a machinery space containing a gas consumer, the engine control room, if applicable; outside the machinery space, and from the navigation bridge.

9.4.4 *(1/1/2017)*
Each gas consumer is to be provided with "double block and bleed" valves arrangement. These valves are to be arranged as outlined in a) or b) so that when the safety system required in [14.2]b) is activated this will cause the shutoff valves that are in series to close automatically and the bleed valve to open automatically and:

a) the two shutoff valves are to be in series in the gas fuel pipe to the gas consuming equipment. The bleed valve is to be in a pipe that vents to a safe location in the open air that portion of the gas fuel piping that is between the two valves in series; or

b) the function of one of the shutoff valves in series and the bleed valve can be incorporated into one valve body, so arranged that the flow to the gas utilization unit will be blocked and the ventilation opened.

9.4.5 *(1/1/2017)*
The two valves are to be of the fail-to-close type, while the ventilation valve is to be fail-to-open.

9.4.6 *(1/1/2017)*
The double block and bleed valves are also to be used for normal stop of the engine.

9.4.7 *(1/1/2017)*
In cases where the master gas fuel valve is automatically shut down, the complete gas supply branch downstream of the double block and bleed valve is to be automatically ventilated assuming reverse flow from the engine to the pipe.

9.4.8 *(1/1/2017)*
There is to be one manually operated shutdown valve in the gas supply line to each engine upstream of the double block and bleed valves to assure safe isolation during maintenance on the engine.

9.4.9 *(1/1/2017)*
For single-engine installations and multi-engine installations, where a separate master valve is provided for each engine, the master gas fuel valve and the double block and bleed valve functions can be combined.

9.4.10 *(1/1/2017)*
For each main gas supply line entering an ESD protected machinery space, and each gas supply line to high pressure installations, means are to be provided for rapid detection of a rupture in the gas line in the engine-room. When rupture is detected a valve is to be automatically shut off. This valve is to be located in the gas supply line before it enters the engine-room or as close as possible to the point of entry inside the engine-room. It can be a separate valve or combined with other functions, e.g. the master valve.

9.5 Regulations for fuel distribution outside of machinery space

9.5.1 *(1/1/2017)*
Where fuel pipes pass through enclosed spaces in the ship, they are to be protected by a secondary enclosure. This enclosure can be a ventilated duct or a double wall piping system. The duct or double wall piping system is to be mechanically under pressure ventilated with 30 air changes per hour, and gas detection as required in 15.8 is to be provided. Other solutions providing an equivalent safety level may also be accepted by the Society.

9.5.2 *(1/1/2017)*
The requirement in [9.5.1] need not be applied for fully welded fuel gas vent pipes led through mechanically ventilated spaces.

9.6 Regulations for fuel supply to consumers in gas-safe machinery spaces

9.6.1 *(1/1/2017)*
Fuel piping in gas-safe machinery spaces is to be completely enclosed by a double pipe or duct fulfilling one of the following conditions:

a) the gas piping is to be a double wall piping system with the gas fuel contained in the inner pipe. The space between the concentric pipes is to be pressurized with inert gas at a pressure greater than the gas fuel pressure. Suitable alarms are to be provided to indicate a loss of inert gas pressure between the pipes. When the inner pipe contains high pressure gas, the system is to be so arranged that the pipe between the master gas valve and the engine is automatically purged with inert gas when the master gas valve is closed; or

b) the gas fuel piping is to be installed within a ventilated pipe or duct. The air space between the gas fuel piping and the wall of the outer pipe or duct is to be equipped with mechanical under pressure ventilation having a capacity of at least 30 air changes per hour. This ventilation capacity may be reduced to 10 air changes per hour provided automatic filling of the duct with nitrogen upon detection of gas is arranged for. The fan motors are to comply with the required explosion protection in the installation area. The ventilation outlet is to be covered by a protection screen and placed in a position where no flammable gas-air mixture may be ignited; or

c) other solutions providing an equivalent safety level may also be accepted by the Society.

9.6.2 *(1/1/2017)*
The connecting of gas piping and ducting to the gas injection valves is to be completely covered by the ducting. The arrangement is to facilitate replacement and/or overhaul of injection valves and cylinder covers. The double ducting is also required for all gas pipes on the engine itself, until gas is injected into the chamber.

9.7 Regulations for gas fuel supply to consumers in ESD-protected machinery spaces

9.7.1 *(1/1/2017)*
The pressure in the gas fuel supply system is not to exceed 1.0 MPa.

9.7.2 *(1/1/2017)*
The gas fuel supply lines is to have a design pressure not less than 1.0 MPa.

9.8 Regulations for the design of ventilated duct, outer pipe against inner pipe gas leakage

9.8.1 *(1/1/2017)*
The design pressure of the outer pipe or duct of fuel systems is not to be less than the maximum working pressure of the inner pipe. Alternatively for fuel piping systems with a working pressure greater than 1.0 MPa, the design pressure of the outer pipe or duct is not to be less than the maximum built-up pressure arising in the annular space considering the local instantaneous peak pressure in way of any rupture and the ventilation arrangements.

9.8.2 *(1/1/2017)*
For high-pressure fuel piping the design pressure of the ducting is to be taken as the higher of the following:

a) the maximum built-up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space;

b) local instantaneous peak pressure in way of the rupture: this pressure is to be taken as the critical pressure given by the following expression:

$$p = p_0 \left(\frac{2}{k+1} \right)^{\frac{k}{k-1}}$$

where:

p_0 : maximum working pressure of the inner pipe

k : C_p/C_v constant pressure specific heat divided by the constant

k = 1,31 for CH_4

The tangential membrane stress of a straight pipe is not to exceed the tensile strength divided by 1,5 (Rm/1,5) when subjected to the above pressures. The pressure ratings of all other piping components are to reflect the same level of strength as straight pipes.

As an alternative to using the peak pressure from the above formula, the peak pressure found from representative tests can be used. Test reports are then to be submitted.

9.8.3 *(1/1/2017)*

Verification of the strength is to be based on calculations demonstrating the duct or pipe integrity. As an alternative to calculations, the strength can be verified by representative tests.

9.8.4 *(1/1/2017)*

For low pressure fuel piping the duct is to be dimensioned for a design pressure not less than the maximum working pressure of the fuel pipes. The duct is to be pressure tested to show that it can withstand the expected maximum pressure at fuel pipe rupture.

9.9 Regulations for compressors and pumps

9.9.1 *(1/1/2017)*

If compressors or pumps are driven by shafting passing through a bulkhead or deck, the bulkhead penetration is to be of gastight type.

9.9.2 *(1/1/2017)*

Compressors and pumps are to be suitable for their intended purpose. All equipment and machinery is to be such as to be adequately tested to ensure suitability for use within a marine environment. Such items to be considered would include, but not be limited to:

a) environmental;

b) shipboard vibrations and accelerations;

c) effects of pitch, heave and roll motions, etc.; and

d) gas composition.

9.9.3 *(1/1/2017)*

Arrangements are to be made to ensure that under no circumstances liquefied gas can be introduced in the gas control section or gas-fuelled machinery, unless the machinery is designed to operate with gas in liquid state.

9.9.4 *(1/1/2017)*

Compressors and pumps are to be fitted with accessories and instrumentation necessary for efficient and reliable function.

10 Power generation including propulsion and other gas consumers

IGF CODE REFERENCE: Ch. 10

10.1 Goal

10.1.1 *(1/1/2017)*

The goal of this paragraph is to provide safe and reliable delivery of mechanical, electrical or thermal energy.

10.2 Functional requirements

10.2.1 *(1/1/2017)*

This paragraph is related to functional requirements in [3.2.1], [3.2.11], [3.2.13], [3.2.16] and [3.2.17]. In particular the following apply:

a) the exhaust systems are to be configured to prevent any accumulation of un- burnt gaseous fuel;

b) unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, engine components or systems containing or likely to contain an ignitable gas and air mixture are to be fitted with suitable

pressure relief systems. Dependent on the particular engine design this may include the air inlet manifolds and scavenge spaces;

c) *the explosion venting is to be led away from where personnel may normally be present; and*

d) *all gas consumers are to have a separate exhaust system.*

10.3 Regulations for internal combustion engines of piston type

10.3.1 General *(1/1/2017)*

a) *The exhaust system is to be equipped with explosion relief ventilation sufficiently dimensioned to prevent excessive explosion pressures in the event of ignition failure of one cylinder followed by ignition of the unburned gas in the system.*

b) *For engines where the space below the piston is in direct communication with the crankcase a detailed evaluation regarding the hazard potential of fuel gas accumulation in the crankcase is to be carried out and reflected in the safety concept of the engine.*

c) *Each engine other than two-stroke crosshead diesel engines is to be fitted with vent systems independent of other engines for crankcases and sumps.*

d) *Where gas can leak directly into the auxiliary system medium (lubricating oil, cooling water), an appropriate means is to be fitted after the engine outlet to extract gas in order to prevent gas dispersion. The gas extracted from auxiliary systems media is to be vented to a safe location in the atmosphere.*

e) *For engines fitted with ignition systems, prior to admission of gas fuel, correct operation of the ignition system on each unit is to be verified.*

f) *A means is to be provided to monitor and detect poor combustion or misfiring. In the event that it is detected, gas operation may be allowed provided that the gas supply to the concerned cylinder is shut off and provided that the operation of the engine with one cylinder cut-off is acceptable with respects to torsional vibrations.*

g) *For engines starting on fuels covered by this Appendix, if combustion has not been detected by the engine monitoring system within an engine specific time after the opening of the fuel supply valve, the fuel supply valve is to be automatically shut off. Means to ensure that any unburnt fuel mixture is purged away from the exhaust system are to be provided.*

10.3.2 **Regulations for dual fuel engines** *(1/1/2017)*

a) *In case of shutoff of the gas fuel supply, the engines are to be capable of continuous operation by oil fuel only without interruption.*

b) *An automatic system is to be fitted to change over from gas fuel operation to oil fuel operation and vice versa with minimum fluctuation of the engine power. Acceptable reliability is to be demonstrated through testing. In the case of unstable operation on engines when gas firing, the engine is to automatically change to oil fuel mode. Manual activation of gas system shutdown is always to be possible.*

c) *In case of a normal stop or an emergency shutdown, the gas fuel supply is to be shut off not later than the ignition source. It is not to be possible to shut off the ignition source without first or simultaneously closing the gas supply to each cylinder or to the complete engine.*

10.3.3 **Regulations for gas-only engines** *(1/1/2017)*

In case of a normal stop or an emergency shutdown, the gas fuel supply is to be shut off not later than the ignition source. It is not to be possible to shut off the ignition source without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

10.3.4 **Regulations for multi-fuel engines** *(1/1/2017)*

a) *In case of shutoff of one fuel supply, the engines are to be capable of continuous operation by an alternative fuel with minimum fluctuation of the engine power.*

b) *An automatic system is to be fitted to change over from one fuel operation to an alternative fuel operation with minimum fluctuation of the engine power. Acceptable reliability is to be demonstrated through testing. In the case of unstable operation on an engine when using a particular fuel, the engine is to automatically change to an alternative fuel mode. Manual activation is always to be possible.*

Table 2 *(1/1/2017)*

	GAS ONLY	DUAL FUEL	MULTI FUEL

IGNITION MEDIUM	Spark	Pilot fuel	Pilot fuel	N/A
MAIN FUEL	Gas	Gas	Gas and/or Oil fuel	Gas and/or Liquid

10.4 Regulations for main and auxiliary boilers

10.4.1 *(1/1/2017)*

Each boiler is to have a dedicated forced draught system. A crossover between boiler force draught systems may be fitted for emergency use providing that any relevant safety functions are maintained.

10.4.2 *(1/1/2017)*

Combustion chambers and uptakes of boilers are to be designed to prevent any accumulation of gaseous fuel.

10.4.3 *(1/1/2017)*

Burners are to be designed to maintain stable combustion under all firing conditions.

10.4.4 *(1/1/2017)*

On main/propulsion boilers an automatic system is to be provided to change from gas fuel operation to oil fuel operation without interruption of boiler firing.

10.4.5 *(1/1/2017)*

Gas nozzles and the burner control system are to be configured such that gas fuel can only be ignited by an established oil fuel flame, unless the boiler and combustion equipment is designed and approved by the Society to light on gas fuel.

10.4.6 *(1/1/2017)*

There are to be arrangements to ensure that gas fuel flow to the burner is automatically cut off unless satisfactory ignition has been established and maintained.

10.4.7 *(1/1/2017)*

On the fuel pipe of each gas burner a manually operated shutoff valve is to be fitted.

10.4.8 *(1/1/2017)*

Provisions are to be made for automatically purging the gas supply piping to the burners, by means of an inert gas, after the extinguishing of these burners.

10.4.9 *(1/1/2017)*

The automatic fuel changeover system required by [10.4.4] is to be monitored with alarms to ensure continuous availability.

10.4.10 *(1/1/2017)*

Arrangements are to be made that, in case of flame failure of all operating burners, the combustion chambers of the boilers are automatically purged before relighting.

10.4.11 *(1/1/2017)*

Arrangements are to be made to enable the boilers purging sequence to be manually activated.

10.5 Regulations for gas turbines

10.5.1 *(1/1/2017)*

Unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, pressure relief systems are to be suitably designed and fitted to the exhaust system, taking into consideration explosions due to gas leaks. Pressure relief systems within the exhaust uptakes are to be led to a safe location, away from personnel.

10.5.2 *(1/1/2017)*

The gas turbine may be fitted in a gas-tight enclosure arranged in accordance with the ESD principle outlined in [5.7] and [9.7], however a pressure above 1.0 MPa in the gas supply piping may be accepted within this enclosure.

10.5.3 *(1/1/2017)*

Gas detection systems and shutdown functions are to be as outlined for ESD protected machinery spaces.

10.5.4 *(1/1/2017)*
Ventilation for the enclosure is to be as outlined in paragraph [12] for ESD protected machinery spaces, but in addition it is to be arranged with full redundancy (2 x 100% capacity fans from different electrical circuits).

10.5.5 *(1/1/2017)*
For other than single fuel gas turbines, an automatic system is to be fitted to change over easily and quickly from gas fuel operation to oil fuel operation and vice-versa with minimum fluctuation of the engine power.

10.5.6 *(1/1/2017)*
Means are to be provided to monitor and detect poor combustion that may lead to unburnt fuel gas in the exhaust system during operation. In the event that it is detected, the fuel gas supply is to be shutdown.

10.5.7 *(1/1/2017)*
Each turbine is to be fitted with an automatic shutdown device for high exhaust temperatures.

11 Explosion prevention

IGF CODE REFERENCE: Ch. 12

11.1 Goal

11.1.1 *(1/1/2017)*
The goal of this paragraph is to provide for the prevention of explosions and for the limitation of effects from explosion.

11.2 Functional requirements

11.2.1 *(1/1/2017)*
This paragraph is related to functional requirements in [3.2.2] to [3.2.5], [3.2.7], [3.2.8], [3.2.12] to [3.2.14] and [3.2.17]. In particular the following apply.

The probability of explosions is to be reduced to a minimum by:

a) reducing number of sources of ignition; and

b) reducing the probability of formation of ignitable mixtures.

11.3 Regulations - General

11.3.1 *(1/1/2017)*
Hazardous areas on open deck and other spaces not addressed in this paragraph are to be decided based on a recognized standard. The electrical equipment fitted within hazardous areas is to be according to the same standard.

11.3.2 *(1/1/2017)*
Electrical equipment and wiring, in general, is not be installed in hazardous areas unless essential for operational purposes based on a recognized standard.

11.3.3 *(1/1/2017)*
Electrical equipment fitted in an ESD-protected machinery space is to fulfil the following:

a) in addition to fire and gas hydrocarbon detectors and fire and gas alarms, lighting and ventilation fans are to be certified safe for hazardous area zone 1; and

b) all electrical equipment in a machinery space containing gas-fuelled engines, and not certified for zone 1 is to be automatically disconnected, if gas concentration above 40% LEL is detected by two detectors in the space containing gas-fuelled consumers.

11.4 Regulations on area classification

11.4.1 *(1/1/2017)*
Area classification is a method of analysing and classifying the areas where explosive gas atmospheres may occur. The object of the classification is to allow the selection of electrical apparatus able to be operated safely in these areas.

11.4.2 *(1/1/2017)*
In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2. See also [11.5] below.

11.4.3 *(1/1/2017)*

Ventilation ducts are to have the same area classification as the ventilated space.

11.5 Hazardous area zones

11.5.1 **Hazardous area zone 0** *(1/1/2017)*

This zone includes, but is not limited to the interiors of fuel tanks, any pipework for pressure- relief or other venting systems for fuel tanks, pipes and equipment containing fuel.

11.5.2 **Hazardous area zone 1** *(1/1/2017)*

This zone includes, but is not limited to:

a) tank connection spaces, fuel storage hold spaces and interbarrier spaces; fuel storage hold spaces containing Type C tanks with all potential leakage sources in a tank connection space and having no access to any hazardous area, they are to be considered non-hazardous.

Where the fuel storage hold spaces include potential leak sources, e.g. tank connections, they are to be considered hazardous area zone 1.

Where the fuel storage hold spaces included bolted access to the tank connection space, they are to be considered hazardous are zone 2.

b) fuel preparation room arranged with ventilation according to [12.6];

c) areas on open deck, or semi-enclosed spaces on deck, within 3 m of any fuel tank outlet, gas or vapour outlet, bunker manifold valve, other fuel valve, fuel pipe flange, fuel preparation room ventilation outlets and fuel tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

d) areas on open deck or semi-enclosed spaces on deck, within 1,5 m of fuel preparation room entrances, fuel preparation room ventilation inlets and other openings into zone 1 spaces;

e) areas on the open deck within spillage coamings surrounding gas bunker manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck;

f) enclosed or semi-enclosed spaces in which pipes containing fuel are located, e.g. ducts around fuel pipes, semi-enclosed bunkering stations;

g) the ESD-protected machinery space is considered a non-hazardous area during normal operation, but will require equipment required to operate following detection of gas leakage to be certified as suitable for zone 1;

h) a space protected by an airlock is considered as non-hazardous area during normal operation, but will require equipment required to operate following loss of differential pressure between the protected space and the hazardous area to be certified as suitable for zone 1; and

i) except for type C tanks, an area within 2.4 m of the outer surface of a fuel containment system where such surface is exposed to the weather.

11.5.3 **Hazardous area zone 2** *(1/1/2017)*

a) This zone includes, but is not limited to areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1.

b) Space containing bolted hatch to tank connection space.

12 Ventilation

IGF CODE REFERENCE: Ch. 13

12.1 Goal

12.1.1 *(1/1/2017)*

The goal of this paragraph is to provide for the ventilation required for safe operation of gas-fuelled machinery and equipment.

12.2 Functional requirements

12.2.1 *(1/1/2017)*

This paragraph is related to functional requirements in [3.2.2], [3.2.5], [3.2.8], [3.2.10], [3.2.12] to [3.2.14] and [3.2.17].

12.3 Regulations - General

12.3.1 *(1/1/2017)*

Any ducting used for the ventilation of hazardous spaces is to be separate from that used for the ventilation of non-hazardous spaces. The ventilation is to function at all temperatures and environmental conditions the ship will be operating in.

12.3.2 *(1/1/2017)*

Electric motors for ventilation fans are not be located in ventilation ducts for hazardous spaces unless the motors are certified for the same hazard zone as the space served.

12.3.3 *(1/1/2017)*

Design of ventilation fans serving spaces containing gas sources is to fulfil the following:

a) Ventilation fans are not to produce a source of vapour ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, are to be of non-sparking construction defined as:

1) impellers or housings of non-metallic material, due regard being paid to the elimination of static electricity;

2) impellers and housings of non-ferrous metals;

3) impellers and housings of austenitic stainless steel;

4) impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous materials is fitted in way of the impeller, due regard being paid to static electricity and corrosion between ring and housing; or

5) any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

b) In no case is the radial air gap between the impeller and the casing to be less than 0.1 of the diameter of the impeller shaft in way of the bearing but not less than 2 mm. The gap need not be more than 13 mm.

c) Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and is not to be used in these places.

12.3.4 *(1/1/2017)*

Ventilation systems required to avoid any gas accumulation are to consist of independent fans, each of sufficient capacity, unless otherwise specified in this Appendix.

12.3.5 *(1/1/2017)*

Air inlets for hazardous enclosed spaces are to be taken from areas that, in the absence of the considered inlet, would be non-hazardous. Air inlets for non-hazardous enclosed spaces are to be taken from non-hazardous areas at least 1,5 m away from the boundaries of any hazardous area. Where the inlet duct passes through a more hazardous space, the duct is to be gas-tight and have over-pressure relative to this space.

12.3.6 *(1/1/2017)*

Air outlets from non-hazardous spaces are to be located outside hazardous areas.

12.3.7 *(1/1/2017)*

Air outlets from hazardous enclosed spaces are to be located in an open area that, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

12.3.8 *(1/1/2017)*

The required capacity of the ventilation plant is normally based on the total volume of the room. An increase in required ventilation capacity may be necessary for rooms having a complicated form.

12.3.9 *(1/1/2017)*

Non-hazardous spaces with entry openings to a hazardous area are to be arranged with an airlock and be maintained at overpressure relative to the external hazardous area. The overpressure ventilation is to be arranged according to the following:

a) During initial start-up or after loss of overpressure ventilation, before energizing any electrical installations not certified safe for the space in the absence of pressurization, it is to be required to:

1) proceed with purging (at least 5 air changes) or confirm by measurements that the space is non-hazardous; and

2) pressurize the space.

b) Operation of the overpressure ventilation is to be monitored and in the event of failure of the overpressure ventilation:

1) an audible and visual alarm is to be given at a manned location; and

2) if overpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to a recognized standard26 is to be required.

12.3.10 *(1/1/2017)*

Non-hazardous spaces with entry openings to a hazardous enclosed space are to be arranged with an airlock and the hazardous space is to be maintained at underpressure relative to the non-hazardous space. Operation of the extraction ventilation in the hazardous space is to be monitored and in the event of failure of the extraction ventilation:

a) an audible and visual alarm is to be given at a manned location; and

b) if underpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to a recognized standard in the non-hazardous space is to be required.

12.4 Regulations for tank connection space

12.4.1 *(1/1/2017)*

The tank connection space is to be provided with an effective mechanical forced ventilation system of extraction type. A ventilation capacity of at least 30 air changes per hour is to be provided. The rate of air changes may be reduced if other adequate means of explosion protection are installed. The equivalence of alternative installations is to be demonstrated by a risk assessment process as outlined in IMO MSC/Circ.1212.

12.4.2 *(1/1/2017)*

Approved automatic fail-safe fire dampers are to be fitted in the ventilation trunk for the tank connection space.

12.5 Regulations for machinery spaces

12.5.1 *(1/1/2017)*

The ventilation system for machinery spaces containing gas-fuelled consumers is to be independent of all other ventilation systems.

12.5.2 *(1/1/2017)*

ESD protected machinery spaces are to have ventilation with a capacity of at least 30 air changes per hour. The ventilation system is to ensure a good air circulation in all spaces, and in particular ensure that any formation of gas pockets in the room are detected. As an alternative, arrangements whereby under normal operation the machinery spaces are ventilated with at least 15 air changes an hour is acceptable provided that, if gas is detected in the machinery space, the number of air changes will automatically be increased to 30 an hour.

12.5.3 *(1/1/2017)*

For ESD protected machinery spaces the ventilation arrangements are to provide sufficient redundancy to ensure a high level of ventilation availability as defined in a standard acceptable to the Society.

12.5.4 *(1/1/2017)*

The number and power of the ventilation fans for ESD protected engine-rooms and for double pipe ventilation systems for gas safe engine-rooms are to be be such that the capacity is not reduced by more than 50% of the total ventilation capacity if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

12.6 Regulations for fuel preparation room

12.6.1 *(1/1/2017)*

Fuel preparation rooms are to be fitted with effective mechanical ventilation system of the underpressure type, providing a ventilation capacity of at least 30 air changes per hour.

12.6.2 *(1/1/2017)*

The number and power of the ventilation fans are to be such that the capacity is not reduced by more than 50%, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

12.6.3 *(1/1/2017)*
Ventilation systems for fuel preparation rooms are to be in operation when pumps or compressors are working.

12.7 Regulations for bunkering station

12.7.1 *(1/1/2017)*
Bunkering stations that are not located on open deck are to be suitably ventilated to ensure that any vapour being released during bunkering operations will be removed outside. If the natural ventilation is not sufficient, mechanical ventilation is to be provided in accordance with the risk assessment required by [8.3.1]a).

12.8 Regulations for ducts and double pipes

12.8.1 *(1/1/2017)*
Ducts and double pipes containing fuel piping are to be fitted with effective mechanical ventilation system of the extraction type, providing a ventilation capacity of at least 30 air changes per hour. This is not applicable to double pipes in the engine-room if fulfilling [9.6.1]a).

12.8.2 *(1/1/2017)*
The ventilation system for double piping and for gas valve unit spaces in gas safe engine-rooms is to be independent of all other ventilation systems.

12.8.3 *(1/1/2017)*
The ventilation inlet for the double wall piping or duct is always to be located in a non-hazardous area away from ignition sources. The inlet opening is to be fitted with a suitable wire mesh guard and protected from ingress of water.

12.8.4 *(1/1/2017)*
The capacity of the ventilation for a pipe duct or double wall piping may be below 30 air changes per hour if a flow velocity of minimum 3 m/s is ensured. The flow velocity is to be calculated for the duct with fuel pipes and other components installed.

13 Electrical installations

IGF CODE REFERENCE: Ch. 14

13.1 Goal

13.1.1 *(1/1/2017)*
The goal of this paragraph is to provide for electrical installations that minimize the risk of ignition in the presence of a flammable atmosphere.

13.2 Functional requirements

13.2.1 *(1/1/2017)*
This paragraph is related to functional requirements in [3.2.1], [3.2.2], [3.2.4], [3.2.7], [3.2.8], [3.2.11], [3.2.13] and [3.2.16] to [3.2.18]. In particular the following apply.
Electrical generation and distribution systems, and associated control systems, are to be designed such that a single fault will not result in the loss of ability to maintain fuel tank pressures and hull structure temperature within normal operating limits.

13.3 Regulations - General

13.3.1 *(1/1/2017)*
Electrical installations are to be in compliance with a standard at least equivalent to those acceptable to the Society.

13.3.2 *(1/1/2017)*
Electrical equipment or wiring are not to be installed in hazardous areas unless essential for operational purposes or safety enhancement.

13.3.3 *(1/1/2017)*
Where electrical equipment is installed in hazardous areas as provided in [13.3.2] it is to be selected, installed and maintained in accordance with standards at least equivalent to those acceptable to the Organization.

Equipment for hazardous areas is to be evaluated and certified or listed by an accredited testing authority or notified body recognized by the Society.

13.3.4 *(1/1/2017)*
Failure modes and effects of single failure for electrical generation and distribution systems in [13.2] are to be analysed and documented to be at least equivalent to those acceptable to the Organization.

13.3.5 *(1/1/2017)*
The lighting system in hazardous areas is to be divided between at least two branch circuits. All switches and protective devices are to interrupt all poles or phases and are to be located in a non-hazardous area.

13.3.6 *(1/1/2017)*
The installation on board of the electrical equipment units is to be such as to ensure the safe bonding to the hull of the units themselves.

13.3.7 *(1/1/2017)*
Arrangements are to be made to alarm in low-liquid level and automatically shut down the motors in the event of low-liquid level. The automatic shutdown may be accomplished by sensing low pump discharge pressure, low motor current, or low-low liquid level. This shutdown is to give an audible and visual alarm on the navigation bridge, continuously manned central control station or onboard safety centre.

13.3.8 *(1/1/2017)*
Submerged fuel pump motors and their supply cables may be fitted in liquefied gas fuel containment systems. Fuel pump motors are to be capable of being isolated from their electrical supply during gas-freeing operations.

13.3.9 *(1/1/2017)*
For non-hazardous spaces with access from hazardous open deck where the access is protected by an airlock, electrical equipment which is not of the certified safe type is to be de-energized upon loss of overpressure in the space.

13.3.10 *(1/1/2017)*
Electrical equipment for propulsion, power generation, manoeuvring, anchoring and mooring, as well as emergency fire pumps, that are located in spaces protected by airlocks, is to be of a certified safe type.

14 Control monitoring and safety systems

IGF CODE REFERENCE: Ch. 15

14.1 Goal

14.1.1 *(1/1/2017)*
The goal of this paragraph is to provide for the arrangement of control, monitoring and safety systems that support an efficient and safe operation of the gas-fuelled installation as covered in the other paragraphs of this Appendix.

14.2 Functional requirements

14.2.1 *(1/1/2017)*
This paragraph is related to functional requirements in [3.2.1], [3.2.2], [3.2.11], [3.2.13] to [3.2.15], [3.2.17] and [3.2.18]. In particular the following apply:

a) the control, monitoring and safety systems of the gas-fuelled installation are to be so arranged that the remaining power for propulsion and power generation is in accordance with [9.3.1] in the event of single failure;

b) a gas safety system is to be arranged to close down the gas supply system automatically, upon failure in systems as described in table 1 and upon other fault conditions which may develop too fast for manual intervention;

c) for ESD protected machinery configurations the safety system is to shut down gas supply upon gas leakage and in addition disconnect all non-certified safe type electrical equipment in the machinery space;

d) the safety functions are to be arranged in a dedicated gas safety system that is independent of the gas control system in order to avoid possible common cause failures. This includes power supplies and input and output signal;

e) the safety systems including the field instrumentation are to be arranged to avoid spurious shutdown, e.g. as a result of a faulty gas detector or a wire break in a sensor loop; and

f) where two or more gas supply systems are required to meet the regulations, each system is to be fitted with its own set of independent gas control and gas safety systems.

14.3 Regulations - General

14.3.1 *(1/1/2017)*

Suitable instrumentation devices are to be fitted to allow a local and a remote reading of essential parameters to ensure a safe management of the whole fuel-gas equipment including bunkering.

14.3.2 *(1/1/2017)*

A bilge well in each tank connection space of an independent liquefied gas storage tank is to be provided with both a high level indicator (e.g float switch) and a temperature sensor. Alarm is to be given at high level in the bilge well. Low temperature indication is to activate the safety system.

14.3.3 *(1/1/2017)*

For tanks not permanently installed in the ship a monitoring system is to be provided as for permanently installed tanks.

14.4 Regulations for bunkering and liquefied gas fuel tank monitoring

14.4.1 *(1/1/2017)*

Level indicators for liquefied gas fuel tanks:

a) Each liquefied gas fuel tank is to be fitted with liquid level gauging device(s), arranged to ensure a level reading is always obtainable whenever the liquefied gas fuel tank is operational. The device(s) is (are) to be designed to operate throughout the design pressure range of the liquefied gas fuel tank and at temperatures within the fuel operating temperature range.

b) Where only one liquid level gauge is fitted, it is to be arranged so that it can be maintained in an operational condition without the need to empty or gas-free the tank.

c) Liquefied gas fuel tank liquid level gauges may be of the following types:

1) indirect devices, which determine the amount of fuel by means such as weighing or in-line flow metering; or

2) closed devices, which do not penetrate the liquefied gas fuel tank, such as devices using radio-isotopes or ultrasonic devices.

14.4.2 *(1/1/2017)*

Overflow control:

a) Each liquefied gas fuel tank is to be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated.

b) An additional sensor operating independently of the high liquid level alarm is to automatically actuate a shutoff valve in a manner that will both avoid excessive liquid pressure in the bunkering line and prevent the liquefied gas fuel tank from becoming liquid full.

c) The position of the sensors in the liquefied gas fuel tank is to be capable of being verified before commissioning. At the first occasion of full loading after delivery and after each dry-docking, testing of high level alarms is to be conducted by raising the fuel liquid level in the liquefied gas fuel tank to the alarm point.

d) All elements of the level alarms, including the electrical circuit and the sensor(s), of the high, and overfill alarms, are to be capable of being functionally tested. Systems are to be tested prior to fuel operation.

e) Where arrangements are provided for overriding the overflow control system, they are to be such that inadvertent operation is prevented. When this override is operated, continuous visual indication is to be provided at the navigation bridge, continuously manned central control station or onboard safety centre.

14.4.3 *(1/1/2017)*

The vapour space of each liquefied gas fuel tank is to be provided with a direct reading gauge. Additionally, an indirect indication is to be provided on the navigation bridge, continuously manned central control station or onboard safety centre.

14.4.4 *(1/1/2017)*

The pressure indicators are to be clearly marked with the highest and lowest pressure permitted in the liquefied gas fuel tank.

14.4.5 *(1/1/2017)*

A high-pressure alarm and, if vacuum protection is required, a low-pressure alarm is to be provided on the navigation bridge and at a continuously manned central control station or onboard safety centre. Alarms are to be activated before the set pressures of the safety valves are reached.

14.4.6 *(1/1/2017)*
Each fuel pump discharge line and each liquid and vapour fuel manifold is to be provided with at least one local pressure indicator.

14.4.7 *(1/1/2017)*
Local-reading manifold pressure indicator is to be provided to indicate the pressure between ship's manifold valves and hose connections to the shore.

14.4.8 *(1/1/2017)*
Fuel storage hold spaces and interbarrier spaces without open connection to the atmosphere are to be provided with pressure indicator.

14.4.9 *(1/1/2017)*
At least one of the pressure indicators provided is to be capable of indicating throughout the operating pressure range.

14.4.10 *(1/1/2017)*
For submerged fuel-pump motors and their supply cables, arrangements are to be made to alarm in low-liquid level and automatically shut down the motors in the event of low-liquid level. The automatic shutdown may be accomplished by sensing low pump discharge pressure, low motor current, or low-low liquid level. This shutdown is to give an audible and visual alarm on the navigation bridge, continuously manned central control station or onboard safety centre.

14.4.11 *(1/1/2017)*
Except for independent tanks of type C supplied with vacuum insulation system and pressure build-up fuel discharge unit, each fuel tank is to be provided with devices to measure and indicate the temperature of the fuel in at least three locations; at the bottom and middle of the tank as well as the top of the tank below the highest allowable liquid level.

14.5 Regulations for bunkering control

14.5.1 *(1/1/2017)*
Control of the bunkering is to be possible from a safe location remote from the bunkering station. At this location the tank pressure, tank temperature if required by [14.4.11] and tank level are to be monitored. Remotely controlled valves required by [8.5.3] are to be capable of being operated from this location. Overfill alarm and automatic shutdown are also to be indicated at this location.

14.5.2 *(1/1/2017)*
If the ventilation in the ducting enclosing the bunkering lines stops, an audible and visual alarm is to be provided at the bunkering control location, see also [14.8].

14.5.3 *(1/1/2017)*
If gas is detected in the ducting around the bunkering lines an audible and visual alarm and emergency shutdown is to be provided at the bunkering control location.

14.6 Regulations for gas compressor monitoring

14.6.1 *(1/1/2017)*
Gas compressors are to be fitted with audible and visual alarms both on the navigation bridge and in the engine control room. As a minimum the alarms are to include low gas input pressure, low gas output pressure, high gas output pressure and compressor operation.

14.6.2 *(1/1/2017)*
Temperature monitoring for the bulkhead shaft glands and bearings are to be provided, which automatically give a continuous audible and visual alarm on the navigation bridge or in a continuously manned central control station.

14.7 Regulations for gas engine monitoring

14.7.1 *(1/1/2017)*
In addition to the instrumentation provided in accordance with part C of SOLAS chapter II-1, indicators are to be fitted on the navigation bridge, the engine control room and the manoeuvring platform for:

a) operation of the engine in case of gas-only engines; or

b) operation and mode of operation of the engine in the case of dual fuel engines.

14.8 Regulations for gas detection

14.8.1 *(1/1/2017)*

Permanently installed gas detectors are to be fitted in:

a) the tank connection spaces;

b) all ducts around fuel pipes;

c) machinery spaces containing gas piping, gas equipment or gas

d) compressor rooms and fuel preparation rooms;

e) other enclosed spaces containing fuel piping or other fuel equipment without ducting;

f) other enclosed or semi-enclosed spaces where fuel vapours may accumulate including interbarrier spaces and fuel storage hold spaces of independent tanks other than type C;

g) airlocks;

h) gas heating circuit expansion tanks;

i) motor rooms associated with the fuel systems; and

j) at ventilation inlets to accommodation and machinery spaces if required based on the risk assessment required in [4.2].

14.8.2 *(1/1/2017)*

In each ESD protected machinery space, redundant gas detection systems provided.

14.8.3 *(1/1/2017)*

The number of detectors in each space is to be considered taking into account the size, layout and ventilation of the space.

14.8.4 *(1/1/2017)*

The detection equipment is to be located where gas may accumulate and in the ventilation outlets. Gas dispersal analysis or a physical smoke test is to be used to find the best arrangement.

14.8.5 *(1/1/2017)*

Gas detection equipment is to be designed, installed and tested in accordance with a recognized standard.

14.8.6 *(1/1/2017)*

An audible and visible alarm is to be activated at a gas vapour concentration of 20% of the lower explosion limit (LEL). The safety system is to be activated at 40% of LEL at two detectors (see footnote 1 in Tab 16).

14.8.7 *(1/1/2017)*

For ventilated ducts around gas pipes in the machinery spaces containing gas-fuelled engines, the alarm limit can be set to 30% LEL. The safety system is to be activated at 60% of LEL at two detectors (see footnote 1 in Tab 16).

14.8.8 *(1/1/2017)*

Audible and visible alarms from the gas detection equipment are to be located on the navigation bridge or in the continuously manned central control station.

14.8.9 *(1/1/2017)*

Gas detection required by this section is to be continuous without delay.

14.9 Regulations for fire detection

14.9.1 *(1/1/2017)*

Required safety actions at fire detection in the machinery space containing gas-fuelled engines and rooms containing independent tanks for fuel storage hold spaces are given in Tab 16 .

14.10 Regulations for ventilation

14.10.1 *(1/1/2017)*

Any loss of the required ventilating capacity is to give an audible and visual alarm on the navigation bridge or in a continuously manned central control station or safety centre.

14.10.2 *(1/1/2017)*

For ESD protected machinery spaces the safety system is to be activated upon loss of ventilation in engine-room.

14.11 Regulations on safety functions of fuel supply systems

14.11.1 *(1/1/2017)*

If the fuel supply is shut off due to activation of an automatic valve, the fuel supply is not to be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect is to be placed at the operating station for the shutoff valves in the fuel supply lines.

14.11.2 *(1/1/2017)*

If a fuel leak leading to a fuel supply shutdown occurs, the fuel supply is not to be operated until the leak has been found and dealt with. Instructions to this effect are to be placed in a prominent position in the machinery space.

14.11.3 *(1/1/2017)*

A caution placard or signboard is to be permanently fitted in the machinery space containing gas-fuelled engines stating that heavy lifting, implying danger of damage to the fuel pipes, is not to be done when the engine(s) is running on gas.

14.11.4 *(1/1/2017)*

Compressors, pumps and fuel supply are to be arranged for manual remote emergency stop from the following locations as applicable:

a) navigation bridge;

b) cargo control room;

c) onboard safety centre;

d) engine control room;

e) fire control station; and

f) adjacent to the exit of fuel preparation rooms.

The gas compressor is also to be arranged for manual local emergency stop.

Table 3 : Monitoring of gas supply system to engines *(1/1/2017)*

Parameter	Alarm	Automatic shutdown of tank valve **(6)**	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comments
Gas detection in tank connection space at 20% LEL	x			
Gas detection on two detectors **(1)** in tank connection space at 40% LEL	x	x		
Fire detection in fuel storage hold space	x			

(1) Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of self-monitoring type the installation of a single gas detector can be permitted

(2) If the tank is supplying gas to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

(3) If the gas is supplied to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing gas-fuelled engines, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

(4) Only double block and bleed valves to close.

(5) If the duct is protected by inert gas (see [9.6.1]a)) then loss of inert gas overpressure is to lead to the same actions as given in this table.

(6) Valves referred to in [9.4.1].

Parameter	Alarm	Automatic shutdown of tank valve **(6)**	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comments
Fire detection in ventilation trunk to the tank connection space and in the tank connection space	x			
Bilge well high level in tank connection space	x			
Bilge well low temperature in tank connection space	x	x		
Gas detection in duct between tank and machinery space containing gas-fuelled engines at 20% LEL	x			
Gas detection on two detectors **(1)** in duct between tank and machinery space containing gas-fuelled engines at 40% LEL	x	x **(2)**		
Gas detection in fuel preparation room at 20% LEL	x			
Gas detection on two detectors **(1)**) in fuel preparation room at 40% LEL	x	x **(2)**		
Gas detection in duct inside machinery space containing gas-fuelled engines at 30% LEL	x			If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection on two detectors **(1)** in duct inside machinery space containing gas-fuelled engines at 60% LEL	x		x **(3)**	If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection in ESD protected machinery space containing gas-fuelled engines at 20% LEL	x			
Gas detection on two detectors **(1)** in ESD protected machinery space containing gas-fuelled engines at 40% LEL	x		x	It is also to disconnect non certified safe electrical equipment in machinery space containing gas-fuelled engines

(1) Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of self-monitoring type the installation of a single gas detector can be permitted

(2) If the tank is supplying gas to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

(3) If the gas is supplied to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing gas-fuelled engines, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

(4) Only double block and bleed valves to close.

(5) If the duct is protected by inert gas (see [9.6.1]a)) then loss of inert gas overpressure is to lead to the same actions as given in this table.

(6) Valves referred to in [9.4.1].

Parameter	Alarm	Automatic shutdown of tank valve **(6)**	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comments
Loss of ventilation in duct between tank and machinery space containing gas-fuelled engines	x		x **(2)**	
Loss of ventilation in duct inside machinery space containing gas-fuelled engines5)	x		x **(3)**	If double pipe fitted in machinery space containing gas-fuelled engines
Loss of ventilation in ESD protected machinery space containing gas-fuelled engines	x		x	
Fire detection in machinery space containing gas-fuelled engines	x			
Abnormal gas pressure in gas supply pipe	x			
Failure of valve control actuating medium	x		x **(4)**	Time delayed as found necessary
Automatic shutdown of engine (engine failure)	x		x **(4)**	
Manually activated emergency shutdown of engine	x		x	

(1) Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of self-monitoring type the installation of a single gas detector can be permitted

(2) If the tank is supplying gas to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

(3) If the gas is supplied to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing gas-fuelled engines, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

(4) Only double block and bleed valves to close.

(5) If the duct is protected by inert gas (see [9.6.1]a)) then loss of inert gas overpressure is to lead to the same actions as given in this table.

(6) Valves referred to in [9.4.1].

15 Manufacture workmanship and testing

IGF CODE REFERENCE: Ch. 16

15.1 General

15.1.1 *(1/1/2017)*

The manufacture, testing, inspection and documentation are to be in accordance with recognized standards and the regulations given in this Appendix.

15.1.2 *(1/1/2025)*

Where post-weld heat treatment is specified or required, the properties of the base material are to be determined in the heat treated condition, in accordance with the applicable Tables of IGF Code Ch 7 and the weld properties are to be determined in the heat treated condition in accordance with IGF Code 16.3. In cases where a post-weld heat treatment is applied, the test regulations may be modified at the discretion of the Society.

15.1.3 *(1/1/2025)*
The requirements of IGF Code 16.2 to 16.7 apply, with the following departures.

15.2 Material Testing

15.2.1 *(1/1/2025)*
When not better or otherwise specified in IGF Code chapter 16, material testing is to be carried out according to Part D as applicable.

15.3 Welding consumables

15.3.1 *(1/1/2025)*
When not better or otherwise specified in IGF Code chapter 16, welding consumables are to be approved according to Pt D, Ch 5, Sec 2 as applicable.

15.4 Non destructive testing

15.4.1 *(1/1/2025)*
When not better or otherwise specified in IGF Code chapter 16, non destructive testing are to be foreseen and carried out according to Part D as applicable and TASNEEF Rules for carrying out non-destructive examinations of welding.

APPENDIX 8 INSTALLATION OF BALLAST WATER MANAGEMENT SYSTEMS

1 Application

1.1 Applicable rules and regulation

1.1.1 *(1/7/2022)*

In addition to the requirements contained in Sec 10, [7] and in Ch 4, Sec 1, [10], the following is to be complied with, when a Ballast water Management system is installed on board

The requirement herewith are additional to the requirements contained in BWM Convention (2004).

2 Definitions

2.1 Definition of terms

2.1.1 *(1/7/2022)*

Ballast Water Management System (hereinafter referred to as 'BWMS') means any system which processes ballast water such that it meets or exceeds the Ballast Water Performance Standard in Regulation D-2 of the BWM Convention. The BWMS includes ballast water equipment, all associated piping arrangements as specified by the manufacturer, control and monitoring equipment and sampling facilities. The categorization of BWMS technologies is given in Tab 1. Applicability of the requirements for each BWMS technology is in accordance with Tab 2.

2.1.2 *(1/7/2022)*

Cargo area of tankers is defined in:

- for tankers to which regulation 1.6.1 of SOLAS Chapter II-2 as amended by IMO resolutions up to MSC.421(98) (hereinafter the same) applies, regulation 3.6 of SOLAS Chapter II-2
- for chemical tankers, Paragraph 1.3.6 of the IBC Code as amended by IMO resolutions up to MSC.460(101)
- for gas carriers, Paragraph 1.2.7 of the IGC Code as amended by IMO resolutions up to MSC.441(99), and
- for offshore support vessels, Paragraph 1.3.1 of the IMO Resolution A.673(16) as amended by Resolution MSC.236(82) or Paragraph 1.2.7 of the IMO Resolution A.1122(30), as applicable.

2.1.3 *(1/7/2022)*

Dangerous gas means any gas which may develop an atmosphere being hazardous to the crew and/or the ship due to flammability, explosivity, toxicity, asphyxiation, corrosivity or reactivity and for which due consideration of the hazards is required, e.g. hydrogen (H_2), hydrocarbon gas, oxygen (O2), carbon dioxide (CO2), carbon monoxide (CO), ozone (O_3), chlorine (Cl_1) and chlorine dioxide (ClO_2), etc.

2.1.4 *(1/7/2022)*

Hazardous area is defined in IEC 60092-502:1999 and means an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus. When a gas atmosphere is present, the following hazards may also be present: toxicity, asphyxiation, corrosivity and reactivity.

2.1.5 *(1/1/2017)*

Dangerous liquid means any liquid that is identified as hazardous in the Material Safety Data Sheet or other documentation relating to this liquid.

2.1.6 *(1/7/2022)*

Non-hazardous area means an area which is not a hazardous area as defined in above [2.1.4].

Table 1 : Categorization of BWMS technologies *(1/7/2022)*

BWMS's Technology category*(informative in [5] should be referred to)→		**1**	**2**	**3a**	**3b**	**3c**	**4**	**5**	**6**	**7a**	**7b**	**8**
Characteristics ↓		In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO2 or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N2 from a N2 Generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-tank de-oxygenation with Inert Gas Generator	In-line full flow electrolysis	In-line side stream electrolysis (2)	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without Discharge treatment tank	In-line side-stream ozone injection with gas/liquid separation tank and Discharge water treatment tank	In-tank pasteurization and de-oxygenation with N2 generator
Des-infection when ballasting	Making use of active substance		X			**In-tank technology: No treatment when ballasting or de-ballasting**	X	X	X	X	X	**In-tank technology: No treatment when ballasting or de-ballasting**
	Full flow of ballast water is passing through the BWMS	X	X	X	X		X				X	
	Only a small part of ballast water is passing through the BWMS to generate the active substance							X				
After-treatment when de-ballasting	Full flow of ballast water is passing through the BWMS	X									X	
	Injection of neutralizer						X	X	X	X	X	
	Not required by the Type Approval Certificate issued by the Administration		X	X								
Examples of dangerous gas as defined in [2.1.3]			(1)	O_2 N_2	CO_2 CO		H_2 Cl_2	H_2 Cl_2	(1)	O_2 O_3 N_2		O_2 N_2

Notes:

(1) To be investigated on a case by case basis based on the result of the IMO (GESAMP) MEPC report for Basic and Final approval in accordance with the G9 Guideline.

(2) In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or de-ballasting).

* Taking into consideration future developments of BWMS technologies, some additional technologies may be considered in this Table by identifying their characteristics in the same manner as for the above BWMS cat.1, 2, 3a, 3b, 3c, 4, 5, 6, 7a, 7b and 8.

Table 2 : Applicability of the requirements for each BWMS technology *(1/7/2022)*

BWMS's Technology category (informative in [5] should be referred to)→	**1**	**2**	**3a**	**3b**	**3c**	**4**	**5**	**6**	**7a**	**7b**	**8**
Requirement ↓	In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO2 or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N2 from a N2 Generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-tank de-oxygenation with Inert Gas Generator	In-line full flow electrolysis	In-line side stream electrolysis (2)	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without Discharge treatment tank	In-line side-stream ozone injection with gas/liquid separation tank and Discharge water treatment tank	In-tank pasteurization and de-oxygenation with N_2 generator
[1] and [2]	X	X	X	X	X	X	X	X	X	X	X
[3.1.1] to [3.1.4]	X	X	X	X	X	X	X	X	X	X	X
[3.1.5]			X	X	X						X
[3.1.6]	X	X	X	X	X	X	X	X	X	X	X
[3.1.7]			X	X	X						X
[3.1.8]				X						X	
[3.1.9]	X	X	X	X	X	X	X	X	X	X	X
[3.2.1], a)				X	X				X	X	
[3.2.1], b)						X	X	X			
[3.2.2]	X	X	X	X		X	X	X	X	X	
[3.2.3]	X	X	X	X	X	X	X	X	X	X	X
[3.2.4]	X	X	X	X		X	X	X	X	X	
[3.3.1], a)		X	X			X	X	X	X	X	X
[3.3.1], b)			X	X	X				X	X	X
[3.3.1], c)									X	X	
[3.3.1], d)						X	X	X	X	X	
[3.3.1], e)						X	X	X			
[3.3.1], f)			X	X	X				X	X	X
[3.3.2], a) to [3.3.2], d)		X	X	X	X	X	X	X	X	X	X
[3.3.2], e)			X			X	X	X	X	X	X
[3.3.2], f)			X						X	X	X
[3.3.2], g)			X			X	X	X	X	X	X
[3.3.3]		X				X	X	X	X	X	
[3.3.4]						X	X	X	X	X	

3 Installation

3.1 General requirements

3.1.1 *(1/7/2022)*

All valves, piping fittings and flanges are to comply with the relevant requirements of IACS UR P2 and P4. In addition, special consideration can be given to the material used for this service with the agreement of Society.

3.1.2 *(1/7/2022)*

The BWMS is to be provided with by-pass or override arrangement to effectively isolate it from any essential ship system to which it is connected. For new installation or retrofit to existing ships, under normal operating conditions of ballasting and de-ballasting given in the Ballast Water Management Plan (BWMP) the adequacy of the generating plant capacity installed on the vessel is to be demonstrated by an electrical load analysis.

For retrofit installation to exiting ships, a revised electrical load analysis with preferential trips of non-essential services can be accepted.

3.1.3 *(1/7/2022)*

The BWMS is to be operated in accordance with the requirements specified in the Type Approval Certificate (TAC) issued by the Flag Administration. BWMS should be operated within its Treatment Rated Capacity (TRC) as per the TAC. This may require limiting of ship's ballast pump flowrates.

The arrangement of the bypasses or overrides of the BWMS is to be consistent with the approved Operation Maintenance and Safety Manual by the Flag Administration's Type Approval.

In case the maximum capacity of the ballast pump(s) exceeds the maximum treatment rated Capacity (TRC) of the BWMS specified in the TAC issued by the Flag Administration, there should be a limitation on the BWMP giving a maximum allowable flow rate for operating the ballast pump(s) that is not to exceed the maximum TRC of the BWMS.

3.1.4 *(1/7/2022)*

BWMS is to be subject to design review by the Society to verify the compliance of the BWMS's manufacturer package with Sec 10, [1.1.1] a). Manufacturers of the BWMS may apply for this design review at the type approval process.

In general, monitoring functions of BWMS belongs to system category I under the application of Ch 3, Sec 3, Tab 2. However, in case a by-pass valve is integrated in the valve remote control system, the by-pass valve belongs to the system category II Ballast transfer remote control system.

The BWMS's components are required to be inspected and certified by the Society at the manufactory (Society Certificate (SC) as defined in Sec 2, [1.5.4] including pressure vessels, piping class I or II, filters, switchboards, etc.

3.1.5 *(1/7/2022)*

Where a vacuum or overpressure may occur in the ballast piping or in the ballast tanks due to the height difference or injection of inert gas or nitrogen (N2), a suitable protection device is to be provided (i.e. P/V valves, P/V breakers, P/V breather valves or pressure safety relief valve or high/low pressure alarms).

The pressure and vacuum settings of the protection device should not exceed the design pressure of the ballast piping (BWMS categories 3a and 3b) or ballast tank (BWMS categories 3a, 3b and 3c), as relevant.

For BWMS categories 3a, 3b and 3c, the inert gas or nitrogen product enriched air from the inert gas system and from the protection devices installed on the ballast tanks (i.e. P/V valves, P/V breakers or P/V breather valves) are to be discharged to a safe location***(1) & (2)** on the open deck.

When the concerned ballast tanks are hazardous areas, an extension of hazardous area is to be considered at the outlet of the protection devices: with reference to IEC 60092-502:1999 §4.2.2.9 the areas on open deck, or semi-enclosed spaces on open deck, within 1,5 m of their outlets are to be categorized hazardous zone 1 and with reference to IEC 60092-502:1999 §4.2.3.1, an additional 1,5 m surrounding the 1,5 m hazardous zone 1 is to be categorized hazardous zone 2. Any source of ignition such as anchor windlass or opening into chain locker should be located outside the hazardous areas.

Where products covered by IEC 60092-502:1999 are stored on-board or generated during operation of the BWMS, the requirements of this standard is to be followed in order to:

- define hazardous areas and acceptable electrical equipment, and
- design ventilation systems.

Note 1: **safe location***(1) and **safe location***(2)

Safe location needs to address the specific types of discharges separately.

Signboards or similar warnings at the discharge areas are to be provided.

Safe location[*(1)]: inert gas or nitrogen product enriched air from:

- in-line (categories 3a and 3b) and in-tank (categories 3c and 8) de-oxygenation BWMS: the protection devices installed on the ballast tanks, nitrogen or inert gas generators, nitrogen buffer tank (if any), or
- in-line ozone injection BWMS (categories 7a and 7b): the oxygen generator.

safe locations on the open deck are:

- not within 3 m of areas traversed by personnel, and
- not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.

Safe location[*(2)]: oxygen-enriched air from:

- in-line and in-tank de-oxygenation BWMS (categories 3a and 8): the nitrogen generator, or
- in-line ozone injection BWMS (categories 7a and 7b): the protection devices or vents from oxygen generator, compressed oxygen vessel, the ozone generator and ozone destructor devices.

safe locations on the open deck are:

- outside of hazardous area
- not within 3 m of any source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard
- not within 3 m of areas traversed by personnel, and
- not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets.

3.1.6 *(1/1/2017)*

Electric and electronic components are not to be installed in a hazardous area unless they are of certified safe type for use in the area. Cable penetrations of decks and bulkheads are to be sealed when a pressure difference between the areas is to be maintained.

3.1.7 *(1/7/2022)*

Inert gas systems installed for de-oxygenation BWMS (categories 3a, 3b, 3c and 8) are to be designed in accordance with the following requirements:

a) FSS Code Ch 15 requirements
   - 2.1.2, 2.1.3
   - 2.2.1.3, 2.2.1.4, 2.2.2.1, 2.2.2.2, 2.2.2.3, 2.2.2.6, 2.2.4.1, 2.2.4.2, 2.2.4.3, 2.2.4.4, 2.2.4.5 except 2.2.4.5.1.3 and 2.2.4.5.3
   - 2.3.1.1.2, 2.3.1.2, 2.3.1.4.2, 2.3.1.5, 2.3.1.6, 2.3.2 except 2.3.2.2.1
   - 2.4.1.3, 2.4.1.4 and 2.4.2
   - For inert gas systems installed for in-tank de-oxygenation BWMS (category 8): 2.2.3.1, 2.2.3.2 except 2.2.3.2.6, 2.2.3.2.7 and 2.2.3.2.10.

   In general, when applying FSS Code Ch.15 requirements to inert-gas based BWMS, the following modifications are to be considered:
   - the terms "cargo tank" and "cargo piping" are to be replaced by "ballast water tank" or "ballast water piping" as relevant
   - the term "cargo control room" is to be replaced by "BWMS control station" as relevant
   - requirements for slop tanks on combination carriers are to be disregarded
   - when applying FSS Code/15.2.2.4.5.1.1, the acceptable oxygen content is to be specified by the manufacturer, 5% oxygen content need not necessarily be applied.

b) Pt E, Ch 7, Sec 4, [1.2.1], Pt E, Ch 8, Sec 1, [3.1.1], Ch 4, Sec 1, [9.5.2] a), b), f), and i), Ch 4, Sec 1, [9.3.1] c), Ch 4, Sec 1, [9.6.3] and Ch 4, Sec 1, [9.6.4]. In applying Ch 4, Sec 1, [9.6.4], the terms “cargo tanks” and “cargo piping” are to be understood as “ballast tanks” and “ballast piping” respectively. For de-oxygenation BWMS (categories 3a, 3b, 3c and 8), the requirements in [3.1.7] a) prevail.

3.1.8 *(1/7/2022)*

When cavitation is the BWMS treatment process (for example by use of pressure vacuum reactor working in combination with a vertical ballast water drop line) or part of the BWMS treatment process (for example by use of “smart pipe” or “special pipe” in BWMS category 7b or by use of “venturi pipe” in BWMS technology 3b) or by use other means, the design and the wall thickness or grade of materials or inside coating or surface treatment of the part of the piping where the cavitation is taking place is to be specifically considered.

3.1.9 *(1/7/2022)*

When it is required to have an automatic shutdown of the BWMS for safety reasons, this is to be initiated by a safety system independent of the BWM control system.

3.2 Additional requirements for tankers

3.2.1 *(1/7/2022)*

Hazardous area classification is to be in accordance with IEC 60092-502:1999 with due consideration of IACS UI SC274.

a) BWMS using ozone generators (categories 7a and 7b) and de-oxygenation BWMS using inert gas generator by treated flue gas from main or auxiliary boilers or gas from an oil or gas-fired gas generator (categories 3b and 3c) are to be located outside the cargo area in accordance with FSS Code Ch 15 §2.3.1.1.2.

Note 1: this requirement does not apply to inert gas generators for which FSS Code Ch 15/2.4.1 and Ch 4, Sec 1, [9.5] and [9.6] apply.

b) In-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6) can be located inside the hazardous areas with due consideration of the requirement of [3.1.6] but should not be located inside the cargo pump room unless it is demonstrated by the BWMS manufacturer that the additional hazards that could be expected from dangerous liquids and dangerous gases stored or evolved from the BWMS (for example H2 generation):

- do not lead to an upgrade of the hazardous area categorization of the cargo pump room
- are not reactive with the cargo vapours expected to be present in the cargo pump room
- are not reactive with the fire-extinguishing medium provided inside the cargo pump room
- are not impacting the performance of the existing fire-fighting systems provided inside the cargo pump room, and
- are not introducing additional hazards inside the cargo pump room such as toxicity hazards that would not have been prior addressed by suitable counter measures.

Note 2:

1) In-line full flow electrolysis BWMS (category 4) could be accepted in cargo compressor rooms of liquefied gas carriers and inside cargo pump rooms of oil tankers or chemical tankers if that cargo pump room is located above the cargo tank deck.

2) For submerged cargo pumps, the room containing the hydraulic power unit or electric motors is not to be considered as the “cargo pump room”.

3) Ballast pump rooms and other pump rooms not containing the cargo pumps are not to be considered as the “cargo pump room”.

3.2.2 *(1/7/2022)*

In general, two independent BWMS should be required i.e. one for ballast tanks located within the cargo area and the other one for ballast tanks located outside cargo area. Specific arrangements where only one single In-line BWMS (categories 1, 2, 3a, 3b, 4, 5, 6, 7a and 7b) could be accepted are given in [4].

Note 1: When the Fore Peak Tank is ballasted with the piping system serving the other ballast tanks within the cargo area in accordance with Pt E, Ch 7, Sec 4, [2.3.8], the ballast water of the Fore Peak tank is to be processed by the BWMS processing the ballast water of the other ballast tanks within the cargo area.

3.2.3 *(1/7/2022)*

Isolation between ballast piping serving the ballast tanks inside and outside of the cargo area is to be in accordance with the following requirements:

a) Interconnection in between the ballast piping serving the ballast tanks located within the cargo area and the ballast piping serving the ballast tanks located outside the cargo area may be accepted if appropriate isolation arrangement is provided in accordance with [4] is applied.

Note 1: The means of appropriate isolation described in a) is necessary for the interconnection specified in said Paragraph regardless of the diameter of the piping.

Note 2: As indicated in [4], the means of appropriate isolation described in [3.2.3] a) is necessary for the interconnection specified in said paragraph in the case of the active substance piping such as N2 gas piping, inert gas piping, neutralizer piping, fresh water piping for filter cleaning, compressed air piping for remaining water purge and sea water piping for adjusting the salinity etc. At the discretion of the Society and for active substance piping and neutralizer piping (both up to 2 inches) only, alternative isolation arrangements, provided preferably on the open deck, offering enhanced safety and gastightness may be considered for penetration of the bulkhead separating the non-hazardous machinery space from a hazardous area (such as the cargo pump room) at as high an elevation in the machinery space as possible, preferably, just below the main deck. The arrangements are to provide suitable protection measures in addressing the pollution hazards and safety concerns due to the potential migration of hydrocarbon or flammable or toxic liquids or vapours from the hazardous areas.

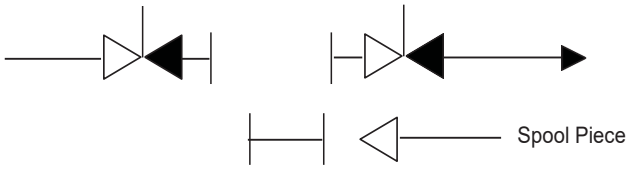
Note 3: The means of appropriate isolation described in [3.2.3] a) for the interconnection specified in said paragraph need not be applied to the sampling lines described in [3.2.4].

The means of appropriate isolation is to be one of the following:

1) Two non-return valves with positive means of closing in series with a spool piece (also mentioned “means of disconnection” [4]), or

Note 4: As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the spool piece.

Figure 1

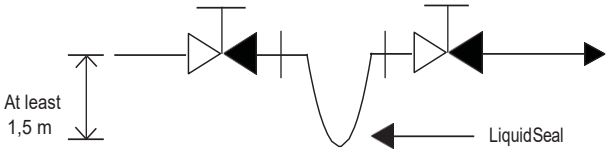


2) Two non-return valves with positive means of closing in series with a liquid seal at least 1,5 m in depth, or

Note 5: As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the liquid seal.

Note 6: For ships operating in cold weather conditions, freeze protection should be provided in the water seal. A portable heating system can be accepted for this purpose.

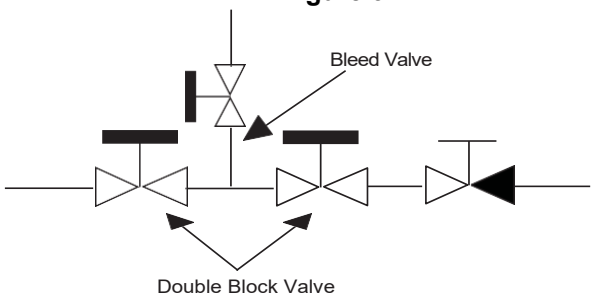
Figure 2



3) Automatic double block and bleed valves and a non-return valve with positive means of closing.

Note 7: As an alternative to positive means of closure, an additional valve having such means of closure may be provided after the non-return valve.

Figure 3



b) The above-mentioned means of appropriate isolation is to be provided on the open deck in the cargo area.

Note 8: When the Fore Peak Tank is ballasted with the piping system serving the other ballast tanks within the cargo area in accordance with Pt E, Ch 7, Sec 4, [2.3.8], the means of appropriate isolation described in [3.2.3] a) and b) is not required in between the Fore Peak Tank and the common ballast water piping serving the other ballast water tanks within the cargo area.

3.2.4 *(1/7/2022)*

Sampling lines which are connected to the ballast water piping system serving the tanks in the cargo area and provided for the purpose of the following:

- for any BWMS: ballast water sampling required by the G2 Guideline of the BWM Convention (2004), or
- for BWMS technologies categories 4, 5, 6, 7a and 7b: total residual oxidant (TRO) analysis in closed loop system

are not to be led into a non-hazardous enclosed space outside the cargo area.

However, the sampling lines may lead into a non-hazardous enclosed space outside the cargo area provided the following requirements are fulfilled:

a) The sampling facility (for BWMS monitoring/control) is to be located within a gas tight enclosure (hereinafter, referred to as a ‘cabinet’), and the following 1) through 4) are to be complied.

1) In the cabinet, a stop valve is to be installed on each sampling line

2) Gas detection equipment is to be installed in the cabinet and the valves specified in 1) above are to be automatically closed upon activation of the gas detection equipment

3) Audible and visual alarm signals are to be activated both locally and at the BWMS control station when the concentration of explosive gases reaches a pre-set value, which should not be higher than 30% of the lower flammable limit (LFL). Upon an activation of the alarm, all electrical power to the cabinet is to be automatically disconnected

Note 1: when the electrical equipment is of a certified safety type, the automatic disconnection of power supply is not required.

4) The cabinet is to be vented to a safe location in non-hazardous area on open deck and the vent is to be fitted with a flame arrester.

b) The standard internal diameter of sampling pipes is to be the minimum necessary in order to achieve the functional requirements of the sampling system.

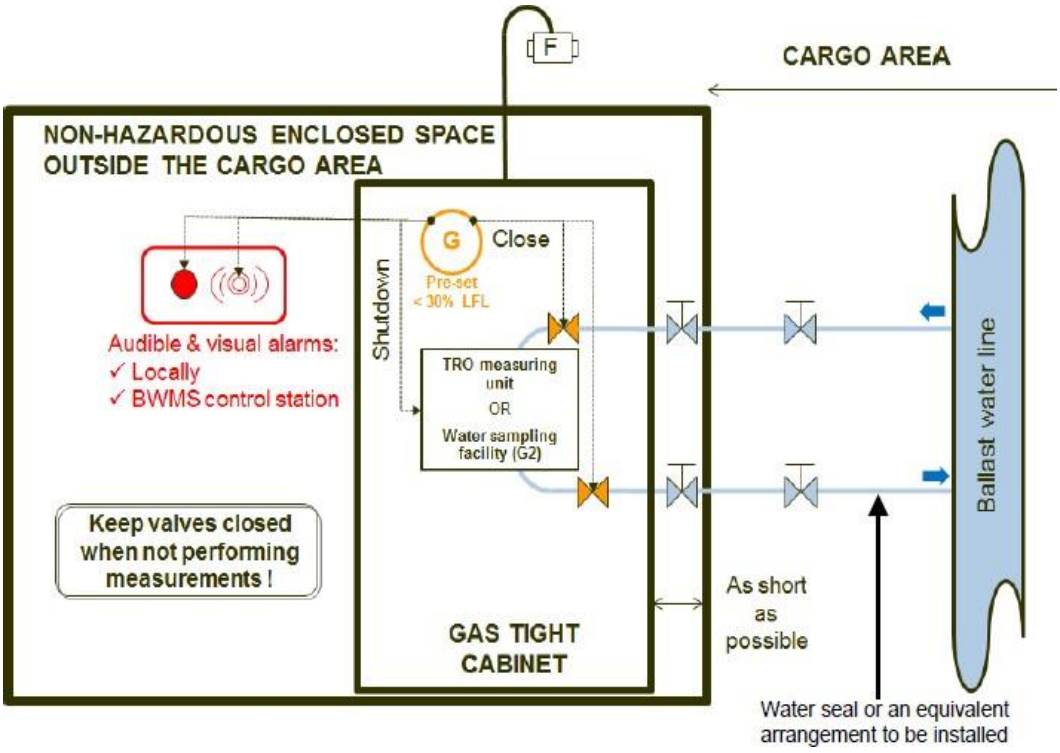
c) The cabinet is to be installed as close as possible to the bulkhead facing the cargo area, and the sampling lines located outside the cargo area are to be routed on their shortest ways.

d) Stop valves are to be located in the non-hazardous enclosed space outside the cargo area, in both the suction and return lines close to the penetrations through the bulkhead facing the cargo area. A warning plate stating "Keep valve closed when not performing measurements" is to be posted near the valves. Furthermore, in order to prevent backflow, a water seal or equivalent arrangement is to be installed on the hazardous area side of the return pipe.

e) A stop valve is to be installed on the cargo area for each sampling line (i.e. both the suction and return lines).

f) The samples which are extracted from the ballast water piping system serving the tanks within the cargo area are not to be discharged to a tank located outside the cargo area and not to discharge to a piping line supplying the spaces located outside the cargo area.

Figure 4



3.3 Special requirements for BWMS categories 2, 3a, 3b, 3c, 4, 5, 6, 7a, 7b and 8 generating dangerous gas or dealing with dangerous liquids.

3.3.1 *(1/7/2022)*

Where the operating principle of the BWMS involves the generation of a dangerous gas, the following requirements are to be satisfied:

a) Gas detection equipment is to be fitted in the spaces where dangerous gas could be present, and an audible and visual alarm is to be activated both locally and at the BWMS control station in the event of leakage.

The gas detectors should be located as close as possible to the BWMS components where the dangerous gas may accumulate.

For flammable gases and explosive atmosphere including but not limited to H_2, the construction, testing and performance of the gas detection devices is to be in accordance with IEC 60079-29-1:2016, IEC 60079-29-2:2015, IEC 60079-29-3:2014 and/or IEC 60079-29-4:2009, as applicable.

Where other hazards are considered like toxicity, asphyxiation, corrosive and reactivity hazards, a recognized standard acceptable to the Society is to be selected with due consideration of the specific gases to be detected and due consideration of the performance of the detection device with regards to the specific atmosphere where it is used.

b) In spaces where inert gas generator systems are fitted (BWMS categories 3b and 3c) or nitrogen generators are fitted (BWMS categories 3a and 8), at least two oxygen sensors are to be positioned at appropriate locations (as required by Paragraph 2.2.4.5.4 of Chapter 15 of the FSS Code as amended by IMO resolutions up to MSC.410(97)) to alarm when the oxygen level falls below 19%. The alarms are to be both audible and visual and are to be activated:

- inside the space
- at the entry into the space, and
- inside the BWMS control station.

For BWMS categories 7a and 7b, at least two oxygen sensors are to be positioned at appropriate locations in the following spaces:

- spaces where ozone generators are fitted, or
- spaces where ozone destructors are fitted, or
- spaces where ozone piping is routed

to alarm when the oxygen level raises above 23 %. The alarms are to be both audible and visual and are to be activated at the following locations:

- inside the space, and
- at the entry into the space, and
- inside the BWMS control station.

Automatic shut-down of the BWMS is to be arranged when the oxygen level raises above 25%. Audible and visual alarms independent from those specified in the preceding paragraph are to be activated prior to this shut-down.

c) For BWMS categories 7a and 7b, at least one ozone sensor is to be provided at the vicinity of the discharge outlet to the open deck from the ozone destructors addressed in the Notes to [3.3.2] c) to alarm when the ozone concentration level raises above 0,1 ppm. The alarms are to be both audible and visual and are to be activated in the BWMS control room. In addition, at least two ozone sensors are to be positioned at appropriate location in the following spaces:

- spaces where ozone generators are fitted, or
- spaces where ozone destructors are fitted, or
- spaces where ozone piping is routed

to alarm when the ozone concentration level raises above 0,1 ppm. The alarms are to be both audible and visual and are to be activated at the following locations:

- inside the space
- at the entry into the space, and
- inside the BWMS control station.

Automatic shut-down of the BWMS is to be arranged when the ozone concentration measured from one of the two sensors inside the space raises above 0,2 ppm.

d) Inside double walled spaces or pipe ducts constructed for the purpose of [3.3.2] a) Note 2, 1), sensors are to be provided for the detection of H_2 leakages (BWMS categories 4, 5 and 6 when relevant) or O_2 leakages (BWMS categories 7a and 7b) or O_3 leakages (BWMS categories 7a and 7b). The sensors are to activate an alarm at the high level settings and automatic shut-down of the BWMS at the high-high level settings described in above [3.3.1] a) to c).

Note 1: As an alternative to the sensor for the gas detection, monitored under-pressurization inside the double walled spaces or pipe ducts could be provided with an automatic alarm and shut-down of the BWMS in case of loss of the under-pressurization. The monitoring can be achieved either by monitoring the pressure inside the double walled spaces or pipe ducts or by monitoring the exhaust fan.

e) For in-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6): the hydrogen de-gas arrangement (when provided) is to be provided with redundant ventilation fans and redundant monitoring of the ventilation system.

In addition the ventilation fan is to be certified explosion proof and have spark arrestor to avoid ignition sources to enter the ventilation systems whereas remaining H_2 gas may be present in dangerous concentrations.

Audible and visual alarms and automatic shut-down of the BWMS are to be arranged for respectively high and high-high levels of H_2 concentration. The open end of the hydrogen by-product enriched gas relieving device is to be led to a safe location*(3) on open deck.

Note 2: For **safe location***(3), refer to Notes to paragraph [3.3.2] c)

f) The open end of inert gas or nitrogen gas enriched air (BWMS categories 3a, 3b, 3c and 8) or oxygen-enriched air (BWMS categories 3a, 7a, 7b and 8) are to be led to a safe location*(1) & (2) on open deck.

Note 3: For **safe location***(1) and **safe location***(2), refer to Notes to paragraph [3.1.5]

3.3.2 *(1/7/2022)*

Where the piping is conveying active substances, by-products or neutralizers that are containing dangerous gas or dangerous liquids as defined respectively in [2.1.3] and [2.1.5], the following requirements are to be satisfied:

Note 1:

1) This requirement is applicable to the injection lines conveying the dangerous gas or dangerous liquids but not applicable to the ballast water lines where the dangerous gas or dangerous liquids are diluted.

2) The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) could be used for assessing the hazards that could be expected from the media conveyed by the BWMS piping.

a) Irrespective of design pressure and temperature, the piping is to be either of Class I (without special safeguard) or Class II (with special safeguard) as required by Sec 10, Tab 3. The selected materials, the testing of the material, the welding, the non-destructive tests of the welding, the type of connections, the hydrostatic tests and the pressure tests after assembly on-board are to be as required in Sec 10, [2.1], Sec 10, [21.3], Sec 10, [3], Sec 10, [3.6.3], Sec 10, [2.4], Sec 10, [21.4.2] and Sec 10, [21.4.7] respectively. Mechanical joints, where allowed, are to be selected in accordance with Sec 10, Tab 16 and Sec 10, Tab 17.

Note 2:

1) For piping class II with special safeguards conveying dangerous gas like hydrogen (H2), oxygen (O2) or ozone (O3), the special safeguards are to be either double walled pipes or pipe duct.

2) For piping class II with special safeguards conveying dangerous liquids, other special safeguards could be considered like shielding, screening, etc.

3) Plastic pipes may be accepted after due assessment of the dangerous gas or dangerous liquids conveyed inside. When plastic pipes are accepted, the requirements of App 3 apply.

b) The length of pipe and the number of connections are to be minimised

c) Inside double walled space or pipe ducts constructed as the special safeguard for the purpose of [3.3.2] a), Note 2, 1) are to be equipped with mechanical exhaust ventilation leading to a safe location*(3) & (4) on open deck.

Note 3: **safe location***(3) and **safe location***(4)

Safe location*(3): hydrogen by-product enriched gas from:

- in-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6): the hydrogen de-gas arrangement (when provided)

safe locations on the open deck are:

- not within 5 m of any source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard
- not within 3 m of areas traversed by personnel, and
- not within 5 m of air intakes from non-hazardous enclosed spaces.

The areas on open deck, or semi-enclosed spaces on open deck, within 3 m of the outlets are to be categorized hazardous zone 1 plus an additional 1,5 m surrounding the 3 m hazardous zone 1 is to be categorized hazardous zone 2.

Electrical apparatus located in the above hazardous areas zone 1 and zone 2 is to be suitable for at least IIC T1.

Safe location*(4): For in-line ozone injection BWMS (categories 7a and 7b), vent outlet from O_3 destructor device (ODS) can be considered as oxygen-enriched air provided that:

- the ODS are duplicated, and
- the manufacturer justified that the quantity of consumable (activated carbon) used by the ODS is sufficient for the considered life cycle of the BWMS, and
- ozone detection is arranged in the vicinity of the discharge outlet from the vent outlet of the ODS to alarm the crew in case the ODS is not working.

If one of the above 3 conditions is not fulfilled, the safe location from ODS on open deck are:

- outside of hazardous area
- not within 3 m of any source of ignition
- not within 6 m of areas traversed by personnel, and
- not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets.

d) The routing of the piping system is to be kept away from any source of heating, ignition and any other source that could react hazardously with the dangerous gas or liquid conveyed inside. The pipes are to be suitably supported and protected from mechanical damage.

e) Pipes carrying acids are to be arranged so as to avoid any projection on crew in case of a leakage.

f) H_2 by-product enriched air vent pipes (BWMS categories 4, 5 and 6) or O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) or O_3 piping (BWMS categories 7a and 7b) are not to be routed through accommodation spaces, services spaces and control stations.

g) O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) are not to be routed through hazardous areas unless it is arranged inside double walled pipes or pipe ducts constructed as the special safeguard for the purpose of [3.3.2] a) Note 2, 1) and provided with suitable gas detection as described in [3.3.1] d) and mechanical exhaust ventilation as described in [3.3.2] c).

h) The routing of H_2 by-product enriched air vent pipes (BWMS categories 4, 5 and 6) or O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) is to be as short and as straight as possible. When necessary, horizontal portions may be arranged with a minimum slope in accordance with the manufacturer's recommendation.

3.3.3 *(1/7/2022)*

For BWMS using chemical substances or dangerous gas which are stored on-board for either:

- storage or preparation of the active substances (BWMS categories 2 and 6), or
- storage or preparation of the neutralizers (BWMS categories 4, 5, 6, 7a and 7b), or
- recycling the wastes produced by the BWMS (BWMS category 2),

procedures are to be in accordance with the Material Safety Data Sheet and BWM.2/Circ.20 "Guidance to ensure safe handling and storage of chemicals and preparations used to treat ballast water and the development of safety procedures for risks to the ship and crew resulting from the treatment process", and the following measures are to be taken as appropriate:

a) The materials, inside coating used for the chemical storage tanks, piping and fittings are to be resistant to such chemicals substances

b) Chemical substances (even if they are not defined as dangerous liquid in the sense of [2.1.5]) and gas storage tanks are to be designed, constructed, tested, inspected, certified and maintained in accordance with:

- for independent tanks permanently fixed onboard containing dangerous liquids (eg. sulfuric acid H_2SO_4) or dangerous gas (eg. oxygen O_2):
  - App 4 for independent fuel oil tanks
  - Sec 3 for pressure vessels
- for independent tanks permanently fixed onboard not containing dangerous liquid (eg. sodium sulphite, sodium biosulphite or sodium thiosulfphate neutralizers) and not containing dangerous gas (eg. nitrogen N_2): App 4
- for portable tanks: the IMDG Code or other industry standard recognized by the Society.

c) When the chemical substances are stored inside integral tanks, the ship's shell plating is not to form any boundary of the tank

d) Dangerous liquids and dangerous gas storage tank air pipes are to be led to a safe location*(1) & (2) on open deck

Note 1: For **safe location***(1) and **safe location***(2), refer to Notes to [3.1.5]

e) An operation manual containing chemical injection procedures, alarm systems, measures in case of emergency, etc. is to be kept onboard

f) Dangerous liquid storage tanks and their associated components like pumps and filters, are to be provided with spill trays or secondary containment system of sufficient volume to contain potential leakages from tank openings, gauge glasses, pumps, filters and piping fittings

Further to the safety and/or pollution assessment of the concerned chemical substances, consideration should be provided for segregation of the drains from such spill trays (or secondary containment system) or piping systems from engine room bilge system or from cargo pump room bilge system, as applicable. When necessary, arrangement should be provided within the spill trays (or within the secondary containment system) for the detection of dangerous liquid or dangerous gas as defined respectively in [2.1.3] and [2.1.5].

Note 2: The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) could be used for this assessment.

3.3.4 *(1/7/2022)*

A risk assessment is to be conducted in a generic manner during the design review mentioned in [3.1.4] and submitted to the Society for approval for the following BWMS categories:

- BWMS category 4: in all cases
- BWMS category 5: in all cases
- BWMS category 6: when one of the MSDS indicates that the chemical substance stored on-board is either flammable, toxic, corrosive or reactive
- BWMS category 7a and 7b: in all cases.

Note 1: The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) could be used as a reference for this assessment.

a) The recommended risk assessment techniques for BWMS and other guidances are listed below but not limited to:
   - FMEA, FMECA, HAZID, HAZOP, etc
   - ISO 31010 – Risk Assessment Techniques
   - IACS Recommendation Rec. 146
   - TASNEEF Guide for Risk Analysis

b) The risk assessment should ensure that the package supplied by the BWMS's manufacturer is intrinsically safe and/or provides mitigation measures to the hazards created by the BWMS which have been identified during the design review mentioned in [3.1.4] but that need to be implemented during the installation on-board.

4 Installation of one single BWMS on tankers

4.1 General

4.1.1 *(1/7/2022)*

This Article provide requirements for the Installation of one single BWMS on tankers; see Tab 3 and Fig 5 to Fig 12.

This Article does not cover In-tank technologies categories 3c and 8.

Table 3 : In-line BWMS's technlogies categorization *(1/7/2022)*

BWMS's Technology category→		1	2	3a	3b	4	5	6	7a	7b
Characteristics ↓		In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO2 or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N2 from a N2 Generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-line full flow electrolysis	In-line side stream electrolysis (2)	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without Discharge treatment tank	In-line side-stream ozone injection with gas/liquid separation tank and Discharge water treatment tank
Des-infection when ballasting	Making use of active substance		X			X	X	X	X	X
	Full flow of ballast water is passing through the BWMS	X	X	X	X	X				X
	Only a small part of ballast water is passing through the BWMS to generate the active substance						X			
After-treatment when de-ballasting	Full flow of ballast water is passing through the BWMS	X								X
	Injection of neutralizer					X	X	X	X	X
	Not required by the Type Approval Certificate issued by the Administration		X	X						
Examples of dangerous gas as defined in [2.1.3]			(1)	O_2 N_2	CO_2 CO	H_2 Cl_2	H_2 Cl_2	(1)	O_2 O_3 N_2	

BWMS's Technology category→		1	2	3a	3b	4	5	6	7a	7b
Arrangement of one single BWMS	BWMS is located in the outside the cargo area	Not Acceptable	Case 1.2 (2)	Case 1.3a (2)	Case 1.3b	Case 1.4 (2)	Case 1.5	Case 1.6	Case 1.7a	Case 1.7b (2)

Notes:

(1) To be investigated on a case by case basis based on the result of the IMO (GESAMP) MEPC report for Basic and Final approval in accordance with the G9 Guideline.

(2) Only « Means of dis-connection » as described in [3.2.3], a) are to be applied.

(3) In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or deballasting)

Figure 5 *(1/7/2022)*

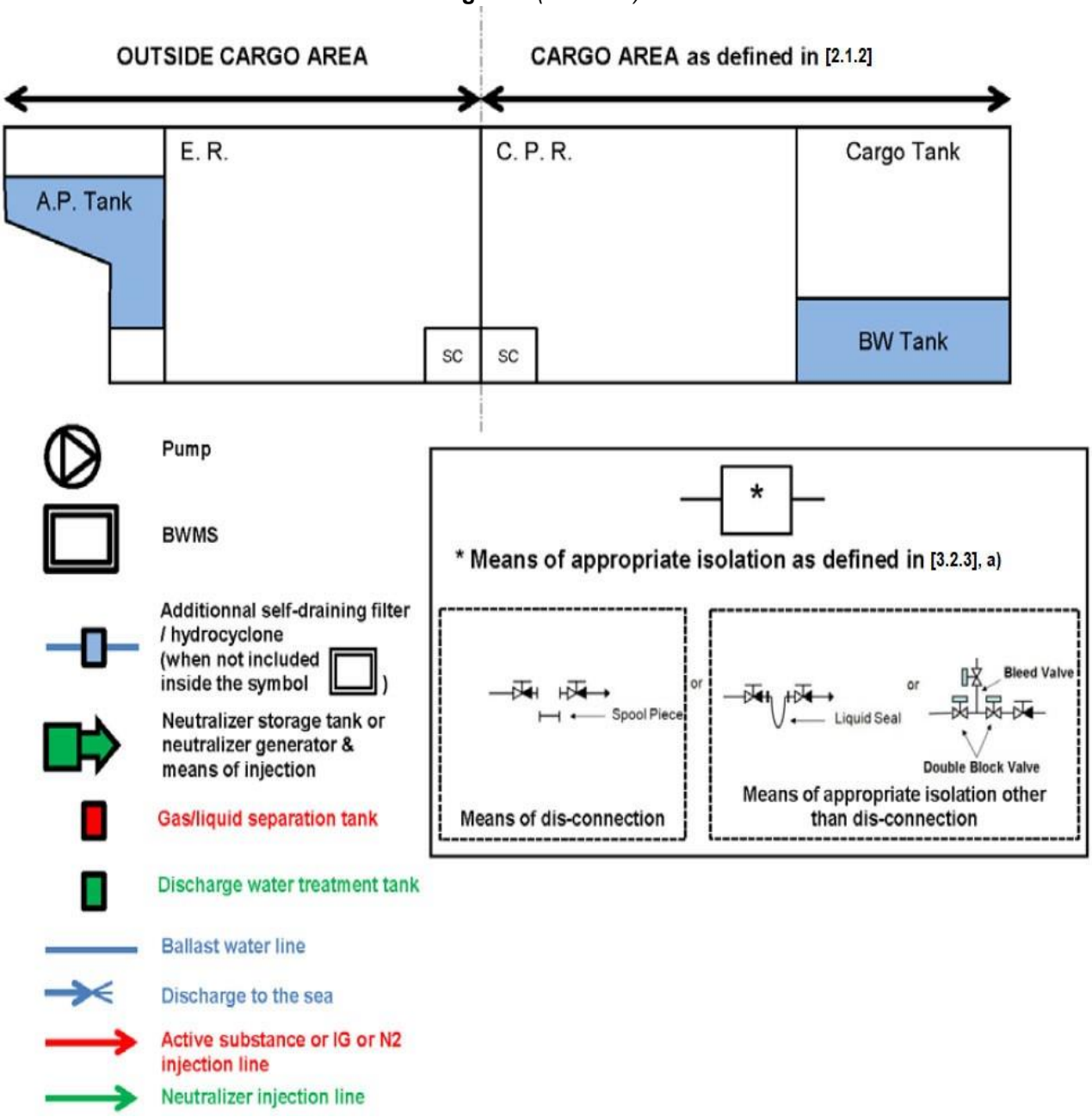


Figure 6 *(1/7/2022)*

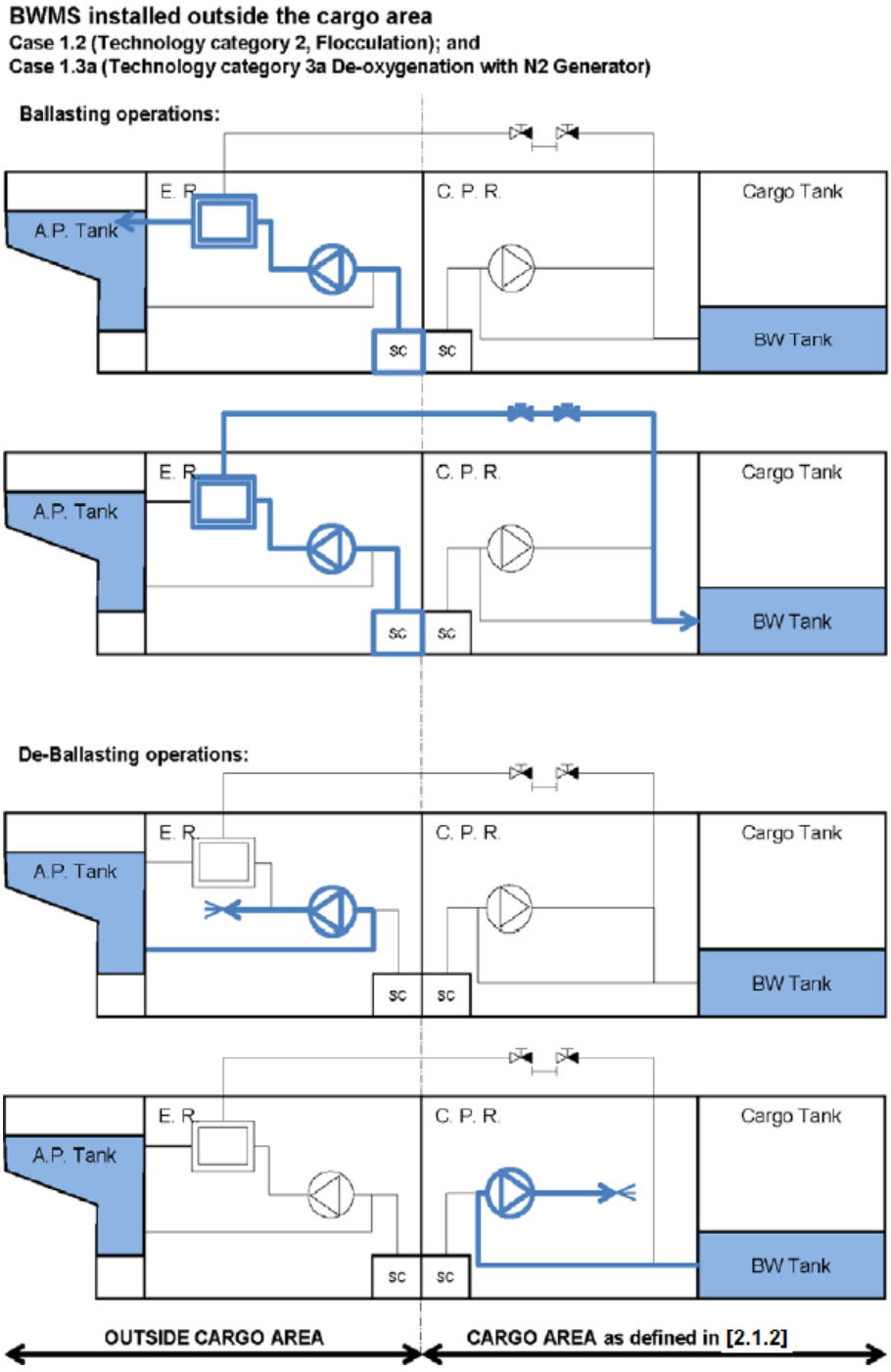


Figure 7 *(1/7/2022)*

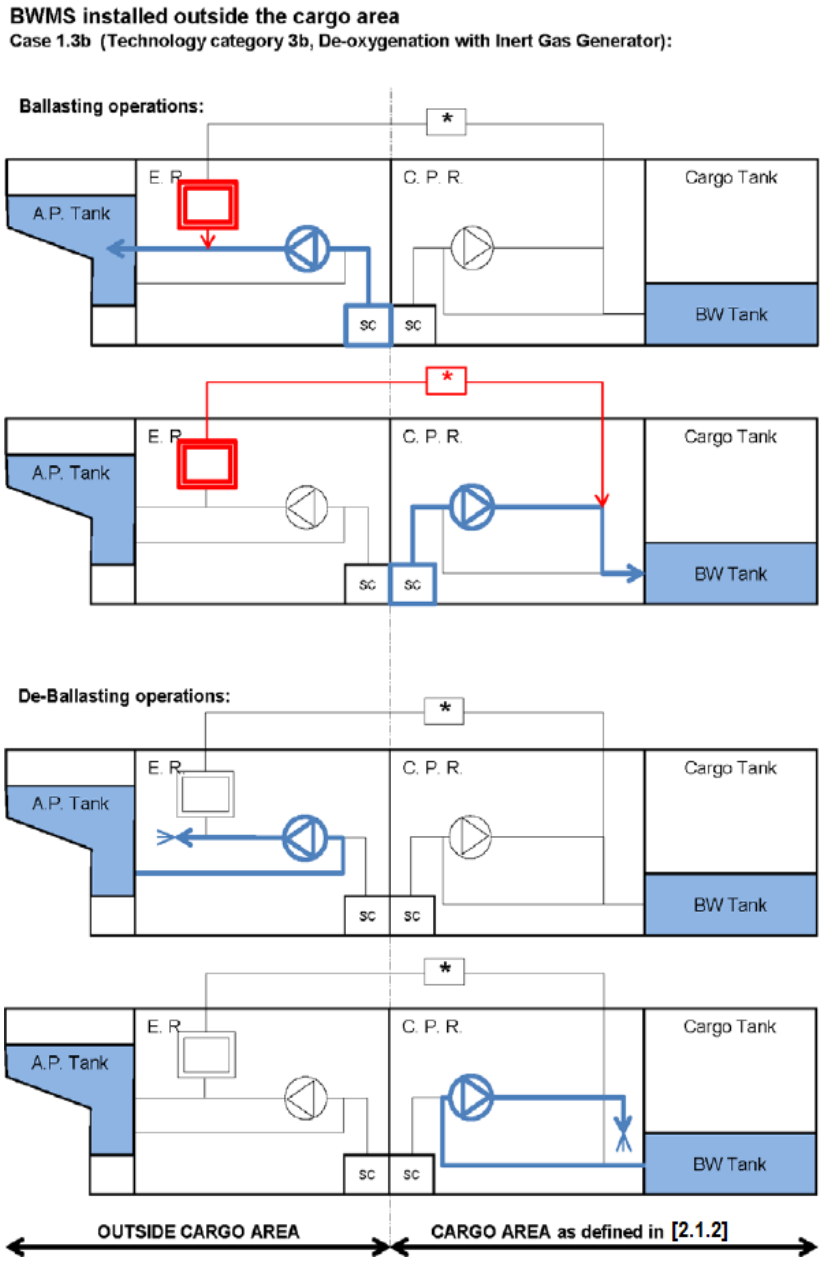


Figure 8 *(1/7/2022)*

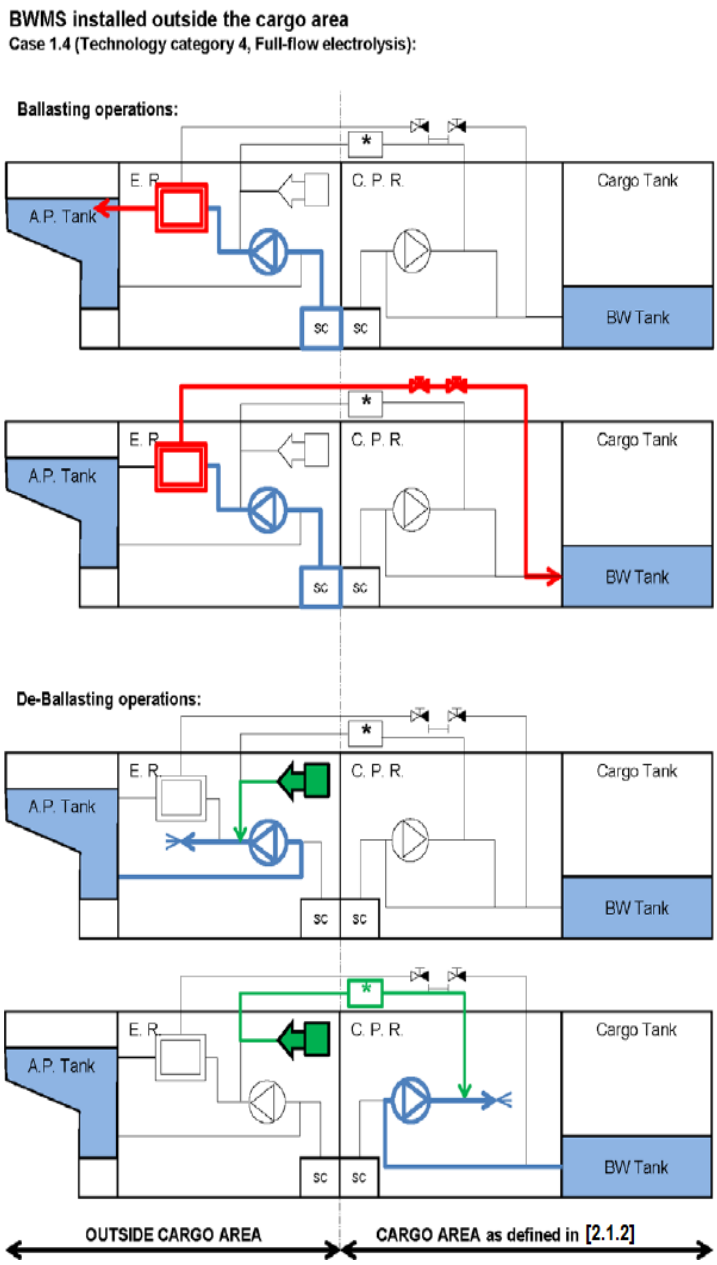


Figure 9 *(1/7/2022)*

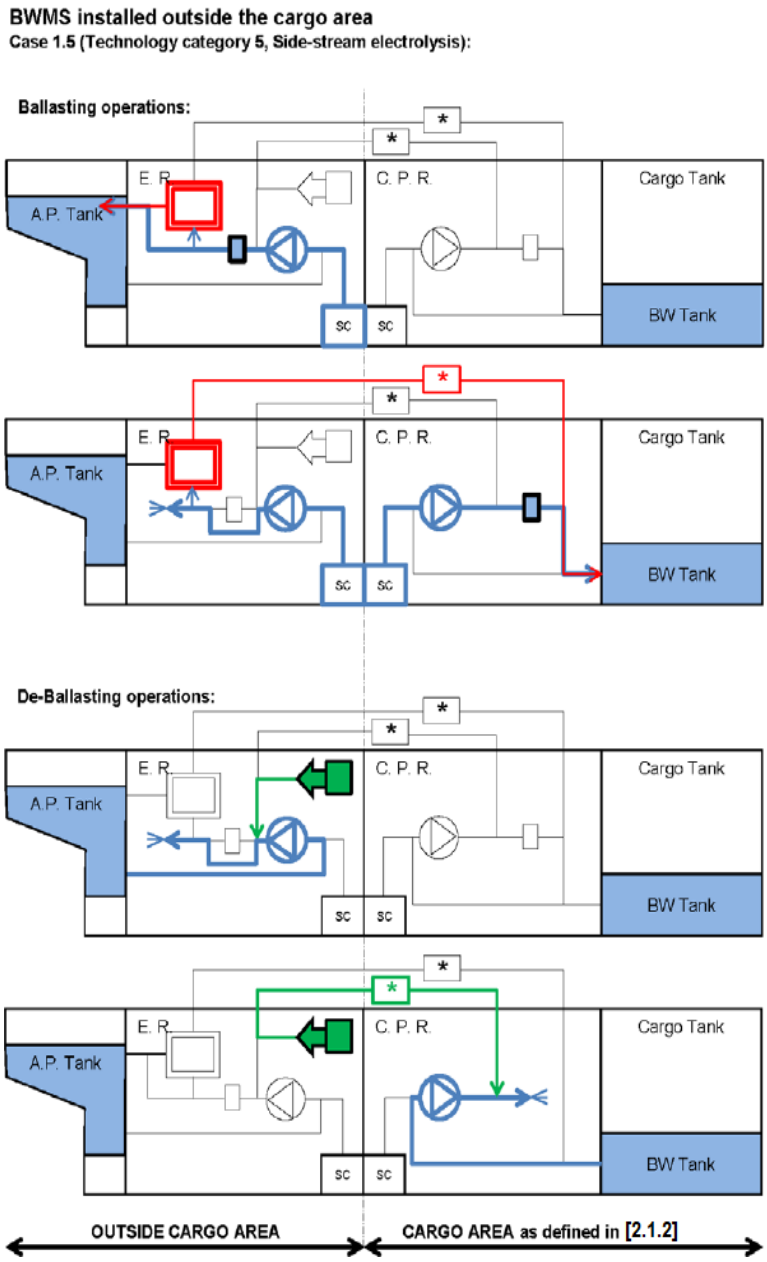


Figure 10 *(1/7/2022)*

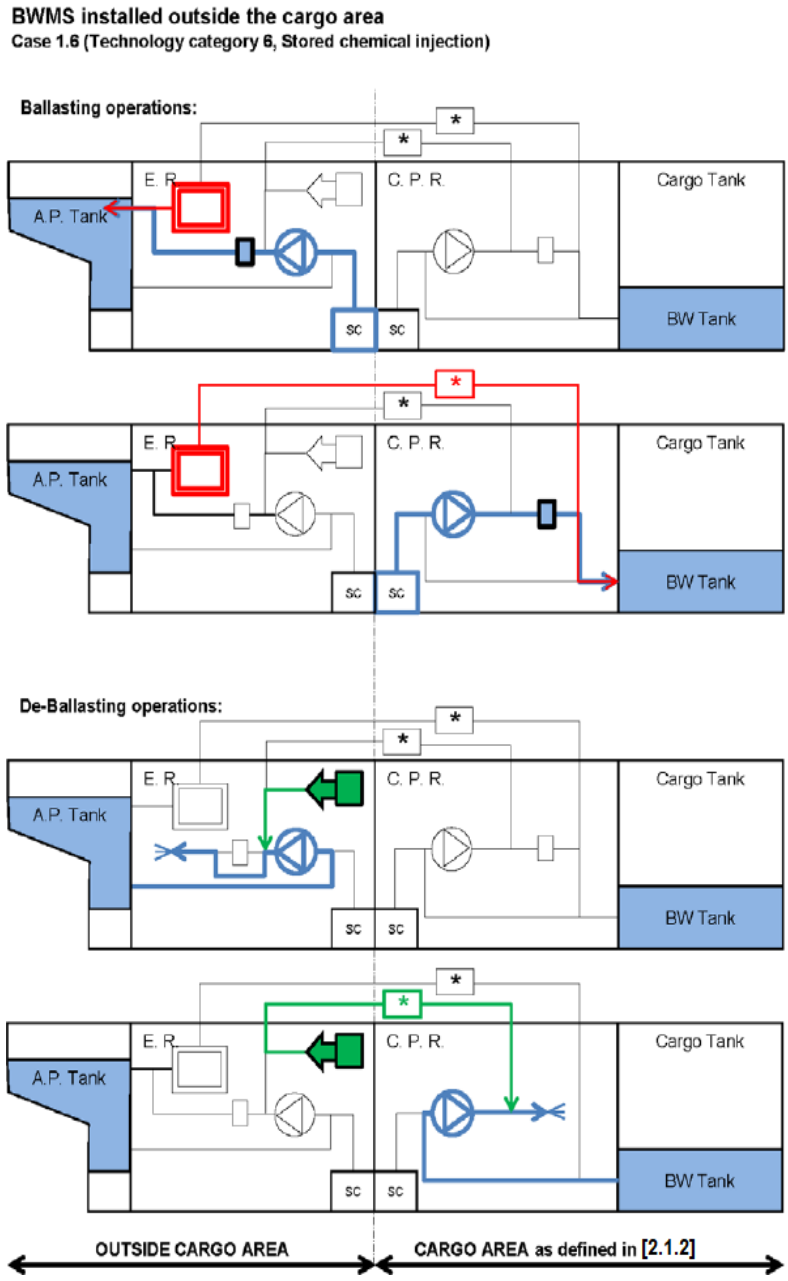


Figure 11 *(1/7/2022)*

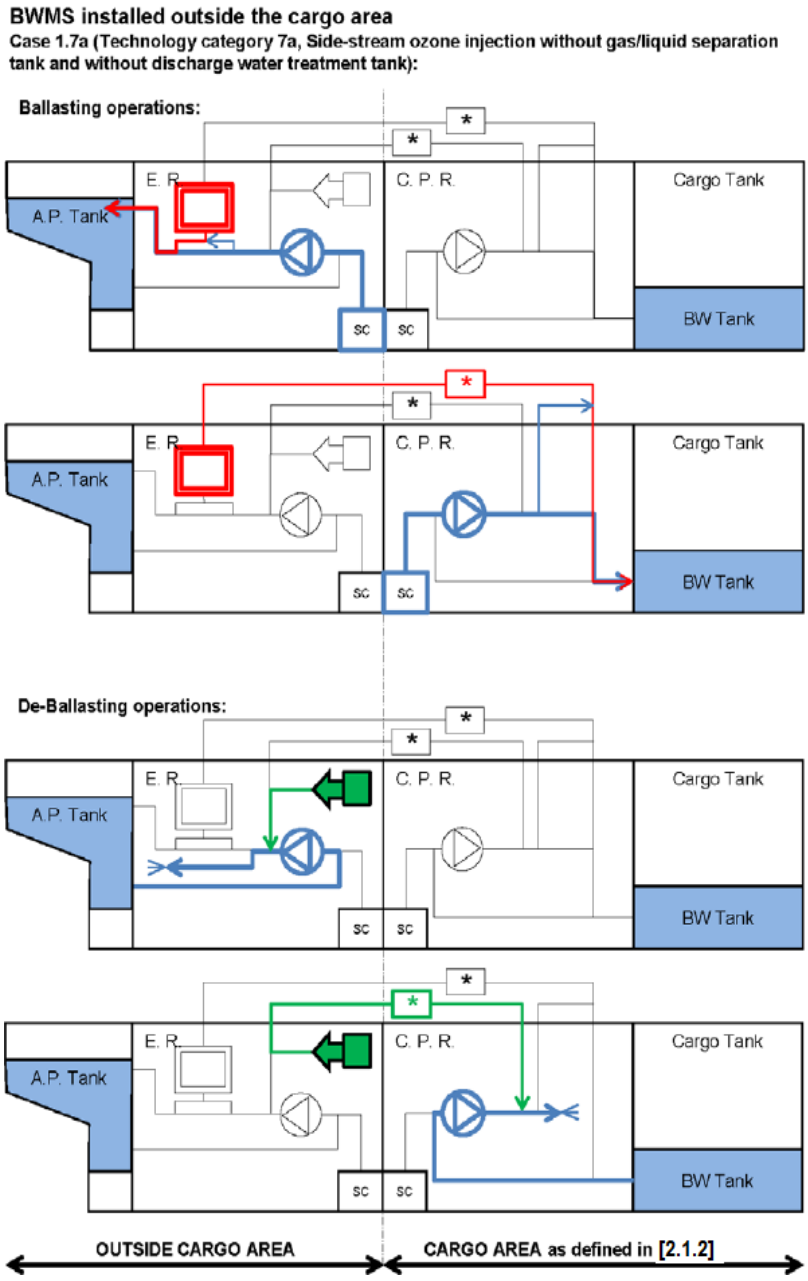
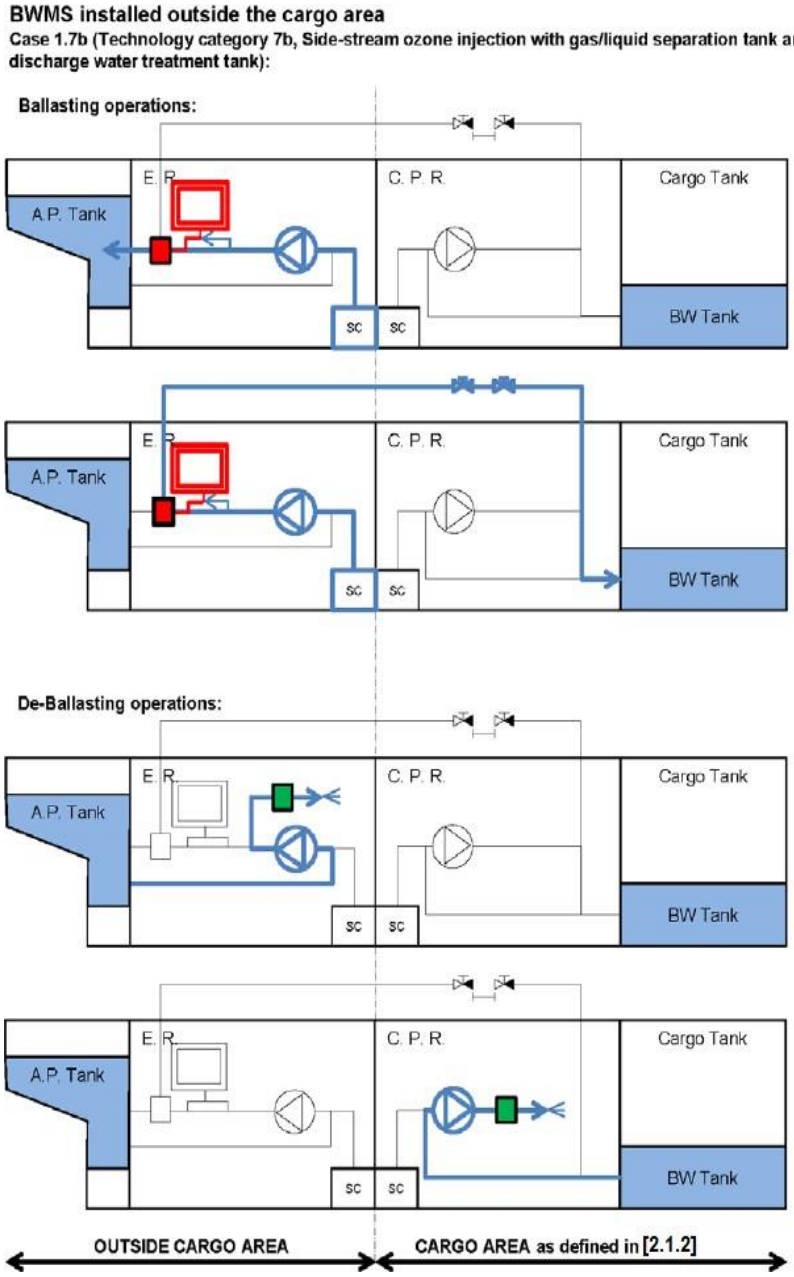


Figure 12 *(1/7/2022)*



5 BWMS Technologies categorization (Informative)

5.1 General

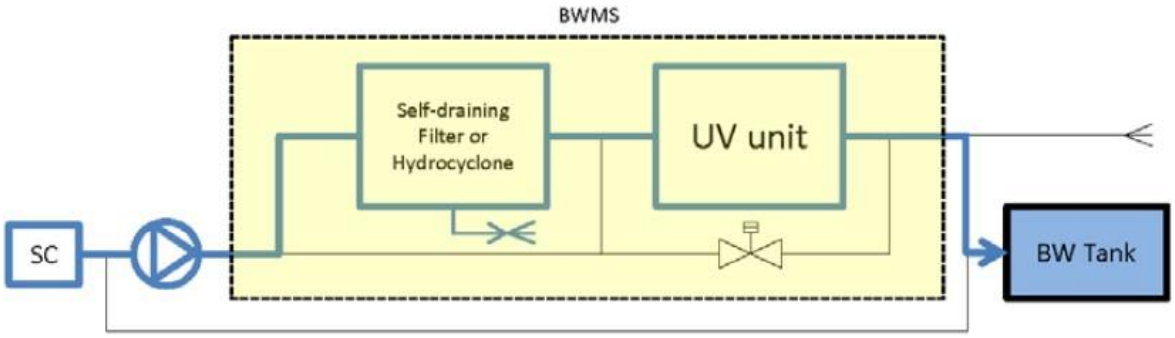
5.1.1 *(1/7/2022)*

This Article provide an informative on BWMS Technologies categorization; see Fig 13 to Fig 23.

Figure 13 *(1/7/2022)*

BWMS Technology Group no. 1
In-Line UV
including UV + AOT
Including UV+TiO2)

Ballasting operation:



De-ballasting operation:

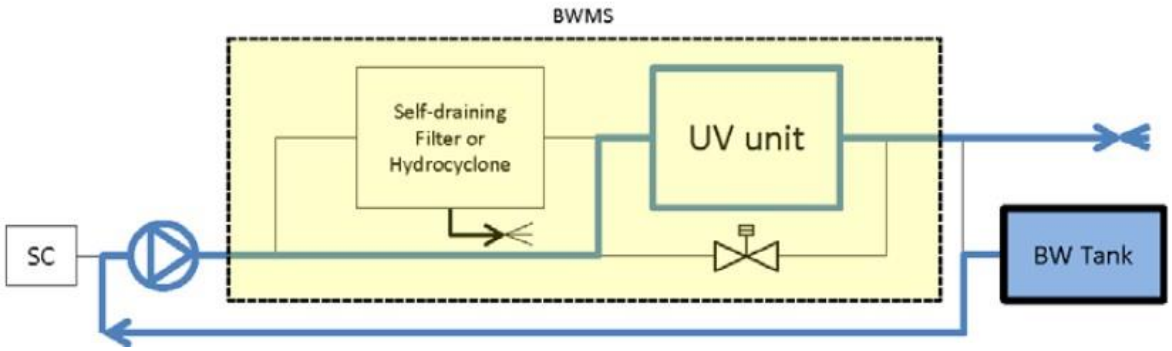
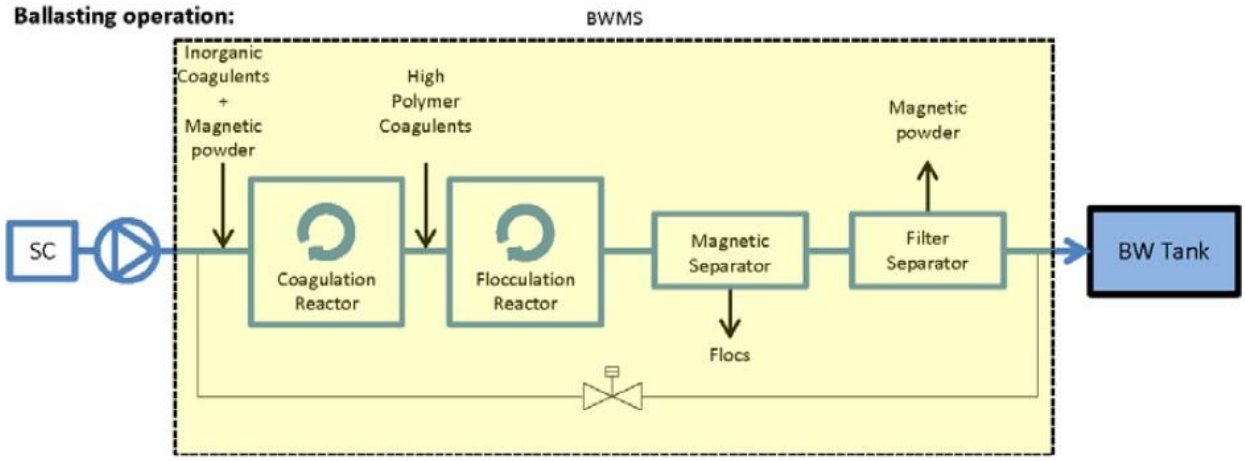


Figure 14 *(1/7/2022)*

BWMS Technology Group no. 2
In-Line Flocculation

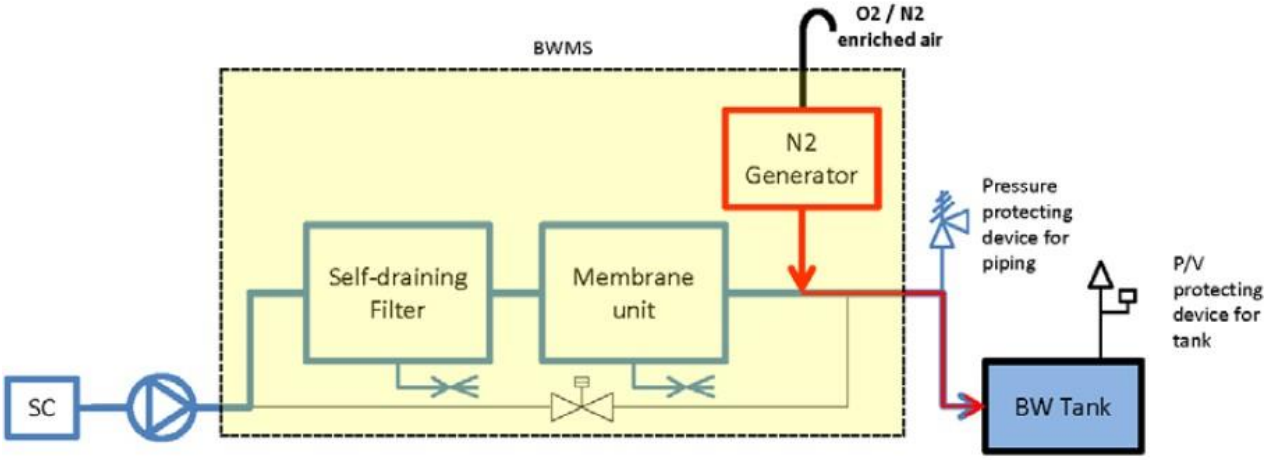


De-ballasting operation: no requirement for after-treatment

Figure 15 *(1/7/2022)*

BWMS Technology Group no. 3a
In-Line membrane separation and de-oxygenation
(injection of N2 from N2 Generator)

Ballasting operation:

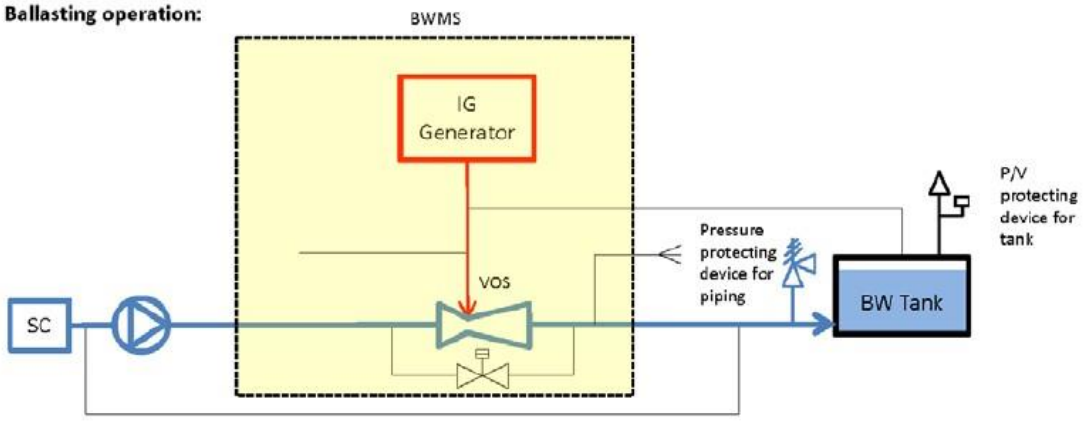


De-ballasting operation: no requirement for after-treatment

Figure 16 *(1/7/2022)*

BWMS Technology Group no. 3b
In-Line de-oxygenation
(injection of inert gas from either an oil fired inert gas generator or inert gas from treatment of the flue gas from main or auxiliary boilers)

Ballasting operation:



De-ballasting operation:

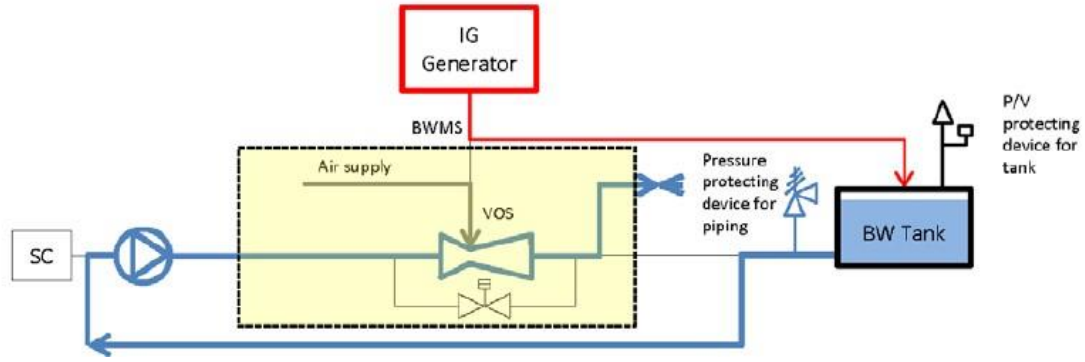


Figure 17 *(1/7/2022)*

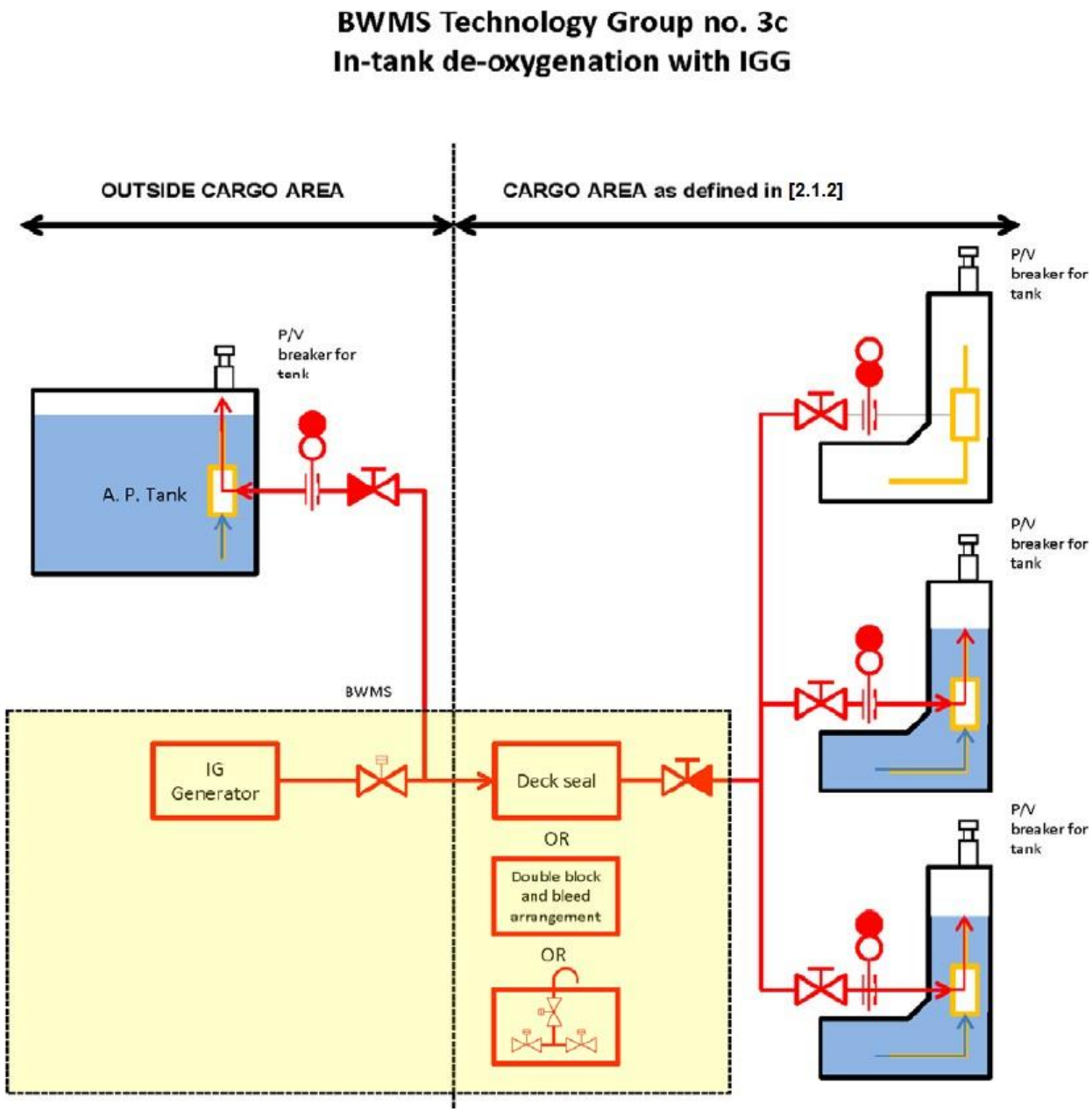
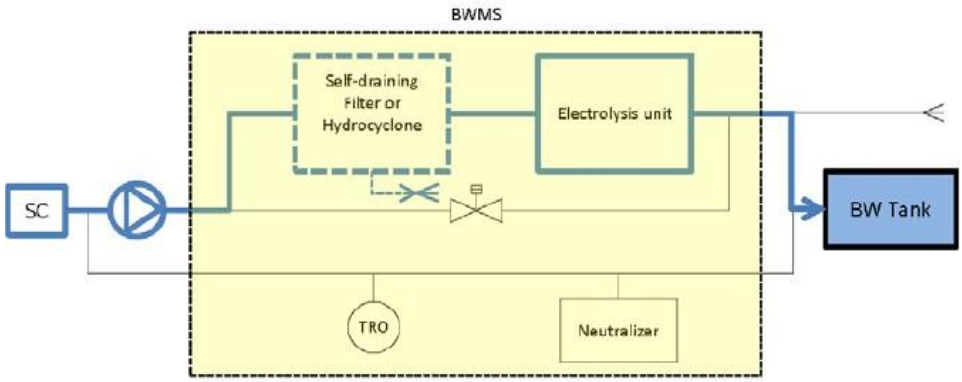


Figure 18 *(1/7/2022)*

BWMS Technology Group no. 4
In-Line Full flow electrolysis

Ballasting operation:



De-ballasting operation:

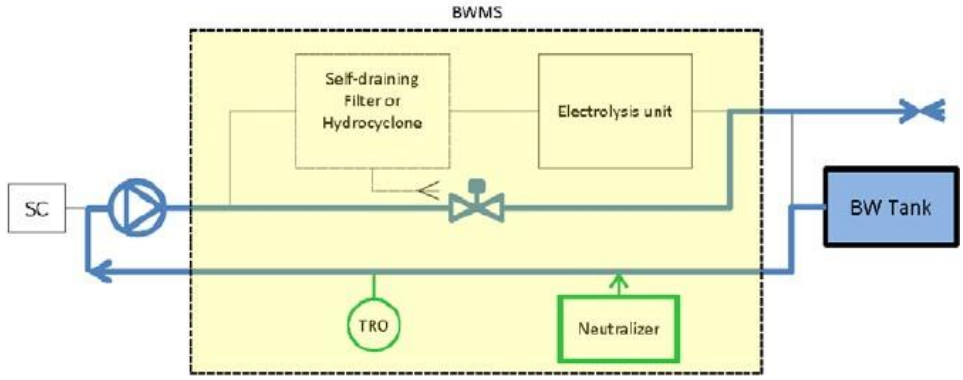
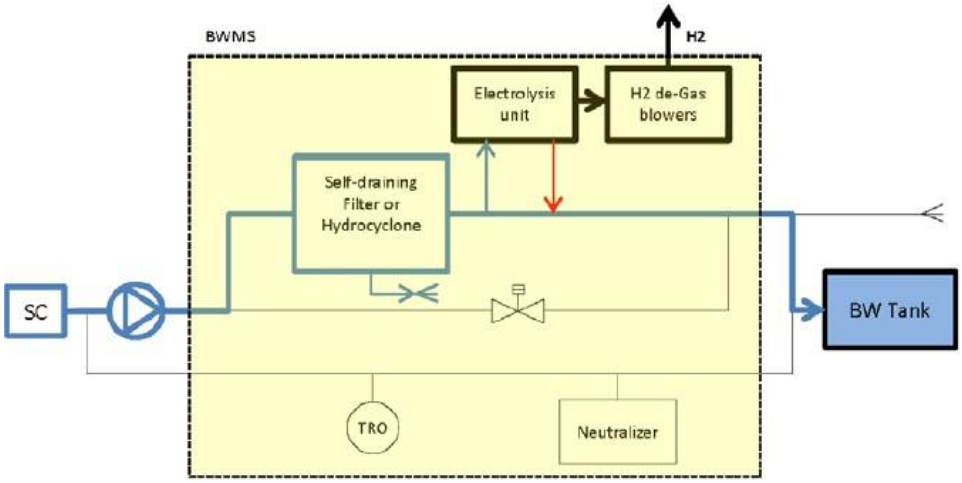


Figure 19 *(1/7/2022)*

BWMS Technology Group no. 5
In-Line Side-Stream electrolysis (electro-chlorinization)

Note: In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or de-ballasting)

Ballasting operation:



De-ballasting operation:

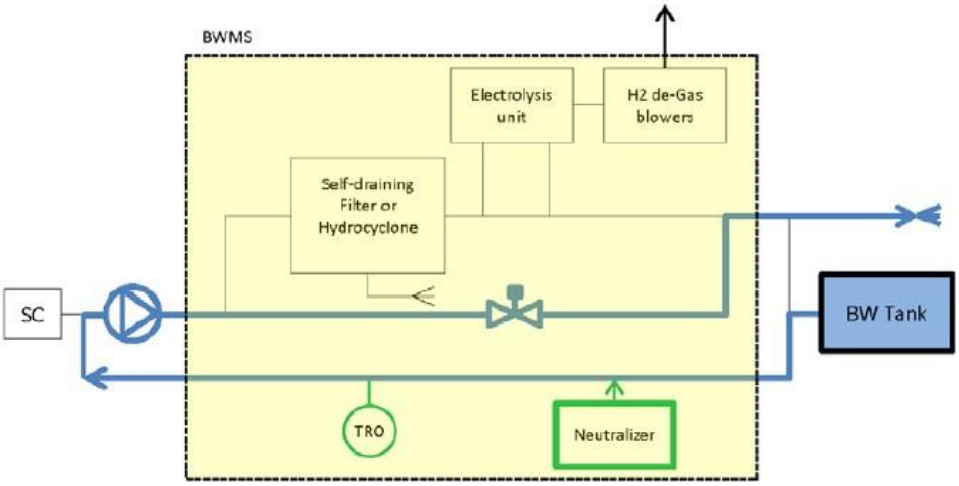


Figure 20 *(1/7/2022)*

BWMS Technology Group no. 6
In-Line Chemical injection

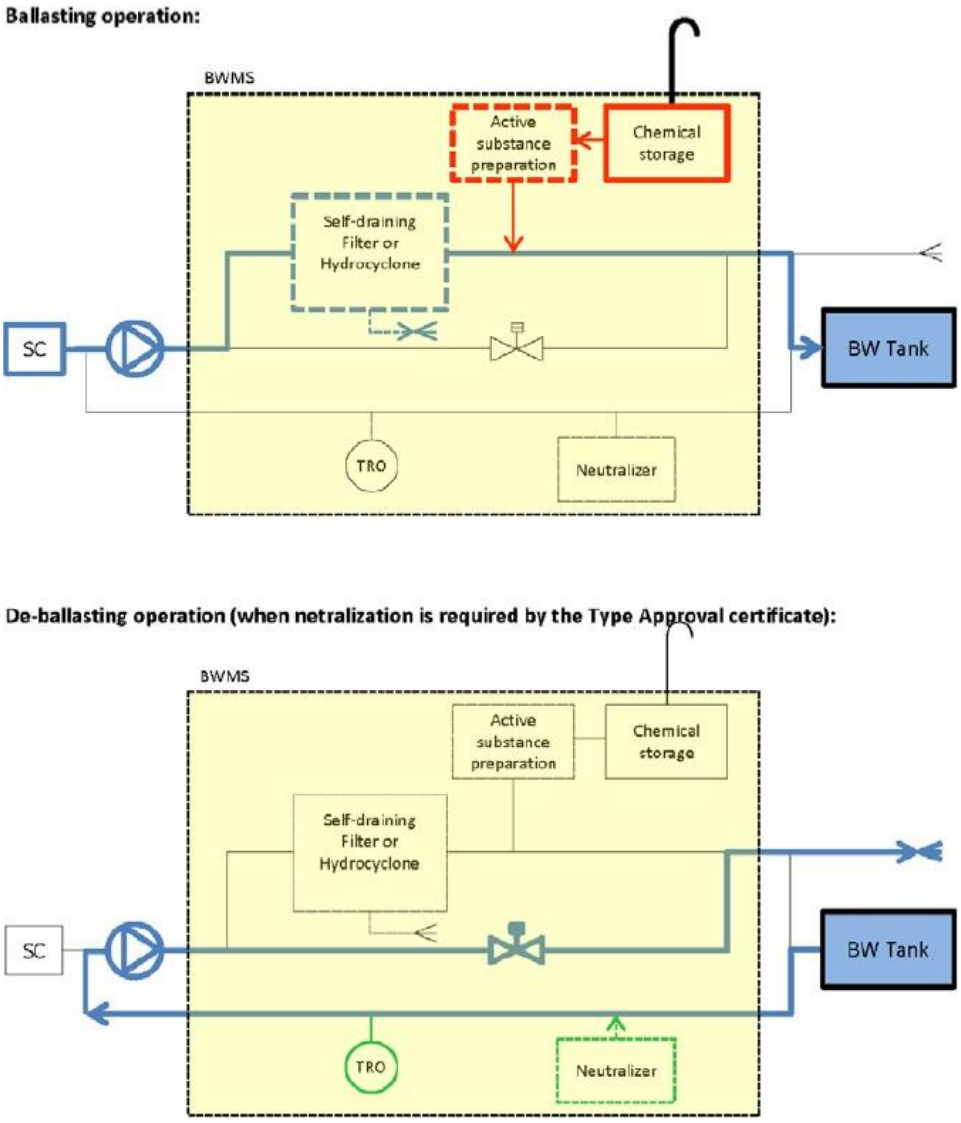


Figure 21 *(1/7/2022)*

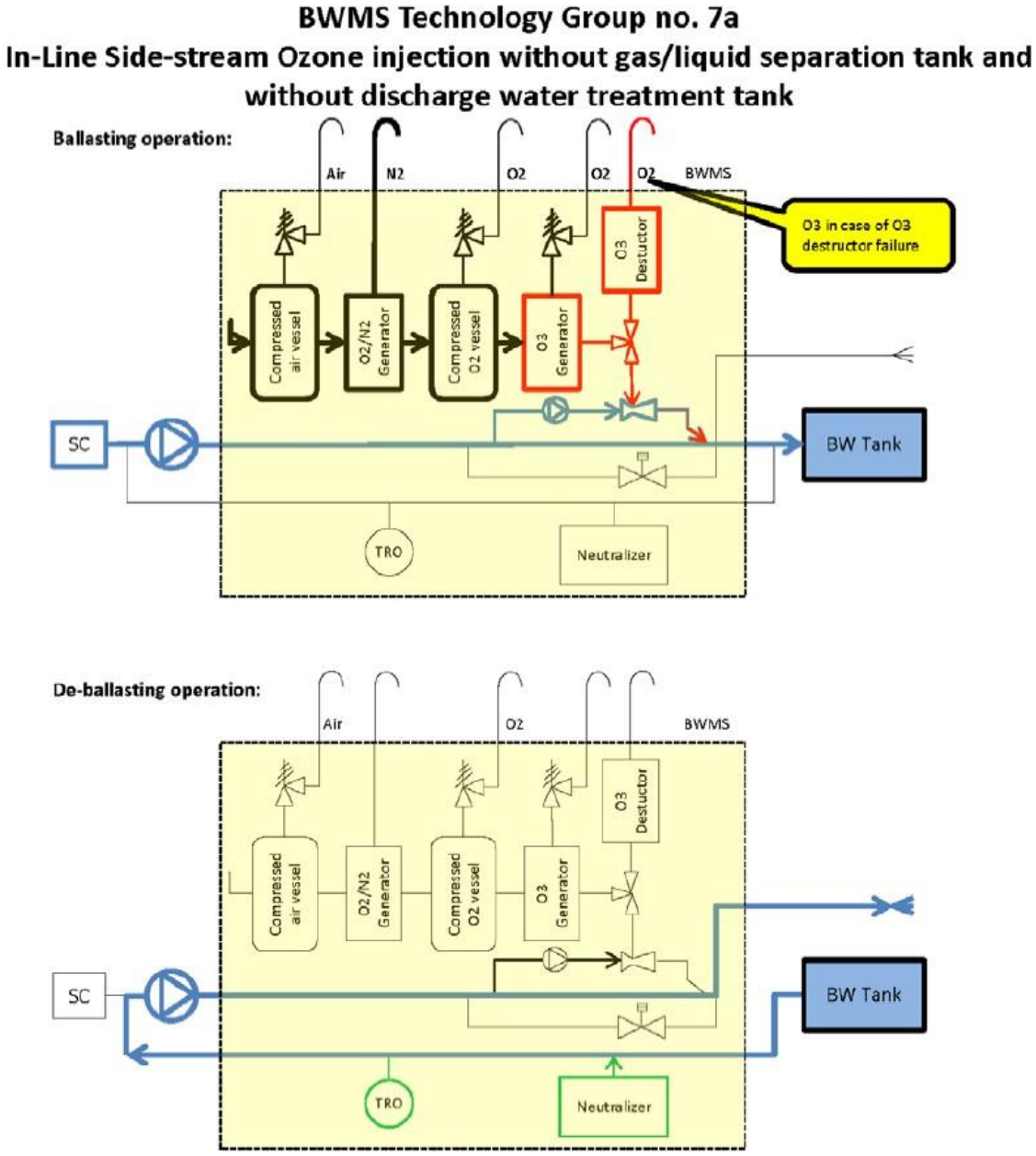


Figure 22 *(1/7/2022)*

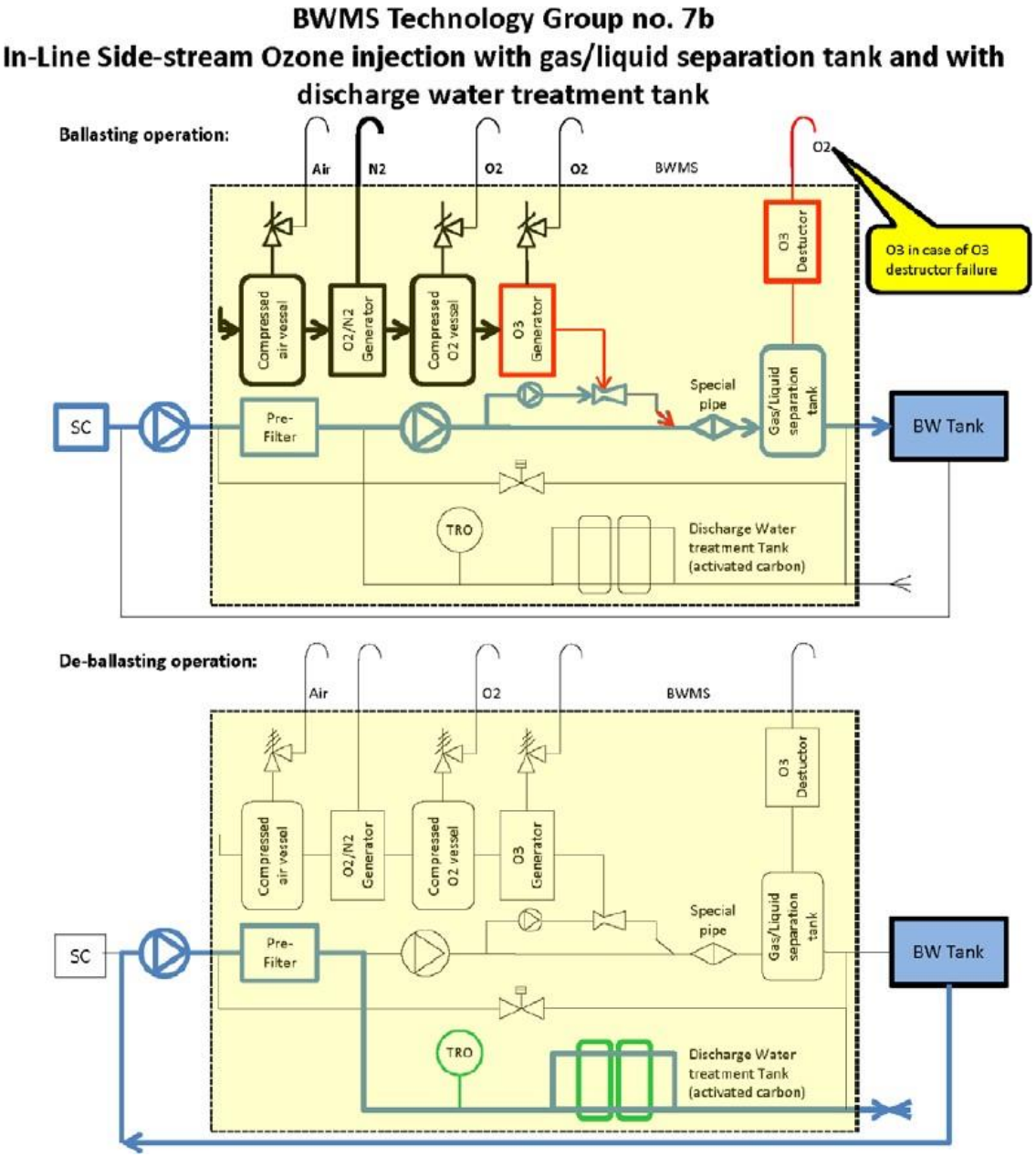
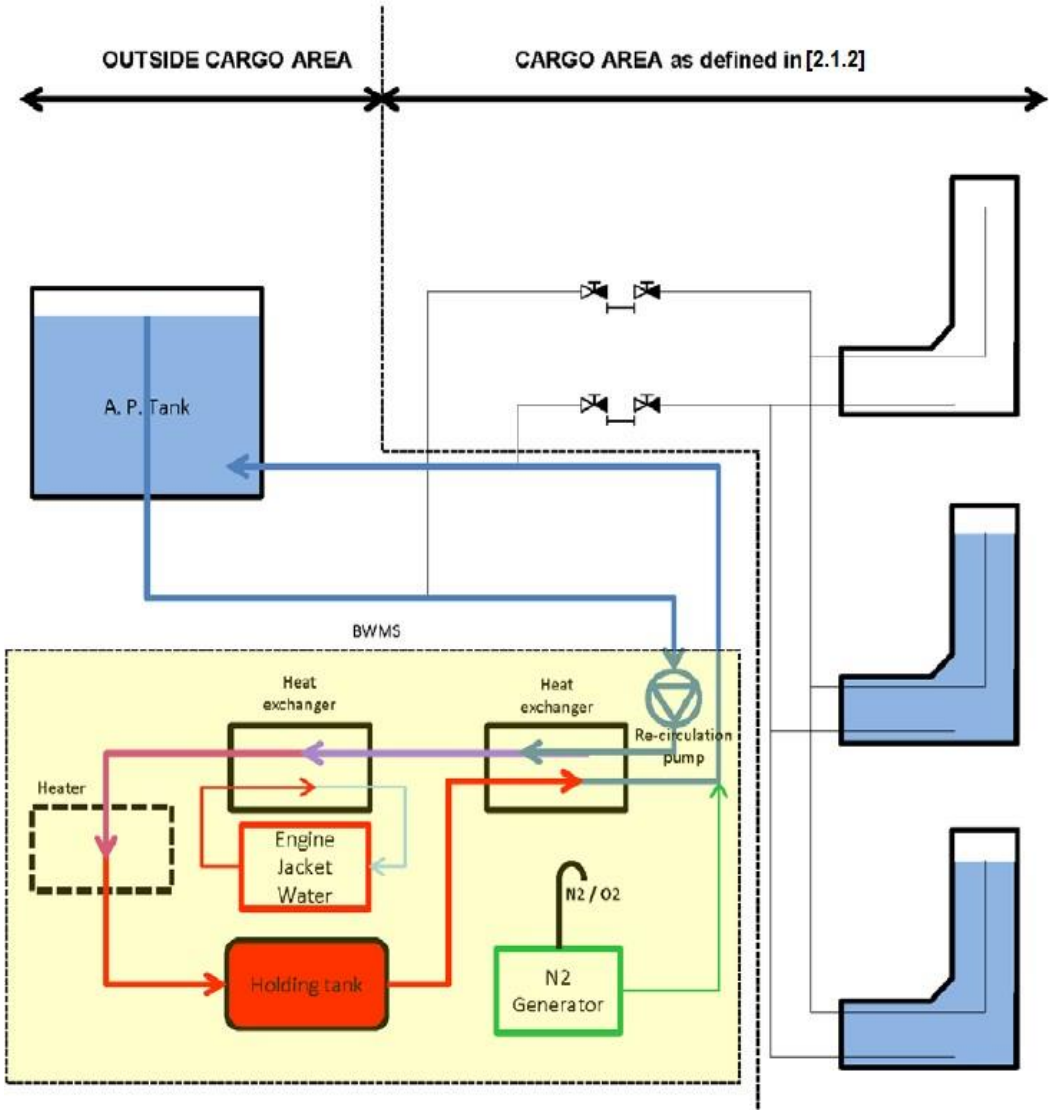


Figure 23 *(1/7/2022)*

BWMS Technology Group no. 8
In-tank Pasteurization + de-oxygenation with N2 Generator



APPENDIX 9 INTERNAL COMBUSTION ENGINE APPROVAL APPLICATION FORM AND DATA SHEET

1 General

1.1 Application form and data sheet for engine approval

1.1.1 *(1/7/2022)*

Class Application number (if applicable): Engine Manufacturer's Application Identification Number:

General Data	
Engine Designer: Contact Person: Address:	Engine Manufacturer(s), Licensee(s) and/or Manufacturing Sites Name Country

1. Document purpose *(select options from either 1a or 1b)*	
1a. Type Approval Application	
Service Requested ☐ New Type Approval ☐ Renew Type Approval ☐ Amend Type Approval ☐ Design Evaluation ☐ Update TA Supplement ☐ Other	*Required activities*[†] • *DA, TT, CoP* • *CoP, if design change then amended or new certificate process to be followed* • *DA & CoP, Further TT if previously approved engine has been substantively modified (as required by UR M71)* • *DA, TT, applicable where designer does not have production facilities, Type Approval to be granted to specific production facility once associated CoP has been completed* • *Update to Supplement, only for minor changes not affecting the Type Approval Certificate* • *e.g. National/Statutory Administration requirements i.e. MSC.81(70), as amended, for emergency engines*
For TA Cert amendments or Supplement updates, details of what is to be changed:	
For 'Other', Details of the requirements to be considered:	
1b. Addendum for Individual Engine FAT and Certification	
☐ Individual engine requiring FAT and Certification, only where the performance data for the engine being certified differs from the details provided on the original Type Approval Application. Only section 3b requires completion. Where changes to other sections are necessary, a new Type Approval Application may be required.	
Reference number of *Internal Combustion Engine Approval Application Form* previously submitted and reference number of the Type Approval Certificate.	*(Copy of original application form to be attached to this document)*

2. Existing documentation			
Previous Class Type Approval Certificate No. or related Design Approval No. *(if applicable)*			
Formerly issued documentation for engine *(E.g. previous type test reports, in-service experience justification reports, etc.)*	Issuing Body:	Document Type:	Document No.:
Existing Certification *(E.g. Manufacturer's quality certification ISO 9001:2015 etc.)*	Issuing Body:	Document Type:	Document No.:

3. Design *(mark all that apply)*					
3a. Engine Particulars:					
Engine Type Manufactured Since[‡]:			Number of delivered marine engines[≠]:		
Application	☐ Direct drive Propulsion (☐ Single engine / ☐ Multi-engine installation)		☐ Auxiliary (☐ Aux. Services / ☐ Electric Propulsion)		☐ Emergency
Mechanical Design	☐ 2-stroke ☐ Cross-head Cylinder bore(mm)	☐ 4-stroke ☐ Trunk-piston	☐ In-line ☐ Reversible Length of piston stroke (mm)	☐ Vee (V-angle °) ☐ Non-reversible	☐ Other ( )
Supercharging	☐ Without supercharging	☐ With supercharging ☐ Without charge air cooling ☐ Constant-pressure charging system		☐ With charge air cooling ☐ Pulsating pressure charging system	
Valve operation	☐ Cam control	☐ Electronic control			
Fuel Injection	☐ Direct injection	☐ Indirect injection	☐ Cam controlled injection	☐ Electronically controlled injection	

Fuel Types§ (Classification according to ISO 8216-1:2017)	☐ Marine residual fuel	cSt (Max. kinematic viscosity at 50°C)
	☐ Marine distillate fuel	DMA, DMB, DMC
	☐ Marine distillate fuel	DMX
	☐ Low flashpoint liquid fuel (specify fuel type)	
	☐ Gas (specify gas type)	
	☐ Other (specify)	
	☐ Dual Fuel (specify combinations of fuels to be used simultaneously)	

3b. Performance Data *(Related to: Barometric pressure 1,000 mbar; Air temperature 45°C; Relative humidity 60%; Seawater temperature 32°C)*	
Model reference No. (if applicable)	
Max. continuous rating	kW/cyl
Rated speed	1/min
Mean indicated pressure	MPa
Mean effective pressure	MPa
Max. firing pressure	MPa
Charge air pressure	MPa
Compression ratio	-
Mean piston speed	m/s

3c. Crankshaft				
Design	☐ Solid	☐ Semi-built	☐ Built	
Method of Manufacture	☐ Cast	☐ Forged		
		☐ Slab forged	☐ Approved die forged	☐ Continuous grain flow process

State approved forge/works name:

Is the crankshaft hardened by an approved process which includes the fillet radii of crankpins and journals? ☐ Yes ☐ No

If yes, state process:

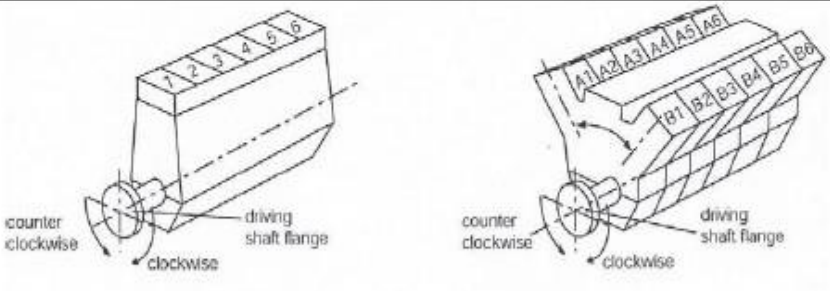
Crankshaft material specification:

U.T.S. (N/mm²) Yield strength (N/mm²)

Hardness value (Brinell/Vickers) Elongation (%)

Dimensional Data	
If shrunk on webs, state shrinkage allowance (mm)	Yield strength of crankweb material (N/mm²)
Centre of gravity of connecting rod from large end centre (mm)	Radius of gyration of connecting rod (mm)
Mass of each crankweb (kg)	Centre of gravity of web from journal axis (mm)
Mass of each counterweight (kg)	Centre of gravity of each counterweight from journal axis (mm)
Axial length of main bearing (mm)	Main bearing working clearance (mm)
Mass of flywheel at driving end (kg)	Mass of flywheel at opposite end (kg)
Nominal alternating torsional stress in crankpin (N/mm²)	Nominal alternating torsional stress in crank journal (N/mm²)
Length between centres (Total length)(mm)	

3d. Firing order



State numbering system of cylinders from left to right as per above diagrams (as applicable)

Number of cylinders	Clockwise firing order	Counter-clockwise firing order

4. Engine Ancillary Systems					
4a. Turbochargers	☐Fitted		☐Not Fitted		
Turbocharger oil supply by:	☐Engine lub. oil system		☐TC internal lub. oil system		
No. of cylinders	No. of aux blowers	No. of charge air coolers	No. of TC	TC manufacturer & type	TC type approval certificate No.
				/ / / / / /	

4b. Speed governor			
Engine application (Main/Aux/Emergency)	Manufacturer / type	Mode of operation	Type approval cert. No. (if electric / electronic gov.)
	/ / /		

4c. Overspeed protection

Independent overspeed protection available ☐ Yes ☐ No Mode of operation:

Manufacturer / type, if electronic: / Type approval certificate No.

4d. Electronic systems

Engine control and management system

Note: use Remarks section to identify when a different engine control system will be used for Type Test

Hardware: Manufacturer & Model: / Type approval certificate No.

Software: Name & Version: / Software conformity certificate No.

Additional electronic system 1: System function:

Manufacturer & type: / Type approval certificate No.

Additional electronic system 2: System function:

Manufacturer & type: / Type approval certificate No.

Additional electronic system 3: System function:

Manufacturer & type: / Type approval certificate No.

4e. Starting System

Type:

4f. Safety devices/functions

A flame arrestor or a bursting disk is installed in the starting air system: before each starting valve ☐ Yes ☐ No; in the starting air manifold ☐ Yes ☐ No

Crankcase relief valves available ☐ Yes ☐ No Manufacturer / type: /

Type approval certificate No.

No. of cyl.	Total crankcase gross volume incl. attachments (m^3)	Type & size (mm) of relief valve	Relief area per relief valve (mm^2)	No. of relief valves
		/ / / /		

Method used for detection of potentially explosive crankcase condition:

☐ Oil mist detector: Manufacturer / type: / Type approval certificate No.

☐ Alternative method: *(mark all that apply)* ☐ crankcase pressure monitoring ☐ oil splash temperature monitoring ☐ bearing temperature monitoring ☐ recirculation arrangements ☐ other:

Cylinder overpressure warning device available ☐ Yes ☐ No

Type: Opening pressure (bar):

4g. Attached ancillary equipment *(Mark all that apply)*

Engine driven pumps:

☐ Main lubricating oil pump ☐ Sea cooling water pump ☐ LT-fresh cooling water pump

☐ HT-fresh cooling water pump ☐ Fuel oil booster pump ☐ Hydraulic oil pump ☐ Other ( )

Engine attached motor driven pumps:

☐ Lubricating oil pump ☐ Cooling fresh water pump ☐ Fuel oil booster pump

☐ Hydraulic oil pump ☐ Other ( )

Engine attached cooler or heater:				
☐ Lubricating oil cooler		☐ Lubricating oil heater		☐ Fuel oil valve cooler
☐ Hydraulic oil cooler		☐ Cooling fresh water cooler		
Engine attached filter:				
Lubricating oil filter	☐ Single	☐ Duplex	☐ Automatic	
Fuel oil filter	☐ Single	☐ Duplex	☐ Automatic	

5. Inclination limits *(engine operation is safeguarded under the following limits)*	Athwartships		Fore-and-aft	
	Static	Dynamic	Static	Dynamic
Main & Auxiliary machinery	☐ 15.0°	☐ 22.5°	☐ 5.0°	☐ 7.5°
Emergency machinery	☐ 22.5°	☐ 22.5°	☐ 10.0°	☐ 10.0°
Emergency machinery on ships for the carriage of liquefied gas and liquid chemicals	☐ 30.0°	☐ 30.0°		

6. Main engine emergency operation		
At failure of one auxiliary blower, engine can be started and operated at partial load	☐ Yes	☐ No
At failure of one turbocharger, engine operation can be continued	☐ Yes	☐ No

7. References: *Additional Information Attached to Application*	
Document Name/Number	Summary of information contained in document

8. Further Remarks:

* All parties that affect the final complete engine (e.g. manufacture, modify, adjust) are to be listed. All sites where such work is carried out may be required to complete CoP assessment.

† DA = Design Appraisal, TT = Type Test, CoP = Assessment of Conformity of Production. See 'Definitions' at the end of this application form for more information.

‡ Only in case of TA Extension.

§ See 'Definitions' at the end of this application form for more information.

Completed By: Signature: _____

Company:

Job Title: Stamp:

Date:

1.1.2 **Definitions** *(1/7/2022)*

Design Appraisal: Evaluation of all relevant plans, calculations and documents related to the design to determine compliance with Sec 2. This includes requirements for all associated ancillary equipment and systems essential for the safe operation of the engine i.e. the Complete Engine. The Design Appraisal is recorded on a Supplement to the Type Approval Certificate.

Type Testing: requires satisfactory completion of testing of the Complete Engine against the requirements in Sec 2. Type testing is only applicable to the first in series; all engines are to complete factory acceptance and shipboard trials as per Sec 2.

Design Evaluation Certification: may be granted upon satisfactory completion of Design Appraisal and Type Testing.

Assessment of Conformity of Production: means the assessment of quality assurance, manufacturing facilities and processes and testing facilities, to confirm the manufacturer's capability to repeatedly produce the complete engine in accordance with the approved and type tested design.

Type Approval Certification: will be granted upon satisfactory completion of Design Appraisal, Type Testing and assessment of Conformity of Production of the complete engine. The Type Approval Certificate will incorporate outputs from the Design Appraisal, the Type Test and the Assessment of Conformity of Production.

Complete Engine: includes the control system and all ancillary systems and equipment referred to in Sec 2, this includes systems allowing the use of different fuel types. The exact list of components/items that will need to be tested in together with the bare engine will depend on the specific design of the engine, its control system and the fuel(s) used but may include, but are not limited to, the following:

- Turbocharger(s)
- Crankcase explosion relief devices
- Oil mist detection and alarm devices
- Piping
- Electronic monitoring and control system(s) - software and hardware
- Fuel management system (where dual fuel arrangements are fitted)
- Engine driven pumps
- Engine mounted filters

Fuel Types:All fuels that the engine is designed to operate with are to be identified on the application form as this may have impact on the requirements that are applicable for Design Appraisal and the scope of the tests required for Type Testing. Where the engine is to operate in a Dual Fuel mode, the combinations of fuel types are to be detailed. E.g. Natural Gas + DMA, Natural Gas + Marine Residual Fuel, the specific details of each fuel are to be provided as indicated in the relevant rows of the Fuel Types part of section 3a of this form.

APPENDIX 10 TABULAR LISTING OF LICENSOR'S AND LICENSEE'S DRAWING AND DATA

1 General

1.1 List of drawing and data of licensor's and licensee's

1.1.1 *(1/7/2016)*

Licensee:_____ Licensor:_____

_____

Licensee Engine No. :_____ Engine type:_____

No.	Components or System	Licensor			Licensee		Has Design been modified by Licensee?	If Yes, indicate following information		
		Dwg. No. & Title	Rev. No.	Date of Class Approval or Review	Dwg. No.	Rev. No.	Yes	No	Identification of Alternative approved by Licensor	Date of Class Approval or Review of Licensee Dwg.
1										
2										
3										
4										
5										
6										
7										
8										
9 ...										

I attest the above information to be correct and accurate.

Person in Charge (Licensee): _____

_____

Printed Name Signature

Date:_____

APPENDIX 11 SAMPLE TEMPLATE FOR CONFIRMATION OF THE LICENSOR'S ACCEPTANCE OF LICENSEE'S MODIFICATIONS

1 General

1.1 Template: engine licensee proposed alternative to licensor's design

1.1.1 *(1/7/2016)*

Engine Licensee Proposed Alternative to Licensor's Design			
Licensee information			
Licensee:		Ref No.:	
Description:		Info No.:	
Engine type:		Main Section:	
Engine No.:		Plant Id.:	
Design Spec: ☐ General ☐ Specific Nos:			
Licensor design:	*State relevant part or drawing. numbers. Insert drawing clips or pictures. Add any relevant information*		*Licensee Proposed Alternative*

		For example: • Differences in geometry • Differences in the functionality • Material • Hardness • Surface condition • Alternative standard • Licensee production information introduced on the drawing • Weldings or castings • etc.	
Reason: ☐ Licensee's production ☐ Sub-supplier's production ☐ Cost down ☐ Tools	Interchangeability w. licensor design ☐ Yes ☐ No	Non-conformity Report Research, Assessment, Evaluation ☐ NCR ☐ RAE	Certified by licensee: Initials: Date:
Licensor comments			
LoAE: ☐ Accepted as alternative execution *(Licensor undertakes responsibility)* ☐ No objection acceptable *(Licensee undertakes responsibility)* ☐ Not		NCR: ☐ Approved ☐ Conditionally approved ☐ Rejected	Certified by licensor: Initials: Date:
Licensor ref.:			Date:
Licensee ref.:			Date:

APPENDIX 12 RECIPROCATING INTERNAL COMBUSTION ENGINES FUELLED BY NATURAL GAS

1 General

1.1 Scope

1.1.1 Type of engines *(1/1/2025)*

This appendix addresses the requirements for marine reciprocating internal combustion engines supplied with natural gas as fuel.

The scope of this appendix is intended for natural gas fuelled engines. It may also be referred for engines using similar fuels with main component methane such as bio-methane or synthetic methane.

It is to be ensured by the gas supply system that the gas supplied to the engine is always in gaseous state. This appendix does not cover requirements for liquid or cryogenic gas.

The engines can be dual fuel engines (hereinafter referred to as DF engines), gas fuel only engines (hereinafter referred to as GF engines), or any variations thereof including fuel sharing capability.

DF engines and GF engines may not be permitted for emergency applications.

This appendix is to be applied in association with other relevant rule requirements, as far as found applicable to the specific engine design.

The requirements of the mandatory international codes for gas carriers (IGC Code) and for other ships burning low flashpoint fuels (IGF Code) must also be considered when the ship is subject to such Codes.

Specific requirements of the IGF Code as referenced in this appendix shall be applied to engine types covered by this appendix installed on any ship, regardless of type, size and trading area, as long as the IGC Code is not referenced or explicitly specified otherwise.

1.2 Definitions

1.2.1 *(1/1/2025)*

Certified safe equipment is equipment certified by an independent national test institution or competent body to be in accordance with a recognised standard for electrical apparatus in hazardous areas.

Note 1: Refer to IEC 60079 series, Explosive atmospheres and IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features

1.2.2 *(1/7/2019)*

Double block and bleed valves means the set of valves referred to in:

- IGC Code, 16.4.5
- IGF Code, 2.2.9 and 9.4.4 to 9.4.6.

1.2.3 *(1/7/2019)*

Dual fuel engine ("DF engine") means an engine that can burn natural gas as fuel simultaneously with liquid fuel, either as pilot oil or bigger amount of liquid fuel (gas mode), and also has the capability of running on liquid diesel fuel oil only (Diesel mode).

1.2.4 *(1/1/2025)*

Explosion relief device means a device to protect personnel and component against a determined overpressure in the event of a gas explosion. The device may be a valve, a rupture disc or other, as applicable.

1.2.5 *(1/1/2025)*

Gas means natural gas used as fuel consisting primarily of methane.

Note 1: Gas may also be bio-methane or synthetic methane etc. with methane as main component.

1.2.6 *(1/1/2025)*

Gas admission valve is a valve or injector on the engine, which controls gas supply to the cylinder(s) according to the engine's gas demand.

1.2.7 *(1/1/2025)*

Gas engine means a DF engine, a GF engine, or any variations thereof.

1.2.8 *(1/7/2019)*

Gas fuel only engine ("GF engine") means an engine capable of operating on gas fuel only and not able to switch over to oil fuel operation.

1.2.9 *(1/1/2025)*

Gas piping means piping containing gas or air / gas mixtures.

1.2.10 *(1/1/2025)*

High pressure gas means gas with a maximum working pressure greater than 10 bar gauge.

1.2.11 *(1/1/2025)*

IGC Code means the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, as amended.

1.2.12 *(1/7/2019)*

IMO means the International Maritime Organisation.

1.2.13 *(1/1/2025)*

IGF Code means the International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels (IMO Resolution MSC.391(95), as amended.

1.2.14 *(1/1/2025)*

Low pressure gas means gas with a maximum working pressure lower or equal to 10 bar gauge.

1.2.15 *(1/7/2019)*

Lower Heating Value ("LHV") means the amount of heat produced from the complete combustion of a specific amount of fuel, excluding latent heat of vaporization of water.

1.2.16 *(1/7/2019)*

Methane Number is a measure of resistance of a gas fuel to knock, which is assigned to a test fuel based upon operation in knock testing unit at the same standard knock intensity.

Note 1: Pure methane is used as the knock resistant reference fuel, that is, methane number of pure methane is 100, and pure hydrogen is used as the knock sensitive reference fuel, methane number of pure hydrogen is 0.

1.2.17 *(1/7/2019)*

Pilot fuel means the fuel oil that is injected into the cylinder to ignite the main gas-air mixture on DF engines.

1.2.18 *(1/1/2025)*

Pre-mixed engine means an engine where gas is supplied in a mixture with air through a common manifold for all cylinders, e.g. mixed before or after the turbocharger.

1.2.19 *(1/7/2019)*

Recognized standards means applicable international or national standards acceptable to the Classification Society or standards laid down and maintained by an organisation which complies with the standards adopted by IMO and which are recognized by the Classification Society.

1.2.20 *(1/1/2025)*

Safety Concept is a document describing the safety philosophy with regard to gas as fuel. It describes how risks associated with this type of fuel are controlled under reasonably foreseeable abnormal conditions as well as possible failure scenarios and their control measures. The results of the risk analysis, see [1.4], are to be reflected in the safety concept.

Note 1: A detailed evaluation regarding the hazard potential of injury from a possible explosion is to be carried out and reflected in the safety concept of the engine.

1.3 Documents and drawings to be submitted

1.3.1 Documents and drawings to be submitted for the approval of DF and GF engines *(1/7/2019)*

The following documents in Tab 1 are to be submitted for the approval of DF and GF engines, in addition to those required in Sec 2.

Table 1 : Documents and drawings to be submitted for the approval of DF and GF engines *(1/1/2025)*

No.	A/I **(1)**	Document
1	A	Schematic layout or other equivalent documents of gas system on the engine
2	A	Gas piping system (including double-walled arrangement where applicable) (2)
3	A	Parts for gas admission system **(2)**
4	A	Arrangement of explosion relief valves (crankcase **(3)**, charge air manifold, exhaust gas manifold and exhaust gas system on the engine) as applicable
5	A	List of certified safe equipment and of relevant certification
6	I	Safety concept
7	I	Report of the risk analysis **(4)**
8	I	Gas used as fuel specification

(1) A = to be submitted for approval, in four copies
I = to be submitted for information, in duplicate.
(2) The documentation to contain specification of design pressures, working pressure, pipe dimensions and materials.
(3) If required by Sec 2.
(4) See [1.4].

1.3.2 Documents and drawings to be submitted for the approval of DF engine *(1/7/2019)*

The following documents in Tab 2 are to be submitted for the approval of DF engines in addition to those required in Sec 2 and Tab 1.

Table 2 : Documents and drawings to be submitted for the approval of DF engines *(1/1/2025)*

No.	Document
1	Schematic layout or other equivalent documents of pilot fuel system
2	Shielding of high pressure fuel pipes for pilot fuel system, assembly
3	High pressure parts for pilot fuel oil injection system **(1)**

(1) The documentation to contain specification of pressures, pipe dimensions and materials.

1.3.3 Documents and drawings to be submitted for the approval of GF engine *(1/7/2019)*

The following documents in Tab 3 are to be submitted for the approval of GF engines in addition to those required in Sec 2 and Tab 1.

Table 3 : Documents and drawings to be submitted for the approval of GF engines *(1/1/2025)*

No.	Document
1	Schematic layout or other equivalent documents of the ignition system

1.3.4 *(1/7/2019)*

Where considered necessary, the Society may request further documents to be submitted.

1.4 Risk analysis

1.4.1 Scope of the risk analysis *(1/1/2025)*

The risk analysis is to address:

- a failure or malfunction of any system or component involved in the gas operation of the engine,
- a gas leakage downstream of the double block and bleed valves,
- the safety of the engine in case of emergency shutdown or blackout, when running on gas,

- the inter-actions between the gas fuel system and the engine.

Note 1: With regard to the scope of the risk analysis it shall be noted that failures in systems external to the engine, such as fuel storage or fuel gas supply systems, may require action from the engine control and monitoring system in the event of an alarm or fault condition. Conversely failures in these external systems may, from the vessel perspective, require additional safety actions from those required by the engine limited risk analysis required by this Appendix.

1.4.2 Form of the risk analysis *(1/1/2025)*

The risk analysis is to be carried out in accordance with international standard IEC 31010:2019: Risk management - Risk assessment techniques, or other recognized standards.

The required analysis is to be based on the single failure concept, which means that only one failure needs to be considered at the same time. Both detectable and non-detectable failures are to be considered. Consequences failures, i.e. failures of any component directly caused by a single failure of another component, are also to be considered.

1.4.3 Procedure for the risk analysis *(1/1/2025)*

The risk analysis is to:

a) identify all the possible failures in the concerned equipment and systems which could lead:
   1) to the presence of gas in components or locations not designed for such purpose, and/or
   2) to ignition, fire or explosion;
b) evaluate the consequences (see also [2.1.2]),
c) where necessary, identify the failure detection method,
d) where the risk cannot be eliminated, identify the corrective measures:
   1) in the system design, such as:
      - redundancies,
      - safety devices, monitoring or alarm provisions which permit restricted operation of the system;
   2) in the system operation, such as:
      - initiation of the redundancy,
      - activation of an alternative mode of operation.

The results of the risk analysis are to be documented.

1.4.4 Equipment and systems to be analysed *(1/1/2025)*

The risk analysis required for engines is to cover at least the following aspects:

a) failure of the gas-related systems or components, in particular:
   - gas piping and its enclosure, where provided
   - gas admission valves

Note 1: Failures of the gas supply components not located directly on the engine, such as block-and-bleed valves and other components of the gas supply system, are not to be considered in the analysis.

b) failure of the ignition system (oil fuel pilot injection, sparking plugs, glow plugs),
c) failure of the air to fuel ratio control system (charge air by-pass, gas pressure control valve, etc.),
d) for engines where gas is supplied upstream of the turbocharger compressor, failure of a component likely to result in a source of ignition (hot spots),
e) failure of the gas combustion or abnormal combustion (misfiring, knocking),
f) failure of the engine monitoring, control and safety systems,

Note 2: Where engines incorporate electronic control systems, a failure mode and effects analysis (FMEA) is to be carried out in accordance with Sec 2, Tab 1, Footnote 5.

g) presence of gas in engine components (e.g. air inlet manifold or scavenge space and exhaust manifold) and in the external systems connected to the engines (e.g. exhaust duct, cooling water system, hydraulic oil system, etc.),
h) changes of operating modes for DF engines,
i) hazard potential for crankcase fuel gas accumulation, for trunk-piston engines, refer to IGF Code 10.3.1.2 and Sec 2, [2.3].
j) risk of crankcase explosion in connection with active crankcase ventilation which produces a flow of external air into the crankcase, (see Sec 2, [2.3]).

2 Design Requirements

2.1 General Principles

2.1.1 *(1/7/2019)*

The manufacturer is to declare the allowable gas composition limits for the engine and the minimum and (if applicable) maximum methane number.

2.1.2 *(1/1/2025)*

Components containing or likely to contain gas are to be designed to:

a) minimise the risk of fire and explosion so as to demonstrate an appropriate level of safety commensurate with that of an oil-fuelled engine;

b) mitigate the consequences of a possible explosion to a level providing a tolerable degree of residual risk, due to the strength of the component(s) or the fitting of suitable explosion relief devices of an approved type.

The strength of the component(s) of arrangement of explosion relief devices is to be documented (e.g., as part of risk analysis) or otherwise demonstrated to be sufficient for a worst-case explosion.

Also refer to the IGF Code 10.2 and 10.3.

2.1.3 *(1/1/2025)*

Discharge from explosion relief devices is to prevent the passage of flame to the machinery space and be arranged such that the discharge does not endanger personnel or damage other engine components or systems

2.1.4 *(1/1/2025)*

Explosion relief devices are to be fitted with a flame arrester.

2.2 Design Requirements

2.2.1 Gas piping *(1/1/2025)*

The requirements of this section apply to engine-mounted gas piping. The piping shall be designed in accordance with the criteria for gas piping (design pressure, wall thickness, materials, piping fabrication and joining details etc.) as given in the IGF Code chapter 7, or IGC Code chapter 5.1 to 5.9 and 16 as applicable.

Other connections as mentioned in IGF Code 7.3.6.4.4 may be accepted subject to type approval in accordance with the requirements of Sec 10.

All single walled or high-pressure gas pipes should be considered as Class I.

Low pressure double walled gas pipes should be considered as Class II.

All secondary enclosures for gas pipes should be considered as Class II.

Single walled gas vent pipes, if permitted, should be considered as Class I, except it is justified that the maximum built up pressure is less than 5 bar gauge, in which case it should be considered as Class II.

Gas vent pipes protected by a secondary enclosure should be considered as Class II.

Secondary enclosure for vent pipes should be considered as Class III.

Table 4 : Design pressure for gas pipes *(1/1/2025)*

	Design pressure	
Gas pipe, low pressure	see IGF Code 7.3.3.1	see IGC Code 5.4.1
Gas pipe, high pressure	see IGF Code 7.3.3.1	see IGC Code 5.4.1
outer pipe, low pressure	see IGF Code 9.8.1	see IGC Code 5.4.4
outer pipe, high pressure	see IGF Code 9.8.2	see IGC Code 5.4.4
Open ended pipes	see IGF Code 7.3.3.2	see IGC Code 5.4.1

Flexible bellows used in the fuel gas system on the engine are to be approved based on the requirements of IGF Code 16.7.2, and IGC Code 5.13.1.2, as applicable.

The number of cycles, pressure, temperature, axial movement, rotational movement and transverse movement which the bellow will encounter in actual service on the engine should be specified by the engine designer.

Endurance against high cycle fatigue due to vibration loads is to be verified by testing or alternatively be documented by the Expansion Joint Manufacturers Association, Inc. (EJMA) calculation or equivalent (i.e., more than 10^7 cycles).

Note 1: The fatigue test due to ship deformations in IGF Code 16.7.2.4 is considered not relevant for bellows which are an integral part of the engine.

2.2.2 Arrangement of the gas piping system on the engine *(1/1/2025)*

Pipes and equipment containing fuel gas are defined as hazardous area Zone 0 (refer to IGF Code 12.5.1).

The space between the gas fuel piping and the wall of the outer pipe or duct is defined as hazardous area Zone 1 (refer to IGF Code 12.5.2.6).

a) Normal "double wall" arrangement

The gas piping system on the engine shall be arranged according to the principles and requirements of the IGF Code 9.6. For gas carriers, IGC Code 16.4.3 applies.

The design criteria for the double pipe or duct are given in the IGF Code 9.8 and 7.4.1.4.

In case of a ventilated double wall, the ventilation inlet is to be located in open air and in accordance with the provisions of IGF Code, regulation 13.8.3. For gas carriers, IGC Code 16.4.3.2 applies.

The pipe or duct is to be pressure tested at 1,5 x design pressure to ensure gas tight integrity and to show that it can withstand the expected maximum pressure at gas pipe rupture.

b) Alternative arrangement

Single walled gas piping is only acceptable:

1) for engines supplied with low pressure gas and installed in ESD protected machinery spaces, as defined in IGF Code 5.4.1.2 and in compliance with other relevant parts of the IGF Code (e.g. 5.6);

2) in the case as per footnote 18 to paragraph 9.6.2 of IGF Code.

For gas carriers, the IGC Code applies.

In case of gas leakage in an ESD-protected machinery space, which would result in the shut-down of the engine(s) in that space, a sufficient propulsion and manoeuvring capability including essential and safety systems is to be maintained.

Therefore the safety concept of the engine is to clearly indicate application of the "double wall" or "alternative" arrangement.

Note 1: The minimum power to be maintained is to be assessed on a case-by-case basis from the operational characteristics of the ship.

2.2.3 Charge air system and exhaust gas system on the engine *(1/1/2025)*

The charge air system and exhaust gas system on the engine are to be designed in accordance with [2.1.2] above.

In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the explosion relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained.

Note 1: Load reduction is to be considered on a case by case basis, depending on engine configuration (single or multiple) and relief mechanism (self-closing valve or rupture disk).

2.2.4 *(1/1/2025)*

Continuous relief of exhaust gas (through open rupture disc) into the engine room or other enclosed spaces is not acceptable.

Suitable explosion relief system for air inlet manifolds, scavenge spaces and exhaust system should be provided unless designed to accommodate the worst-case overpressure due to ignited gas leaks or justified by the safety concept of the engine. A detailed evaluation regarding the hazard potential of overpressure in air inlet manifolds, scavenge spaces and exhaust system should be carried out and reflected in the safety concept of the engine.

Explosion relief devices for air inlet and exhaust manifold are to be type approved according to App 17.

The necessary total relief area and the arrangement of the explosion relief devices are to be determined taking into account:

- The worst-case explosion pressure depending on initial pressure and gas concentration,
- the volume and geometry of the component, and
- the strength of the component.

The arrangement is to be determined in the risk analysis (see [1.4.4], g)) and reflected in the safety concept.

2.2.5 Engine crankcase *(1/1/2025)*

a) Crankcase explosion relief valves

Crankcase explosion relief valves are to be installed in accordance with Sec 2, [4.3.4]. Refer also to IGF Code 10.3.1.2.

For engines not covered by Sec 2, [4.3.4], the detailed evaluation as required in [1.4.4], i) is to determine if crankcase explosion relief valves are necessary.

b) Inerting

For maintenance purposes, a connection, or other means, are to be provided for crankcase inerting and ventilating and gas concentration measuring.

c) Crankcase ventilation

Ventilation of crankcase (either supply or extraction), if arranged, is to comply with Sec 2, [4.3.4].

Relevant evidence is to be documented in Safety Concept.

The ventilation systems for crankcase, sump and other similar engine spaces are to be independent from the systems on the other engines.

2.2.6 Gas ignition in the cylinder *(1/7/2019)*

Requirements of IGF Code 10.3 apply. For gas carriers, IGC Code 16.7 applies.

2.2.7 Control, monitoring, alarm and safety systems *(1/1/2025)*

The engine control system is to be independent and separate from the safety system.

The gas admission valves are to be controlled by the engine control system or by the engine gas demand.

Combustion is to be monitored on an individual cylinder basis.

In the event that poor combustion is detected on an individual cylinder, gas operation may be allowed in the conditions specified in IGF Code 10.3.1.6.

If monitoring of combustion for each individual cylinder is not practicable due to engine size and design, common combustion monitoring may be accepted.

Unless the risk analysis required by [1.4] proves otherwise, the monitoring and safety system functions for DF or GF engines are to be provided in accordance with Tab 5 in addition to the general monitoring and safety system functions required in Sec 2 and, for ship having the relevant additional class notations, Part F, Chapter 3.

Note 1: For DF engines, Tab 5 applies only to the gas mode.

2.2.8 Gas admission valves *(1/1/2025)*

Electrically operated gas admission valves shall be certified safe as follows:

a) The inside of the valve contains gas and shall therefore be certified for Zone 0.

b) When the valve is located within a pipe or duct in accordance with [2.2.2] a), the outside of the valve shall be certified for Zone 1.

c) When the valve is arranged without enclosure in accordance with the "ESD-protected machinery space" (see [2.2.2] b)) concept, no certification is required for the outside of the valve, provided that the valve is de-energized upon gas detection in the space.

However, if they are not rated for the zone they are intended for, it shall be documented that they are suitable for that zone. Documentation and analysis are to be based on IEC 60079-10-1:2015 or IEC 60092-502:1999.

Gas admission valves operated by hydraulic oil system are to be provided with sealing arrangement to prevent gas from entering the hydraulic oil system.

Table 5 : Monitoring and Safety System Functions for DF and GF Engines *(1/1/2025)*

Parameter	Alarm	Automatic activation of the double block-and-bleed valves	Automatic switching over to oil fuel mode **(1)**	Engine shutdown
Abnormal pressures in the gas fuel supply line	X	X	X	X **(5)**
Gas fuel supply systems - malfunction	X	X	X	X **(5)**
Pilot fuel injection or spark ignition systems - malfunction	X	X **(2)**	X	X **(2) (5)**
Exhaust gas temperature after each cylinder - high	X	X **(2)**	X	X **(2) (5)**
Exhaust gas temperature after each cylinder, deviation from average - low **(3)**	X	X **(2)**	X	X **(2) (5)**
Cylinder pressure or ignition - failure, including misfiring, knocking and unstable combustion	X	X **(2) (4)**	X **(4)**	X **(2) (4) (5)**
Oil mist concentration in crankcase or bearing temperature **(6)** - high	X	X		X (9)
Pressure in the crankcase - high (8)	X	X	X	
Engine stops - any cause	X	X		
Failure of the control-actuating medium of the block and bleed valves	X	X	X	
Failure of crankcase ventilation system, if applicable	X	X (7)	X (7)	

(1) DF engine only, when running in gas mode

(2) For GF engines, the double block-and-bleed valves and the engine shutdown may not be activated in case of specific failures affecting only one cylinder, provided that the concerned cylinder can be individually shutoff and the safe operation of the engine in such conditions is demonstrated by the risk analysis.

(3) Required only if necessary for the detection of misfiring

(4) In the case where the failure can be corrected by an automatic mitigation action, only the alarm may be activated. If the failure persists after a given time, the safety actions are to be activated.

(5) GF engine only

(6) Where required by Sec 2, [4.3.5]

(7) Automatic safety actions to be activated as specified by the engine manufacturer, see Sec 2, [4.3]

(8) Only for trunk piston engines. This pressure sensor cannot replace or substitute a gas detector

(9) Only for trunk piston engines. For crosshead engines slow down is to apply (see Pt F, Ch 3, Sec 1, Tab.2)

3 Specific Design Requirements

3.1 DF Engines

3.1.1 General *(1/1/2025)*

The maximum continuous power that a DF engine can develop in gas mode may be lower than the approved MCR of the engine (i.e. in oil fuel mode), depending in particular on the gas composition of its quality or the engine design.

This maximum continuous power available in gas mode and the corresponding conditions shall be stated by the engine manufacturer.

3.1.2 Starting, changeover and stopping *(1/1/2025)*

DF engines are to be arranged to be started using either oil fuel or gas fuel with pilot oil fuel for ignition. The engines are to be arranged for rapid changeover from gas use to fuel oil use. In the case of changeover to either fuel supply, the engines are to be capable of continuous operation using the alternative fuel supply without interruption to the power supply.

Changeover to gas fuel operation is to be only possible at a power level and under conditions where it can be done with acceptable reliability and safety as demonstrated through testing.

Changeover from gas fuel operation mode to oil fuel operation mode is to be possible at all situations and power levels.

The changeover process itself from and to gas operation is to be automatic but manual interruption is to be possible in all cases.

If the power level or other conditions do not allow safe and reliable gas operation, changeover to oil fuel mode is to be automatically performed.

In case of shut-off of the gas supply, the engines are to be capable of continuous operation by oil fuel only.

3.1.3 Pilot injection *(1/7/2019)*

Gas supply to the combustion chamber is not to be possible without operation of the pilot oil injection.

Note 1: Pilot injection is to be monitored for example by fuel oil pressure and combustion parameters.

3.2 GF Engines

3.2.1 Spark ignition system *(1/7/2019)*

In case of failure of the spark ignition, the engine is to be shut down except if this failure is limited to one cylinder, subject to immediate shut off of the cylinder gas supply and provided that the safe operation of the engine is substantiated by the risk analysis and by tests.

3.3 Pre-Mixed Engines

3.3.1 Charge air system *(1/7/2019)*

Inlet manifold, turbo-charger, charge air cooler, etc. are to be regarded as parts of the fuel gas supply system. Failures of those components likely to result in a gas leakage are to be considered in the risk analysis (see [1.4]).

Flame arresters are to be installed before each cylinder head, unless otherwise justified in the risk analysis, considering design parameters of the engine such as the gas concentration in the charge air system, the path length of the gas-air mixture in the charge air system, etc.

3.4 Two-stroke engines

3.4.1 Scavenge air system *(1/1/2025)*

The risk analysis required in [1.4] is to cover the possible gas accumulation in a scavenge space.

3.4.2 Crankcase *(1/1/2025)*

The risk analysis required in [1.4] is to cover the possible failure of a piston rod stuffing box.

4 Type Testing, Factory Acceptance Tests and Shipboard Trials

4.1 Type Testing

4.1.1 General *(1/7/2019)*

Type approval of DF and GF engines is to be carried out in accordance with Sec 2, [6], taking into account the additional requirements below.

4.1.2 Type of engine *(1/1/2025)*

In addition to the criteria given in Sec 2, [1.5.1] the type of engine is defined by the following:

- gas admission method (cylinder injection after compression stroke, cylinder individual injection before compression stroke or pre-mixed)
- gas admission valve operation (mechanical or electronically controlled)
- ignition system (pilot injection, spark ignition, glow plug or gas self-ignition)
- ignition system (mechanical or electronically controlled).

Note 1: Cylinder-individual injection before compression stroke may be port injection into the air inlet channel before the cylinder inlet valve, injection into the cylinder before or during compression stroke, or similar arrangements.

4.1.3 Safety precautions *(1/7/2019)*

In addition to the safety precautions mentioned in Sec 2, [6.6], measures to verify that gas fuel piping on engine is gas tight are to be carried out prior to start-up of the engine.

4.1.4 Test programme *(1/1/2025)*

The type testing of the engine is to be carried out in accordance with Sec 2, [6.7].

The influence of the methane number and LHV of the fuel gas is not required to be verified during the Stage B type tests. It shall however be justified by the engine designer through internal tests or calculations and documented in the type approval test report.

4.1.5 Measurements and records *(1/1/2025)*

In addition to the measurements and records required in Sec 2, [6.8], the following engine data are to be measured and recorded:

- each fuel index for gas and diesel as applicable (or equivalent reading),
- gas pressure and temperature at the inlet of the gas manifold,
- Pilot fuel temperature and pressure (supply or common rail as appropriate)
- gas concentration in the crankcase

Note 1: The gas concentration in the crankcase should normally be measured inside the crankcase or at the crankcase outlet (crankcase vent pipe). Gas concentration measurements may be carried out as part of Stage A if the method and the results are properly documented.

Additional measurements may be required in connection with the design assessment.

4.1.6 Stage A - internal tests *(1/1/2025)*

In addition to tests required in Sec 2, [6.9], the following conditions are to be tested:

- DF engines are to run the load points defined in Sec 2, [6.9] in both gas and diesel modes (with and without pilot injection in service) as found applicable for the engine type,
- for DF engines with variable liquid / gas ratio, the load tests are to be carried out at different ratios between the minimum and the maximum allowable values,
- for DF engines, switch over between gas and diesel modes are to be tested at different loads.
- the influence of the methane number and LHV of the fuel gas on the engine's maximum continuous power available in gas mode is to be verified.

4.1.7 Stage B - witnessed tests *(1/1/2025)*

a) General

Gas engines are to undergo the different tests required in Sec 2, [6.10].

In case of DF engine,

- all load points must be run in both gas and diesel modes that apply for the engine type as defined by the engine designer. The independent overspeed protection device has to be tested both in gas and diesel mode (see Sec 2, [6.10.2]).
- For engines with variable liquid / gas ratio, selected load tests are to be carried out at different ratios between the minimum and the maximum allowable values (most relevant and critical loads and ratios should be selected for the test)
- The maximum continuous power available in gas mode (see [3.1.1]) is to be demonstrated
- Overload testing is not required in gas mode for DF engines, provided that changeover to oil fuel mode is automatically performed in case of overload
- The load tests are to be carried out in diesel mode and in gas mode at the different percentages of the engine's MCR.

b) Functional tests

In addition to the functional tests required in Sec 2, [6.10.3], the following tests are to be carried out:

- for DF engines, the lowest specified speed is to be verified in diesel mode and gas mode,
- for DF engines, switch over between gas and diesel modes are to be tested at different loads,
- For DF engines, verification of automatic changeover to diesel mode when the load demand exceeds the maximum continuous power available in gas mode (see [3.1.1] and [3.1.2])
- the efficiency of the ventilation arrangement or other approved principal of the double walled gas piping system is to be verified,

Engines intended to produce electrical power are to be tested as follows:

- capability to take sudden load and loss of load in accordance with the provisions of Sec 2, [4.7.5] c) and d),
- for GF and premixed engines, the influences of LHV, methane number and ambient conditions on the dynamic load response test results are to be theoretically determined and specified in the test report. Referring to the limitations as specified in [2.1.1], the margin for satisfying dynamic load response is to be determined.

Note 1: For DF engines, switchover to oil fuel during the test is acceptable.

Note 2: Application of electrical load in more than 2 load steps can be permitted in the conditions stated in Sec 2, [4.7.5] d).

c) Integration Tests

GF and DF engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine system is as predicted for all intended operational modes. The scope of these tests is to be agreed with the Society for selected cases based on the risk analysis required in [1.4], and shall at least include the following incidents:

- Failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure
- Failure of a gas admission valve
- Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.)
- Abnormal gas pressure
- Abnormal gas temperature (see note 3)

Note 3: This test may be carried out using a simulation signal of the temperature.

4.1.8 Stage C - Component inspection *(1/1/2025)*

Component inspection is to be carried out in accordance with the provisions of Sec 2, [6.11].

The components to be inspected after the test run are to include also:

- gas admission valve including pre-chamber as found applicable,
- spark igniter (for GF engines),
- pilot fuel injection valve (for DF engines)

4.1.9 Engine type approval certificate *(1/1/2025)*

For DF engines, the maximum continuous power available in gas mode should be specified on the type approval certificate in addition to the maximum continuous rating in diesel mode if differing.

4.2 Factory Acceptance Test

4.2.1 General *(1/1/2025)*

Factory acceptance tests of DF and GF engines are to be carried out in accordance with Sec 2, [7.4], taking into account the additional requirements below.

For DF engines, the load tests referred to in Sec 2, [7.4.4] are to be carried out in diesel mode and in gas mode at the different percentages of the engine's MCR.

Maximum continuous power available in gas mode is to be demonstrated (see [3.1.1]).

4.2.2 Safety precautions *(1/7/2019)*

In addition to the safety precautions mentioned Sec 2, [6.6], measures to verify that gas fuel piping on engine is gas tight are to be carried out prior to start-up of the engine.

4.2.3 Records *(1/1/2025)*

In addition to the records required in Sec 2, [7.4.3], the following engine data are to be recorded:

- fuel index, both gas and diesel as applicable (or equivalent reading),
- gas pressure and temperature,
- pilot fuel temperature and pressure (supply or common rail as appropriate)

4.2.4 Test loads *(1/7/2019)*

Test loads for various engine applications are given in Sec 2, [7.4.4]. DF engines are to be tested in both diesel and gas mode as found applicable. In addition the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

4.2.5 Integration tests *(1/1/2025)*

GF and DF engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes.

The scope of these tests is to be agreed with the Society for selected cases based on the risk analysis required in [1.4] and shall at least include the following incidents:

- failure of ignition (spark ignition or pilot injection systems), for one cylinder unit,
- failure of a gas admission valve,
- failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.),
- abnormal gas pressure,

- abnormal gas temperature.

The above tests may be carried out using simulation or other alternative methods, subject to special consideration by the Society.

4.3 Shipboard Trials

4.3.1 *(1/1/2025)*

A leak test is to be carried out for the gas piping system (IGF Code 16.7.3.3) after assembly on board.

Shipboard trials are to be carried out in accordance with the provisions of Sec 16, [3.4]

For DF engines, the test loads required in Sec 16, [3.4.4] are to be carried out in all operating modes (gas mode, diesel mode, etc.) as applicable (see [3.1.1]).

The maximum continuous power available in gas mode is to be demonstrated.

Note 1: If a test load is performed in all applicable operation modes without interruption (direct changeover at same power and speed), the duration as required in Sec 16, [3.4.4] may be considered as the total duration demonstrated in all fuel modes. However, demonstration at each mode shall not be less than one hour.

The starting maneuvers required in Sec 16, [3.4.2] are to be carried out in diesel mode and gas mode, if applicable.

For DF engines, automatic switching over to oil fuel mode is to be tested.

Further, manual change over from diesel to gas mode and vice versa is to be tested.

The efficiency of the ventilation arrangement, or other approved principle, of the double walled gas piping system is to be verified.

5 Certification of Engine Components

5.1 General

5.1.1 *(1/1/2025)*

The principals, definitions, and general requirements of Sec 2, [7] apply.

In addition to those components specified in Sec 2, Tab 8, the engine components listed in Tab 6 are to be documented as listed in the table.

Table 6 : Required documentation for engine components *(1/1/2025)*

Item	Part	Material properties	Non-destructive examination	Pressure testing	Visual inspection of welds	Component certificate
1	Gas pipe Low-pressure double walled	W(C+M)	W (2), (6)	W (4)	X	
2	Single walled Gas pipes	W(C+M)	W (1)	W (4)	X	SC
3	High-pressure gas pipes	W(C+M)	W (1)	W (4)	X	SC
4	Secondary enclosure for gas pipes	W(C+M)	W (2)	W (3)	X	
5	Gas pipe Low-pressure, Flanges (8)	W(C+M)	W (2), (6)		X	
6	Gas pipe High-pressure, Flanges (8)	W(C+M)	W (1)		X	SC
7	Gas pipe Low-pressure, Fittings and other components	W(C+M)		W (4)	X	

(1) 100 % radiographic or ultrasonic inspection of all butt-welded joints (IGF Code 16.6.3.1)
(2) 10 % radiographic or ultrasonic inspection of butt-welded joints (IGF Code 16.6.3.4)
(3) Pressure test at 1.5 x design pressure to ensure gas tight integrity, not less than the expected maximum pressure at gas pipe rupture (as per IGF 16.7.3.4, and 9.8.4)
(4) Pressure test at 1.5 x design pressure
(5) Leak test
(6) If inside diameter > 75 mm or wall thickness > 10 mm: 100 % radiographic or ultrasonic inspection of all butt-welded joints (IGF Code 16.6.3.1)
(7) If nominal diameter > 25 mm
(8) “Flanges” limited to the final connection to the engine.

Item	Part	Material properties	Non-destructive examination	Pressure testing	Visual inspection of welds	Component certificate
8	Gas pipe High-pressure, Fittings and other components	W(C+M)		W (4)	X	SC
9	Gas pipe Low-pressure Bodies of valves, (7)	W(C+M)		W (4)		
10	Gas pipe High-pressure Bodies of valves	W(C+M)		W (4)		SC
11	Gas venting pipes and flanges (8), build up pressure less than 5,0bar	TR(C+M)	W	W (4)	X	
12	Gas venting pipes and flanges (8), build up pressure at 5,0bar or more with secondary enclosure	TR(C+M)	W	W (4)	X	
13	Gas venting pipes and flanges (8), build up pressure at 5,0bar or more	W(C+M)	W (1)	W (4)	X	SC
14	Gas venting pipes Secondary enclosure			W (5)	X	

(1) 100 % radiographic or ultrasonic inspection of all butt-welded joints (IGF Code 16.6.3.1)

(2) 10 % radiographic or ultrasonic inspection of butt-welded joints (IGF Code 16.6.3.4)

(3) Pressure test at 1.5 x design pressure to ensure gas tight integrity, not less than the expected maximum pressure at gas pipe rupture (as per IGF 16.7.3.4, and 9.8.4)

(4) Pressure test at 1.5 x design pressure

(5) Leak test

(6) If inside diameter > 75 mm or wall thickness > 10 mm: 100 % radiographic or ultrasonic inspection of all butt-welded joints (IGF Code 16.6.3.1)

(7) If nominal diameter > 25 mm

(8) “Flanges” limited to the final connection to the engine.

APPENDIX 13 LPG OR NH3 FUELLED SHIPS

1 General

1.1 Scope

1.1.1 Application *(1/5/2021)*

The provisions of this Appendix apply to the arrangement, installation, control and monitoring of machinery, equipment and systems of ships using LPG or NH3 as fuel, other than ships covered by the IGC Code (hereinafter named “LPG or NH3 fuelled ships”). These ships are to comply with the requirements of the latest version of the International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels (IGF Code), as amended. In these Rules, reference to this Code and its amendments is made by the wording "IGF Code".

1.1.2 Acceptance by the flag Administration *(1/5/2021)*

The use of LPG or NH3 as fuel in ships requires additional acceptance by the Administration of the State whose flag the ship is entitled to fly on the basis of the alternative design approach as required in IGF Code 2.3.

1.1.3 IGF Code requirements and the Society's rules *(1/5/2021)*

a) For LPG or NH3 fuelled ships, the IGF Code requirements are to be considered as rule requirements, with the departures given in this Appendix;

b) for the scope of classification, the references to "LNG" and "gas" that are given in the IGF Code, are to be regarded as referring to LPG or NH3;

c) for the scope of classification, the references to "the Administration" that are given in the IGF Code, are to be regarded as referring to "the Society";

d) unless otherwise specified, the machinery, equipment and systems of ships using LPG or NH3 as fuel are also to comply with the requirements given in Part C;

e) the requirements of this Appendix include additional mandatory class requirements, as well as the Society's interpretations of the IGF Code, which are also to be considered mandatory for Class;

f) in general, this Appendix applies to machinery, equipment and systems of ships using LPG or NH3 as fuel and to the inter-faces between these systems and the other parts of the ship.

1.1.4 IGF Code requirements not within the scope of classification *(1/5/2021)*

The following requirements of the IGF Code are not within the scope of classification:

- Chapter 11 - Fire Safety
- Chapter 17 - Drills and emergency exercises
- Chapter 18 - Operation
- Chapter 19 - Training

These requirements are applied by the Society when acting on behalf of the flag Administration, within the scope of delegation (see [1.1.6]).

1.1.5 Correspondence of the IGF Code with the Rules *(1/5/2021)*

All the requirements of this Appendix are cross referenced to the applicable Chapters, Sections or paragraphs of the IGF Code, as appropriate.

1.1.6 Certificate of Fitness *(1/5/2021)*

The responsibility for interpretation of the IGF Code requirements for the purpose of issuing an International Certificate of Fitness for the Gas-fuelled Ships lies with the Administration of the State whose flag the ship is entitled to fly.

Whenever the Society is authorised by an Administration to issue on its behalf the "Certificate of Fitness for the Gas-Fuelled ships", or where the Society is authorised to carry out investigations and surveys on behalf of an Administration on the basis of which the "Certificate of Fitness for the Gas-Fuelled ships" will be issued by the Administration, or where the Society is requested to certify compliance with the IGF Code, the full compliance with the requirements of the IGF Code, including the operative requirements mentioned in [1.1.4], will be granted by the Society, subject to [1.1.2].

1.2 Documentation to be submitted

1.2.1 *(1/5/2021)*

Tab 1 lists the plans, information, analysis, etc. which are to be submitted in addition to the information required in the other Parts of the Rules, for the portion of the ship not involved in the LNG or NH3 handling.

Table 1 : Documents to be submitted *(1/5/2021)*

No.	A/I **(1)**	Document
1	I	Propulsion system general arrangement - Design philosophy including information on the machinery configuration, engine room arrangements, fuel arrangements, shutdown philosophy (if applicable), redundancy considerations etc. are to be submitted before other documentation
2	I	Fuel system Risk assessment
3	A	Fuel system arrangement plan - including: • gas tanks and gas containment systems with indication of distances required in [5.4] and calculations per, if applicable • tank connection spaces • fuel storage hold spaces • fuel preparation rooms • bunkering stations and other shore connections • machinery and boiler spaces, service and control station spaces • doors and openings to fuel preparation rooms and other hazardous areas
4	I	Fuel gas system operational manual including procedures for: • bunkering, including filling limits curve • gas freeing and inerting • normal operation • emergency operation
5	A	Fuel gas tanks including drawings of: • tanks • supports and stays • secondary barriers • insulation • marking plates • tank hatches, pipes and any other openings to gas tanks Fuel gas tank design analysis: • specification of design loads and structural analysis of gas tanks • complete stress analysis for independent tanks type B and type C. Fuel gas tanks production process including: • fuel gas tank non-destructive testing (NDT) plan including: • information about strength and tightness testing • specification of stress relieving procedures for independent tanks type C (thermal or mechanical). • fuel gas tank welding procedures • fuel gas tank material specifications including connected pipes
6	A	Fuel gas tank safety relief valves and associated vent piping specification, piping capacity analysis including back pressure
7	A	Fuel gas tank gas freeing and purging system piping diagram
8	A	Fuel gas tank control and monitoring system
9	A	Fuel gas piping system: Pipe routing sketch Piping diagram (including bunkering lines and vent lines for safety relief valves or similar piping, vent mast, and secondary enclosure for gas pipes)
(1) A = to be submitted for approval, in four copies I = to be submitted for information, in duplicate.		

No.	A/I **(1)**	Document
10	I	Fuel gas piping system - Specification of valves, flanges and fittings including offsets, loops, bends, expansion elements such as bellows and slip joints. For valves intended for service with a design temperature be-low -55°C, documentation of leak test and functional test at design temperature (type test) is to be included
11	A	Fuel gas system drip trays - System arrangement plan - Hull protection beneath liquid piping where leakages may be anticipated, such as at shore connections and at pump seals. Including specification
12	I	Electrical bonding of piping - Specification
13	A	Cooling system - Piping diagram in connection with fuel gas system
14	A	Heating system - Piping diagram in connection with fuel gas system
15	A	Fuel gas system control, monitoring and safety systems, including a test program for safety functions
16	A	Fuel gas driven engines - Failure mode and effect analysis
17	A	Exhaust gas system - Piping diagram
18	A	Hazardous area classification drawing, including air-lock location, construction details and alarm equipment
19	A	Gastight bulkhead penetrations - Detailed drawing
20	A	Ventilation of gas fuel system spaces - Ducting diagram for spaces containing gas installations, such as gas pipe ducts led through enclosed spaces, storage tanks below deck. Including capacity and location of fans and their motors
21	I	Explosion protection • System arrangement plan of electrical equipment in hazardous areas • Single line diagrams for all intrinsically safe circuits, for each circuit, including data for verification of the compatibility between the barrier and the field components • List of non-certified safe electrical equipment to be disconnected for ESD protected machinery spaces • Documentation to demonstrate the fulfilment of [4.3] • List of certified safe type equipment/instruments (Ex) • Certificates of the safe type (Ex) equipment/instrumentation as per [1.3.2]
22	A	Fixed gas detection system arrangement plan Detectors, call points and alarm devices specification
23	I	FMEA of the whole gas-fuelled system
24	A	Test procedures of safety-critical items, in particular those related to the gas system as ascertained by the FMEA
25	I	Documentation of alternative design as per [2], as applicable

(1) A = to be submitted for approval, in four copies
I = to be submitted for information, in duplicate.

1.3 Definitions

1.3.1 *(1/5/2021)*

IGF CODE REFERENCE: Ch. 2, 2.1

Unless otherwise stated below, definitions are as defined in SOLAS chapter II-2 and IGF Code 2.2.

1.3.2 *(1/5/2021)*

IGF CODE REFERENCE: Ch. 2, 2.2

Certified safe type means electrical equipment that is certified safe by the relevant recognized authorities for operation in a flammable atmosphere based on a recognized standard.

Note 1: Refer to IEC 60079 series, Explosive atmospheres and IEC 60092-502:1999 Electrical Installations in Ships - Tankers - Special Features.

1.3.3 *(1/5/2021)*

LPG means liquefied petroleum gas, but it also means LPG vapours.

1.3.4 *(1/5/2021)*
Immediately Dangerous to Life and Health (IDLH) for NH3 means a volumetric concentration of 300 ppm, according to the USA National Institute for Occupational Safety and Health (NIOSH).

1.3.5 *(1/5/2021)*
Gas and Gas Fuel in the context of this appendix in general mean either LPG or NH3 in liquefied or vapour form (except specified otherwise, like "inert gas" or "liquid gas").

1.3.6 *(1/5/2021)*
High pressure means a maximum working pressure greater than 2.0 MPa.

1.3.7 *(1/5/2021)*
NH3 means liquefied anhydrous ammonia, but it also includes ammonia vapours.

1.3.8 *(1/5/2021)*
Permissible exposure limit (PEL) for NH3 means a volumetric concentration of 50 ppm, according to UE Directive 2019/1831 “Indicative occupational exposure limit value”.

2 Alternative design

IGF CODE REFERENCE: Ch. 2, 2.3

2.1 Deviation, equivalence and operational measures

2.1.1 *(1/5/2021)*
Appliances and arrangements may deviate from those set out in this Appendix provided that these meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant paragraphs.

2.1.2 *(1/7/2021)*
The equivalence of the alternative design is to be demonstrated as specified in SOLAS regulation II-1/55, and approved by the Society. Operational methods or procedures will not be allowed as an alternative to a particular fitting, material, appliance, apparatus, item of equipment, or type thereof which is prescribed by this Appendix.

3 Goal and functional requirements

IGF CODE REFERENCE: Ch. 3

3.1 Goal

3.1.1 *(1/5/2021)*
The goal of this Appendix is to provide for safe and environmentally-friendly design, construction and operation of ships and in particular their installations of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery using gas as fuel.

3.2 Functional requirements

3.2.1 *(1/5/2021)*
The safety, reliability and dependability of the systems is to be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery. A FMEA consistent with the "TASNEEF Guide for FMEA" is to be carried out for the whole gas-fuelled system, including process system, electrical power supplies and control system, to check the potential existence of failure modes that can jeopardize the ship's safety. The results of the FMEA are then to be used to establish a trial program.

3.2.2 *(1/5/2021)*
The probability and consequences of fuel-related hazards are to be limited to a minimum through arrangement and system design, such as ventilation, detection and safety actions. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions are to be initiated.

3.2.3 *(1/5/2021)*
The design philosophy is to ensure that risk reducing measures and safety actions for the gas fuel installation do not lead to an unacceptable loss of power.

3.2.4 *(1/5/2021)*

Hazardous areas are to be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment.

3.2.5 *(1/5/2021)*

Equipment installed in hazardous areas are to be minimized to that required for operational purposes and are to be suitably and appropriately certified.

3.2.6 *(1/5/2021)*

Unintended accumulation of explosive, flammable or toxic gas concentrations are to be prevented.

3.2.7 *(1/5/2021)*

System components are to be protected against external damages.

3.2.8 *(1/5/2021)*

Sources of ignition in hazardous areas are to be minimized to reduce the probability of explosions.

3.2.9 *(1/5/2021)*

It is to be arranged for safe and suitable fuel supply, storage and bunkering arrangements capable of receiving and containing the fuel in the required state without leakage. Other than when necessary for safety reasons, the system is to be designed to prevent venting under all normal operating conditions including idle periods.

3.2.10 *(1/5/2021)*

Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application are to be provided.

3.2.11 *(1/5/2021)*

Machinery, systems and components are to be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.

3.2.12 *(1/5/2021)*

Fuel containment system and machinery spaces containing source that might release gas into the space are to be arranged and located such that a fire or explosion in either will not lead to an unacceptable loss of power or render equipment in other compartments inoperable.

3.2.13 *(1/5/2021)*

Suitable control, alarm, monitoring and shutdown systems are to be provided to ensure safe and reliable operation.

3.2.14 *(1/5/2021)*

Fixed gas detection suitable for all spaces and areas concerned are to be arranged.

3.2.15 *(1/5/2021)*

Fire detection, protection and extinction measures appropriate to the hazards concerned are to be provided.

3.2.16 *(1/5/2021)*

Commissioning, trials and maintenance of fuel systems and gas utilization machinery are to satisfy the goal in terms of safety, availability and reliability.

3.2.17 *(1/5/2021)*

The technical documentation is to permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.

3.2.18 *(1/5/2021)*

A single failure in a technical system or component is not to lead to an unsafe or unreliable situation.

4 General requirements

IGF CODE REFERENCE: Ch. 4, 4.1

4.1 Goal

4.1.1 *(1/5/2021)*

The goal of this paragraph is to ensure that the necessary assessments of the risks involved are carried out in order to eliminate or mitigate any adverse effect to the persons on board, the environment or the ship.

4.2 Risk assessment

IGF CODE REFERENCE: Ch. 4, 4.2

4.2.1 *(1/5/2021)*

A risk assessment is to be conducted to ensure that risks arising from the use of LPG or NH3 as fuel and potentially affecting persons on board, the environment, the structural strength or the integrity of the ship are addressed. Consideration are to be given to the hazards associated with physical layout, operation and maintenance, following any reasonably foreseeable failure.

4.2.2 *(1/5/2021)*

For ships to which this Appendix applies, the risk assessment required by [4.2.1] need to be conducted:

a) where explicitly required by:
   - IGF Code paragraphs 5.10.5, 5.12.3, 6.4.1.1, 6.4.15.4.7.2, 8.3.1.1, 13.4.1, 13.7 and 15.8.1.10, and
   - paragraphs 4.4 and 6.8 of Annex to IGF Code, and
   - paragraphs 5.2.1, 5.4.2, 5.10.5, 5.10.6, 5.12.2, 6.3.3, 6.4.2, 6.7.2, 8.3.1, 9.7.2, 13.7.1 and 15.8.2 of this Appendix, and

b) when other potential hazards connected with the use of LPG or NH3 as fuel are to be addressed.

4.2.3 *(1/5/2021)*

The risks are to be analysed using acceptable and recognized risk analysis techniques, and loss of function, component damage, fire, explosion and electric shock are as a minimum to be considered. The analysis is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as necessary. Details of risks, and the means by which they are mitigated, are to be documented to the satisfaction of the Society. Guidance on risk analysis techniques can be found in the "TASNEEF Guide on Risk Analysis".

4.2.4 *(1/5/2021)*

The assumptions for the risk assessment are to be agreed by a team of experts acceptable to the Society. It may include a representative of Class, owner, builder or designer, and consultants having the necessary knowledge and experience in safety, design and/or operation as necessary for the specific evaluation at hand. Other members may include marine surveyors, ship operators, safety engineers, equipment manufacturers, human factors experts, naval architects and marine engineers, according to the problem under scope.

4.3 Limitation of explosion consequences

IGF CODE REFERENCE: Ch. 4, 4.3

4.3.1 *(1/5/2021)*

The preferred safety policy is to be the elimination of either any source of release or any source of ignition, or both. Only in case this is demonstrated not to be feasible, the following applies.

An explosion in any space containing any potential sources of release (note 1) and potential ignition sources is not to:

a) cause damage to or disrupt the proper functioning of equipment/systems located in any space other than that in which the incident occurs;

b) damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur;

c) damage work areas or accommodation in such a way that persons who stay in such areas under normal operating conditions are injured;

d) disrupt the proper functioning of control stations and switchboard rooms necessary for power distribution;

e) damage life-saving equipment or associated launching arrangements;

f) disrupt the proper functioning of fire-fighting equipment located outside the explosion-damaged space;

g) affect other areas of the ship in such a way that chain reactions involving, inter alia, cargo, gas and bunker oil may arise; or

h) prevent persons access to life-saving appliances or impede escape routes.

Note 1: Double wall fuel pipes are not considered as potential sources of release.

The aforesaid points are to be demonstrated in a way acceptable to the Society.

5 Ship design and arrangement

IGF CODE REFERENCE: Ch. 5

5.1 Goal

IGF CODE REFERENCE: Ch. 5, 5.1

5.1.1 *(1/5/2021)*

The goal of this paragraph [5] is to provide for safe location, space arrangements and mechanical protection of power generation equipment, fuel storage systems, fuel supply equipment and refuelling systems.

5.2 Functional requirements

IGF CODE REFERENCE: Ch. 5, 5.2

5.2.1 *(1/5/2021)*

This paragraph [5] is related to functional requirements in IGF Code paragraphs 3.2.1 to 3.2.3, 3.2.5, 3.2.6, 3.2.8, 3.2.12 to 3.2.15 and 3.2.17. In particular the following apply:

a) the fuel tank(s) is (are) to be located on open deck; consideration may be given to accepting the tanks under deck upon satisfactory consideration in the context Risk Analysis.

Anyway, the tank(s) is (are) to *be located in such a way that the probability for the tank(s) to be damaged following a collision or grounding is reduced to a minimum taking into account the safe operation of the ship and other hazards that may be relevant to the ship;*

b) fuel containment systems, fuel piping and other fuel sources of release are to be so located and arranged that released gas is lead to a safe location in the open air;

c) the access or other openings to spaces containing fuel sources of release are to be so arranged that flammable, asphyxiating or toxic gas cannot escape to spaces that are not designed for the presence of such gases;

d) fuel piping is to be protected against mechanical damage;

e) the propulsion and fuel supply system are to be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power; and

f) the probability of a gas explosion in a machinery space with gas or low-flashpoint fuelled machinery is to be minimized.

5.3 Regulations - General

IGF CODE REFERENCE: Ch. 5, 5.3

5.3.1 *(1/5/2021)*

The requirements in IGF Code 5.3 apply.

5.4 Machinery space concepts

IGF CODE REFERENCE: Ch. 5, 5.4

5.4.1 *(1/5/2021)*

In a machinery space with LPG fuelled machinery, one of these two alternative concepts may be applied:

a) Gas safe machinery spaces: arrangements in machinery spaces are such that the spaces are considered gas safe under all conditions, normal as well as abnormal conditions, i.e. inherently gas safe.

In a gas safe machinery space a single failure cannot lead to release of fuel gas into the machinery space.

b) ESD-protected machinery spaces: arrangements in machinery spaces are such that the spaces are considered non-hazardous under normal conditions, but under certain abnormal conditions may have the potential to become hazardous. In the event of abnormal conditions involving gas hazards, emergency shutdown (ESD) of non-safe equipment (ignition sources) and machinery is to be automatically executed while equipment or machinery in use or active during these conditions is to be of a certified safe type.

In an ESD protected machinery space a single failure may result in a gas release into the space. Venting is designed to accommodate a probable maximum leakage scenario due to technical failures.

Failures leading to dangerous gas concentrations, e.g. gas pipe ruptures or blow out of gaskets are covered by explosion pressure relief devices and ESD arrangements.

5.4.2 *(1/5/2021)*

In a machinery space with NH3 fuelled machinery only gas safe machinery is allowed, such that the spaces are considered gas safe under all conditions, normal as well as abnormal conditions, i.e. inherently gas safe.

In a gas safe machinery space a single failure cannot lead to release of fuel gas into the machinery space.

Consideration may be given to accepting an ESD protected machinery space on small ships, upon satisfactory consideration in the context of the Risk analysis.

5.5 Regulations for gas safe machinery space

IGF CODE REFERENCE: Ch. 5, 5.5

5.5.1 *(1/5/2021)*

The requirements in IGF Code 5.5 apply.

5.6 Regulations for ESD-protected machinery spaces

IGF CODE REFERENCE: Ch. 5, 5.6

5.6.1 *(1/5/2021)*

The requirements in IGF Code 5.6 apply.

5.7 Regulations for location and protection of fuel piping

IGF CODE REFERENCE: Ch. 5, 5.7

5.7.1 *(1/5/2021)*

The requirements in IGF Code 5.7 apply.

5.8 Regulations for fuel preparation room design

IGF CODE REFERENCE: Ch. 5, 5.8

5.8.1 *(1/5/2021)*

The requirements in IGF Code 5.8 apply.

5.9 Regulations for bilge systems

IGF CODE REFERENCE: Ch. 5, 5.9

5.9.1 *(1/5/2021)*

The requirements in IGF Code 5.9 apply.

5.10 Regulations for drip trays

IGF CODE REFERENCE: Ch. 5, 5.10

5.10.1 *(1/5/2021)*

The requirements in IGF Code 5.10 apply.

5.10.2 *(1/5/2021)*

The risk assessment is to follow the steps outlined below.

a) The experts team is to conduct a Hazard Identification (HAZID) to agree on the scenarios to be subjected to the risk analysis, and on the assumptions regarding the most critical events (typically, connection failures causing an LPG or NH3 spill).

b) Reasonable assumptions on the extent of connection failures or other selected events and the process parameters of the LPG or NH3 are to be made by the team of experts, preferably on the basis of statistics available in the public domain or provided and documented by stakeholders.

c) Reasonable assumptions on the operation of ventilation system are to be made according to layout and procedures of the affected space.

d) In order to verify the drip tray capacity, a specific simulation is to be set up, aimed at evaluating the maximum amount of LPG or NH3 spilled into the drip tray, the evaporation rate, and the possibility to fully accommodate the LPG or NH3 in the drip tray. The dispersion of vapours resulting from LPG or NH3 evaporation in the affected space is also to be ascertained in respect of explosive and toxic atmosphere. For NH3 release the toxicity level (e.g. concentration in ppm) shall be evaluated together with possible risks connected to the presence of persons in the same space or area, taking into account that according to UE Directive 2019/1831 "Indicative occupational exposure limit value" the Short Term Exposure Limit (STEL -15 minutes) is 50 ppm and according to the USA National Institute for Occupational Safety and Health (NIOSH) the Immediately Dangerous to Life and Health (IDLH) is of 300 ppm.

e) The simulation is to be conducted by commercially available and validated tools (typically, by CFD tools). It is to focus on the calculation of the amount of LPG or NH3spilled before the stop of LPG or NH3 flow. Other calculation methods (e.g. empirical formulas based on literature) are subject to special consideration.

f) As a precaution, in order to maximize the accumulation of LPG or NH3 into the drip tray, LPG or NH3 release is to be directed downward, impinging on the drip tray, and ambient temperature is to be set to the minimum credible winter temperature. Equipment and space surfaces and drip tray are to be considered adiabatic, to conservatively minimize the heat exchange with the LPG or NH3 droplets, and to increase the amount of liquid accumulated in the drip tray.

g) Reasonable assumptions are to be made by the experts team regarding detection time, LPG or NH3 flow stop time and human reaction time, in case operators are credited in the emergency.

h) If the simulation demonstrates that the drip tray cannot accommodate the LPG or NH3 spill, mitigating measures are to be provided and subjected to the same simulation process, to appreciate the risk reduction.

5.11 Regulations for arrangement of entrances and other openings in enclosed spaces

IGF CODE REFERENCE: Ch. 5, 5.11

5.11.1 *(1/5/2021)*

The requirements in IGF Code 5.11 apply.

5.12 Regulations for airlocks

IGF CODE REFERENCE: Ch. 5, 5.12

5.12.1 *(1/5/2021)*

The requirements in IGF Code 5.12 apply.

5.12.2 *(1/5/2021)*

In the context of the risk analysis required in IGF Code 5.12.3, the team of experts is to conduct a Hazard Identification (HAZID) to agree on the airlocks to be subjected to the risk analysis, and on the assumptions regarding the most critical events.

In order to assess the structural integrity of the room and the suitability of the designed airlock, the maximum pressure within the spaces identified by the HAZID has to be evaluated, considering the effectiveness of the ventilation system. This calls for a simulation by means of the tools mentioned in [5.10.2]. The following steps, as a minimum, are to be performed.

a) Representative accidental scenarios of loss of LPG or NH3 from failures in process or containment systems are to be selected by the team of experts in the identified spaces. The simulation is to focus on the calculation of the amount of LPG or NH3 spilled before the stop of the LPG or NH3 flow

b) Reasonable assumptions on the extent of containment failure and the process parameters of the LPG or NH3 are to be made by the team of experts, preferably on the basis of statistics available in the public domain or provided and documented by stakeholders.

c) Reasonable assumptions on the operation of ventilation system are to be made according to layout and procedures of the selected spaces.

d) As a precaution, in order to maximize the accumulation of LPG or NH3 onto the space floor, LPG or NH3 release is to be directed downward, impinging on the floor, and ambient temperature is to be set to the maximum credible summer temperature in the space. The surfaces are to be considered isothermal at ambient temperature, to conservatively increase the evaporation rate and, consequently, the pressure buildup.

e) Reasonable assumptions are to be made by the team of experts regarding detection time, LPG or NH3 flow stop time and human reaction time, in case operators are credited in the emergency.

If the simulation demonstrates that the analysed airlocks cannot prevent gas release in safe space, mitigating measures are to be provided and subjected to the same simulation process, to appreciate the risk reduction.

6 Fuel containment system

IGF CODE REFERENCE: Ch. 6

6.1 Goal

6.1.1 *(15/2021)*

The goal of this paragraph [6] is to provide that gas storage is adequate so as to minimize the risk to personnel, the ship and the environment to a level that is equivalent to a conventional oil fuelled ship.

6.2 Functional requirements

6.2.1 *(1/5/2021)*

This paragraph [6] relates to functional requirements in IGF Code 3.2.1, 3.2.2, 3.2.5 and 3.2.8 to 3.2.17. In particular the following apply:

a) the fuel containment system is to be so designed that a leak from the tank or its connections does not endanger the ship, persons on board or the environment. Potential dangers to be avoided include:

1) exposure of ship materials to temperatures below acceptable limits;

2) flammable fuels spreading to locations with ignition sources;

3) toxicity potential and risk of oxygen deficiency due to fuels and inert gases;

4) restriction of access to assembly stations, escape routes and life-saving appliances (LSA); and

5) reduction in availability of LSA.

b) the pressure and temperature in the fuel tank are to be kept within the design limits of the containment system and possible carriage requirements of the fuel;

c) the fuel containment arrangement is to be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power; and

d) if portable tanks are used for fuel storage, the design of the fuel containment system is to be equivalent to permanent installed tanks as described in this paragraph.

6.3 Regulations - General

6.3.1 *(1/5/2021)*

The requirements in IGF Code 6.3 apply, with the following departures from IGF Code 6.3.1 and 6.3.4.

6.3.2 *(1/5/2021)*

LPG and NH3 in a liquid state may be stored with a maximum allowable relief valve setting (MARVS) of up to 2.0 MPa.

6.3.3 *(1/5/2021)*

All tank connections, fittings, flanges and tank valves are to be enclosed in a tank connection spaces which is gastight toward other enclosed spaces, including tank connections on open deck, unless, for LPG only, the risk assessment exclude the risk of gas accumulating on the deck or flowing into non-hazardous areas. The tank connection space is to be able to safely contain leakage from the tank connections.

6.4 Regulations for liquefied gas fuel containment

6.4.1 *(1/1/2025)*

The requirements in IGF Code 6.4 apply, taking into account the provisions in [6.4.4] to [6.4.11] of App 7.

6.4.2 Tank types *(1/5/2021)*

Normally LPG and NH3 should be stored in Type C tanks designed to withstand the full gauge vapour pressure of the fuel under conditions of the upper ambient design temperature, so that no system is required to be operated to maintain the fuel tanks' pressure and temperature within their design range.

Consideration may be given to accepting Type C tanks designed to withstand a pressure lower than the full gauge vapour pressure of the fuel under conditions of the upper ambient design temperature; for NH3 this will be limited to

cases where the storage conditions and tank properties ensure compliance with IGF Code 6.9.1.1 by pressure accumulation.

Other types of tanks will be considered on a case by case basis, for justified reasons and upon satisfactory consideration in the context of the Risk analysis.

6.4.3 Materials and construction *(1/5/2021)*

When applying IGF Code 6.4.13.1.1.1.5, loss of vacuum for vacuum insulated tanks shall also be considered.

6.5 Regulations for portable liquefied gas fuel tanks

6.5.1 *(1/5/2021)*

The requirements in IGF Code 6.5 apply, with the following departure.

6.5.2 *(1/5/2021)*

Portable fuel tanks for NH3 are to be located in dedicated areas on open deck.

6.6 Regulations for CNG fuel containment

6.6.1 *(1/5/2021)*

The requirements in IGF Code 6.6 apply to containment system for LPG and NH3 when the design pressure is 0,07 MPa or above.

6.7 Regulations for pressure relief system

6.7.1 General *(1/5/2021)*

The requirements in IGF Code 6.7.1 and 6.7.3 apply. IGF Code 6.7.2 is replaced by the following.

6.7.2 Pressure relief systems for liquefied gas fuel tanks *(1/5/2021)*

a) If fuel release into the vacuum space of a vacuum insulated tank cannot be excluded, the vacuum space is to be protected by a pressure relief device which is to be connected to a vent system.

b) Liquefied gas fuel tanks are to be fitted with a minimum of 2 pressure relief valves (PRVs) allowing for disconnection of one PRV in case of malfunction or leakage.

c) Interbarrier spaces are to be provided with pressure relief devices. For membrane systems, the designer is to demonstrate adequate sizing of interbarrier space PRVs.

d) The setting of the PRVs is not to be higher than the vapour pressure that has been used in the design of the tank. Valves comprising not more than 50% of the total relieving capacity may be set at a pressure up to 5% above MARVS to allow sequential lifting, minimizing unnecessary release of vapour.

e) The following temperature regulations apply to PRVs fitted to pressure relief systems:

1) PRVs on fuel tanks with a design temperature below 0oC are to be designed and arranged to prevent their becoming inoperative due to ice formation;

2) the effects of ice formation due to ambient temperatures are to be considered in the construction and arrangement of PRVs;

3) PRVs are to be constructed of materials with a melting point above 925°C. Lower melting point materials for internal parts and seals may be accepted provided that fail-safe operation of the PRV is not compromised; and

4) sensing and exhaust lines on pilot operated relief valves are to be of suitably robust construction to prevent damage.

f) In the event of a failure of a fuel tank PRV a safe means of emergency isolation is to be available.

1) procedures are to be provided and included in the operation manual;

2) the procedures are to allow only one of the installed PRVs for the liquefied gas fuel tanks to be isolated, physical interlocks are to be included to this effect; and

3) isolation of the PRV is to be carried out under the supervision of the master. This action is to be recorded in the ship's log, and at the PRV.

g) Each pressure relief valve installed on a liquefied NH3 or LPG gas fuel tank is to be connected to a collecting system venting system whose discharge position will be considered on a case-by-case, subject to:

- the submission of an appropriate risk assessment. Such a risk assessment is to be based on a ship specific gas dispersion analysis;

- the discharge will be unimpeded and directed toward areas where the discharge does not cause risks to be determined according to d), also taking into account the density of discharged gases;
- minimizing the possibility of water or snow entering the vent system;

h) The outlet from the pressure relief valves is normally to be located at a suitable distance from the nearest:

- air intake, air outlet or opening to accommodation, service and control spaces, or other non-hazardous area; and
- exhaust outlet from machinery installations.

i) All other fuel gas vent outlets are also to be arranged in accordance with g) and h). Means are to be provided to prevent liquid overflow from gas vent outlets, due to hydrostatic pressure from spaces to which they are connected.

j) The distances needed to fulfil the requirements in g) and h) are to be determined by the Risk assessment required in [4.2], considering the physical properties of the released gas and relevant dispersion.

k) *In the vent piping system, means for draining liquid,* including condensed LPG or NH3*, from places where it may accumulate are to be provided. The PRVs and piping are to be arranged so that liquid can, under no circumstances, accumulate in or near the PRVs;* to this purpose the discharge line from the PRV is to be equipped with a drainage system leading to a suitable tank.

l) Suitable protection screens of not more than 13 mm square mesh are to be fitted on vent outlets to prevent the ingress of foreign objects without adversely affecting the flow.

m) All vent piping is to be designed and arranged not to be damaged by the temperature variations to which it may be exposed, forces due to flow or the ship's motions.

n) PRVs are to be connected to the highest part of the fuel tank. PRVs are to be positioned on the fuel tank so that they will remain in the vapour phase at the filling limit (FL) as given in [6.8], under conditions of 15° list and 0.015L trim, where L is defined in IGF Code 2.2.25.

6.8 Regulations on loading limit for liquefied gas fuel tanks

6.8.1 *(1/5/2021)*

The requirements in IGF Code 6.8 apply.

6.9 Regulations for the maintaining of fuel storage condition

6.9.1 *(1/5/2021)*

The requirements in IGF Code 6.9 apply, with the following departures to IGF Code 6.9.1.

6.9.2 Control of tank pressure and temperature *(1/5/2021)*

a) With the exception of liquefied gas fuel tanks designed to withstand the full gauge vapour pressure of the fuel under conditions of the upper ambient design temperature, liquefied gas fuel tanks' pressure and temperature are to be maintained at all times within their design range by means acceptable to the Society, e.g. by one of the following methods:

1) reliquefaction of vapours;

2) thermal oxidation of vapours;

3) pressure accumulation in a separate tank; or

4) liquefied gas fuel cooling.

The method chosen is to be capable of maintaining tank pressure below the set pressure of the tank pressure relief valves for a period of 15 days assuming full tank at normal service pressure, a tank valve closed by the safety system and the ship in idle condition, i.e. only power for domestic load is generated.

b) Venting of fuel vapour for control of the tank pressure is not acceptable except in emergency situations.

The activation of the safety system alone is not deemed as an emergency situation.

6.10 Regulations on atmospheric control within the fuel containment system

6.10.1 *(1/5/2021)*

The requirements in IGF Code 6.10 apply.

6.11 Regulations on atmosphere control within fuel storage hold spaces (Fuel containment systems other than type C independent tanks)

6.11.1 *(1/5/2021)*
The requirements in IGF Code 6.11 apply.

6.12 Regulations on environmental control of spaces surrounding type C independent tanks

6.12.1 *(1/5/2021)*
The requirements in IGF Code 6.12 apply.

6.13 Regulations on inerting

6.13.1 *(1/5/2021)*
The requirements in IGF Code 6.13 apply.

6.13.2 *(1/5/2021)*
The spaces where the inert gas double block and bleed valves and closable non-return valve are fitted are to be classified as a Zone 1 hazardous spaces.

6.14 Regulations on inert gas production and storage on board

6.14.1 *(1/5/2021)*
The requirements in IGF Code 6.14 apply.

7 Material and general pipe design

IGF CODE REFERENCE: Ch. 7

7.1 Goal

7.1.1 *(1/5/2021)*
The goal of this paragraph [7] is to ensure the safe handling of fuel, under all operating conditions, to minimize the risk to the ship, personnel and to the environment, having regard to the nature of the products involved.

7.2 Functional requirements

7.2.1 *(1/5/2021)*
This paragraph [7] relates to functional requirements in IGF Code 3.2.1, 3.2.5, 3.2.6, 3.2.8, 3.2.9 and 3.2.10. In particular the following apply:

a) Fuel piping is to be capable of absorbing thermal expansion or contraction caused by extreme temperatures of the fuel without developing substantial stresses.

b) Provision is to be made to protect the piping, piping system and components and fuel tanks from excessive stresses due to thermal movement and from movements of the fuel tank and hull structure.

c) If the fuel gas contains heavier constituents that may condense in the system, means for safely removing the liquid are to be fitted.

d) Low temperature piping is to be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material.

7.3 Regulations for general pipe design

7.3.1 General *(1/5/2021)*
The requirements in IGF Code 7.3 apply.

7.4 Regulations for materials

7.4.1 **Metallic materials** *(1/5/2021)*
The requirements in IGF Code 7.4 apply.

8 Bunkering

IGF CODE REFERENCE: Ch. 8

8.1 Goal

8.1.1 *(1/5/2021)*

The goal of this paragraph [8] is to provide for suitable systems on board the ship to ensure that bunkering can be conducted without causing danger to persons, the environment or the ship.

8.2 Functional requirements

8.2.1 *(1/5/2021)*

This paragraph [8] relates to functional requirements in IGF Code 3.2.1 to 3.2.11 and 3.2.13 to 3.2.17. In particular the following apply.

The piping system for transfer of fuel to the storage tank is to be designed such that any leakage from the piping system cannot cause danger to personnel, the environment or the ship.

8.3 Regulations for bunkering station

8.3.1 General *(1/5/2021)*

The requirements in IGF Code 8.3 apply, with the following additions:

a) The bunkering station is to be under direct view from a bunkering control station, if any, or from the bridge; as an alternative a CCTV system may be considered.

   For bunkering of LPG or NH3, a risk assessment is to be carried out, following the steps outlined below.

   1) The team of experts is to conduct a Hazard Identification (HAZID) to agree on the scenarios to be subjected to the risk analysis, and on the assumptions regarding the most critical events (typically, connection failures causing an LPG or NH3 spill). The effects in the bunker station and above and below it are to be simulated by means of the tools mentioned in [5.10.2].

   2) As a minimum, a scenario to be assumed is the failure of the presentation flange on the liquid bunkering line. The simulation is to focus on the calculation of the amount of LPG or NH3 spilled before the intervention of ESD and the stop of the bunkering pumps. After the stop of the pumps, the amount of the discharge of the residual inventory of the hose or loading arm is to be calculated according to the bunkering configuration, to estimate whether it is significant; in this case, it is to be taken into account in the simulation.

   3) Reasonable assumptions on the extent of connection failures or other selected events and the parameters of the LPG or NH3 process are to be made by the team of experts, preferably on the basis of statistics available in the public domain or provided and documented by stakeholders or using industry safety standards.

   4) Reasonable assumptions on the operation of ventilation system are to be made according to layout and procedures of the bunker station.

   5) In order to verify the drip tray capacity, a specific simulation is to be set up, aimed at evaluating the maximum amount of LPG or NH3 spilled onto the drip tray, the evaporation rate, and the possibility to fully accommodate the LPG or NH3 in the drip tray avoiding any overboard disposal.

   6) In particular, the dispersion of methane resulting from LPG or NH3 evaporation in the bunker station and from the bunker station to the upper decks, if realistically possible, is to be simulated.

   7) As a precaution, in order to maximize the accumulation of LPG or NH3 onto the drip tray, LPG or NH3 release is to be directed downward, impinging on the drip tray, and ambient temperature is to be set to the minimum credible winter temperature. Equipment, bunker station floor and surfaces and drip tray are to be considered adiabatic, to conservatively increase the amount of liquid accumulated in the drip tray.

   8) Reasonable assumptions are to be made by the team of experts regarding detection time, LPG or NH3 flow stop time and human reaction time, in case operators are credited in the emergency. If the simulation demonstrates that the drip tray cannot accommodate the LPG or NH3 spill, or the dispersion of evaporated gas reaches areas not suitable to an explosive gas or toxic gas atmosphere, mitigating measures are to be provided and subjected to the same simulation process, to appreciate the risk reduction.

b) Low temperature steel shielding is to be considered if the escape of cold jets impinging on surrounding hull structure is possible.

8.4 Regulations for manifold

8.4.1 *(1/5/2021)*
The requirements in IGF Code 8.4 apply.

8.5 Regulations for bunkering system

8.5.1 *(1/5/2021)*
An arrangement for purging fuel bunkering lines with inert gas is to be provided.

8.5.2 *(1/5/2021)*
The bunkering system is to be so arranged that the gas discharged to the atmosphere during filling of storage tanks is minimized.

8.5.3 *(1/5/2021)*
A manually operated stop valve and a remote operated shutdown valve in series, or a combined manually operated and remote valve is to be fitted in every bunkering line close to the connecting point. It is to be possible to operate the remote valve in the control location for bunkering operations and/or from another safe location.

8.5.4 *(1/5/2021)*
Means are to be provided for draining any fuel from the bunkering pipes upon completion of operation, unless these are arranged for a permanent containment of LPG or NH3.

8.5.5 *(1/5/2021)*
Bunkering lines are to be arranged for inerting and gas freeing. When not engaged in bunkering, the bunkering pipes are to be free of gas, unless these are arranged for a permanent containment of LPG or NH3 and the consequences of not gas freeing are evaluated and approved.

8.5.6 *(1/5/2021)*
In case bunkering lines are arranged with a cross-over it is to be ensured by suitable isolation arrangements that no fuel is transferred inadvertently to the ship side not in use for bunkering, unless the lines are arranged for a permanent containment of LPG or NH3.

8.5.7 *(1/5/2021)*
A ship-shore link (SSL) or an equivalent means for automatic and manual ESD communication to the bunkering source is to be fitted.

8.5.8 *(1/7/2021)*
If not demonstrated to be required at a higher value due to pressure surge considerations a default time as calculated in accordance with IGF Code 16.7.3.7 from the trigger of the alarm to full closure of the remote operated valve required by [8.5.3] is to be adjusted.

8.5.9 *(1/5/2021)*
Means are to be provided to manage the vapours generated during the bunkering, either by vapour return to the bunkering manifold or by one of the systems required in [6.9.2].

9 Fuel supply to consumers

IGF CODE REFERENCE: Ch. 9

9.1 Goal

9.1.1 *(1/7/2021)*
The goal of this paragraph [9] is to ensure safe and reliable distribution of fuel to the consumers.

9.2 Functional requirements

9.2.1 *(1/7/2021)*
This paragraph [9] is related to functional requirements in IGF Code 3.2.1 to 3.2.6, 3.2.8 to 3.2.11 and 3.2.13 to 3.2.17. In particular the following apply:

a) the fuel supply system is to be so arranged that the consequences of any release of fuel will be minimized, while providing safe access for operation and inspection;

b) the piping system for fuel transfer to the consumers is to be designed in a way that a failure of one barrier cannot lead to a leak from the piping system into the surrounding area causing danger to the persons on board, the environment or the ship; and

c) fuel lines outside the machinery spaces are to be installed and protected so as to minimize the risk of injury to personnel and damage to the ship in case of leakage.

d) the fuel supply system is to be so arranged that when the fuel is intended to be supplied in a specific status (liquid/gaseous), arrangement are in place to prevent its change of status, e.g. by providing heat tracing to gaseous fuel lines.

9.3 Regulations on redundancy of fuel supply

9.3.1 *(1/7/2021)*

The requirements in IGF Code 9.3 apply.

9.4 Regulations on safety functions of gas supply system

9.4.1 *(1/7/2021)*

The requirements in IGF Code 9.4 apply with the following departures from IGF Code 9.4.7.

9.4.2 *(1/7/2021)*

In cases where the master gas fuel valve is automatically shut down, the complete gas supply branch downstream of the double block and bleed valve is to be automatically vented; the requirements in [6.7.2] i) apply.

9.5 Regulations for fuel distribution outside of machinery space

9.5.1 *(1/5/2021)*

Fuel pipes are to be protected by a secondary enclosure.

This enclosure can be a ventilated duct or a double wall piping system. The duct or double wall piping system is to be mechanically under pressure ventilated with 30 air changes per hour, and gas detection as required in IGF Code 15.8 is to be provided. Other solutions providing an equivalent safety level may also be accepted by the Society.

9.5.2 *(1/5/2021)*

The requirement in [9.5.1] need not be applied for fully welded open ended fuel gas vent pipes led through mechanically ventilated spaces nor for fully welded fuel gas pipes on the open deck.

9.6 Regulations for fuel supply to consumers in gas-safe machinery spaces

9.6.1 *(1/5/2021)*

The requirements in IGF Code 9.6 apply.

9.7 Regulations for gas fuel supply to consumers in ESD-protected machinery spaces

9.7.1 *(1/5/2021)*

The requirements in IGF Code 9.7 apply.

9.7.2 *(1/5/2021)*

Pressures higher than 1.0 MPa will be considered on a case by case basis, for justified reasons and upon satisfactory consideration in the context of the Risk analysis.

9.8 Regulations for the design of ventilated duct, outer pipe against inner pipe gas leakage

9.8.1 *(1/5/2021)*

The design pressure of the outer pipe or duct of fuel systems is not to be less than the maximum working pressure of the inner pipe.

Alternatively for fuel piping systems with a working pressure greater than 1.0 MPa, the design pressure of the outer pipe or duct is not to be less than the maximum built-up pressure arising in the annular space considering the higher between:

- maximum built-up pressure as the static pressure in way of the rupture resulting from the gas flowing in the annular space.
- the local instantaneous peak pressure in way of any rupture considering the ventilation arrangements.

The tangential membrane stress of a straight pipe is not to exceed the tensile strength divided by 1,5 (Rm/1,5) when subjected to the above pressures. The pressure ratings of all other piping components are to reflect the same level of strength as straight pipes.

9.8.2 *(1/5/2021)*

Verification of the strength is to be based on calculations demonstrating the duct or pipe integrity. As an alternative to calculations, the strength can be verified by representative tests.

9.8.3 *(1/5/2021)*

The duct is to be pressure tested to show that it can withstand the expected maximum pressure at fuel pipe rupture.

9.9 Regulations for compressors and pumps

9.9.1 *(1/5/2021)*

The requirements in IGF Code 9.9 apply.

10 Power generation including propulsion and other gas consumers

IGF CODE REFERENCE: Ch. 10

10.1 Goal

10.1.1 *(1/5/2021)*

The goal of this paragraph [10] is to provide safe and reliable delivery of mechanical, electrical or thermal energy.

10.2 Functional requirements

10.2.1 *(1/5/2021)*

This paragraph [10] is related to functional requirements in IGF Code 3.2.1, 3.2.11, 3.2.13, 3.2.16 and 3.2.17. In particular the following apply:

a) the exhaust systems are to be configured to prevent any accumulation of unburnt gaseous fuel;

b) unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, engine components or systems containing or likely to contain an ignitable gas and air mixture are to be fitted with suitable pressure relief systems. Dependent on the particular engine design this may include the air inlet manifolds and scavenge spaces;

c) the explosion venting is to be led away from where personnel may normally be present; and

d) all gas consumers are to have a separate exhaust system.

10.3 Regulations for internal combustion engines of piston type

10.3.1 General *(1/5/2021)*

The requirements in IGF Code 10.3 apply with the following additions to IGF Code 10.3.1.2 and 10.3.1.4:

a) for NH3 fuelled engines where the space below the piston is in direct communication with the crankcase, a crankcase ventilation is required that goes to the vent system. In the vent line a NH3 gas detection should be installed for monitoring/alarm function;

b) *the gas extracted from auxiliary systems media is to be vented to a safe location in the atmosphere.* In the vent line a gas detection should be installed for monitoring/alarm function.

10.4 Regulations for main and auxiliary boilers

10.4.1 *(1/5/2021)*

The requirements in IGF Code 10.4 apply.

10.5 Regulations for gas turbines

10.5.1 *(1/5/2021)*

The requirements in IGF Code 10.5 apply.

11 Fire safety

11.1 Application

11.1.1 *(1/5/2021)*

This paragraph is void, as the provisions of IGF Code Ch 11 are not within the scope of classification.

12 Explosion prevention

IGF CODE REFERENCE: Ch. 12

12.1 Goal

12.1.1 *(1/5/2021)*

The goal of this paragraph [12] is to provide for the prevention of explosions and for the limitation of effects from explosion.

12.2 Functional requirements

12.2.1 *(1/5/2021)*

This paragraph [12] is related to functional requirements in IGF Code 3.2.2 to 3.2.5, 3.2.7, 3.2.8, 3.2.12 to 3.2.14 and 3.2.17. In particular the following apply.

The probability of explosions is to be reduced to a minimum by:

a) reducing number of sources of ignition; and

b) reducing the probability of formation of ignitable mixtures.

12.3 Regulations - General

12.3.1 *(1/5/2021)*

The requirements in IGF Code 12.3 apply.

12.4 Regulations on area classification

12.4.1 *(1/5/2021)*

The requirements in IGF Code 12.4 apply.

12.5 Hazardous area zones

12.5.1 *(1/5/2021)*

The requirements in IGF Code 12.5 apply.

12.5.2 Hazardous area zone 1 *(1/5/2021)*

a) Fuel storage hold spaces containing Type C tanks with all potential leakage sources in a tank connection space and having no access to any hazardous area, are to be considered as non-hazardous.

b) Where the fuel storage hold spaces include potential leak sources, e.g. tank connections, they are to be considered hazardous area zone 1.

c) Where the fuel storage hold spaces included bolted access to the tank connection space, they are to be considered hazardous are zone 2.

13 Ventilation

IGF CODE REFERENCE: Ch. 13

13.1 Goal

13.1.1 *(1/5/2021)*

The goal of this paragraph [13] is to provide for the ventilation required for safe operation of gas-fuelled machinery and equipment.

13.2 Functional requirements

13.2.1 *(1/5/2021)*
This paragraph [13] is related to functional requirements in IGF Code 3.2.2, 3.2.5, 3.2.8, 3.2.10, 3.2.12 to 3.2.14 and 3.2.17.

13.3 Regulations - General

13.3.1 *(1/5/2021)*
The requirements in IGF Code 13.3 apply.

13.3.2 *(1/5/2021)*
Areas where fuel covered by this Appendix can be present are to be provided with suction points of the mechanical exhaust system fitted in the lower part of the space, where LPG or NH3 is likely to accumulate.

13.4 Regulations for tank connection space

13.4.1 *(1/5/2021)*
The requirements in IGF Code 13.4 apply.

13.5 Regulations for machinery spaces

13.5.1 *(1/5/2021)*
The requirements in IGF Code 13.5 apply.

13.6 Regulations for fuel preparation room

13.6.1 *(1/5/2021)*
The requirements in IGF Code 13.6 apply.

13.7 Regulations for bunkering station

13.7.1 *(1/5/2021)*
Bunkering station are to be suitably ventilated to ensure that any vapour being released during bunkering operations will be removed. *If the natural ventilation is not sufficient, mechanical ventilation is to be provided in accordance with the risk assessment required by IGF Code 8.3.1.1.*

13.8 Regulations for ducts and double pipes

13.8.1 *(1/5/2021)*
The requirements in IGF Code 13.8 apply with the following departures from IGF Code 13.8.2 and 13.8.3.

13.8.2 *(1/5/2021)*
The ventilation system for double piping and for gas valve unit spaces in gas safe engine-rooms is to be independent of all other ventilation systems except other fuel supply ventilation systems.

13.8.3 *(1/5/2021)*
The ventilation inlet for the double wall piping or duct is always to be located in a non-hazardous area in open air away from ignition sources. The inlet opening is to be fitted with a suitable wire mesh guard and protected from ingress of water.

14 Electrical installations

IGF CODE REFERENCE: Ch. 14

14.1 Goal

14.1.1 *(1/5/2021)*
The goal of this paragraph [14] is to provide for electrical installations that minimize the risk of ignition in the presence of a flammable atmosphere.

14.2 Functional requirements

14.2.1 *(1/5/2021)*

This paragraph [14] is related to functional requirements in IGF Code 3.2.1, 3.2.2, 3.2.4, 3.2.7, 3.2.8, 3.2.11, 3.2.13 and 3.2.16 to 3.2.18. In particular the following apply.

Electrical generation and distribution systems, and associated control systems, are to be designed such that a single fault will not result in the loss of ability to maintain fuel tank pressures and hull structure temperature within normal operating limits.

14.3 Regulations - General

14.3.1 *(1/5/2021)*

The requirements in IGF Code 14.3 apply.

15 Control monitoring and safety systems

IGF CODE REFERENCE: Ch. 15

15.1 Goal

15.1.1 *(1/5/2021)*

The goal of this paragraph [15] is to provide for the arrangement of control, monitoring and safety systems that support an efficient and safe operation of the gas-fuelled installation as covered in the other paragraphs of this Appendix.

15.2 Functional requirements

15.2.1 *(1/5/2021)*

This paragraph [15] is related to functional requirements in IGF Code 3.2.1, 3.2.2, 3.2.11, 3.2.13 to 3.2.15, 3.2.17 and 3.2.18. In particular the following apply:

a) the control, monitoring and safety systems of the gas-fuelled installation are to be so arranged that the remaining power for propulsion and power generation is in accordance with IGF Code 9.3.1 in the event of single failure;

b) a gas safety system is to be arranged to close down the gas supply system automatically, upon failure in systems as described in IGF Code Table 1 complemented by Table 2 for NH3 fuelled ships *and upon other fault conditions which may develop too fast for manual intervention;*

c) for ESD protected machinery configurations the safety system is to shut down gas supply upon gas leakage and in addition disconnect all non-certified safe type electrical equipment in the machinery space;

d) the safety functions are to be arranged in a dedicated gas safety system that is independent of the gas control system in order to avoid possible common cause failures. This includes power supplies and input and output signal;

e) the safety systems including the field instrumentation are to be arranged to avoid spurious shutdown, e.g. as a result of a faulty gas detector or a wire break in a sensor loop; and

f) where two or more gas supply systems are required to meet the regulations, each system is to be fitted with its own set of independent gas control and gas safety systems.

15.3 Regulations - General

15.3.1 *(1/5/2021)*

The requirements in IGF Code 15.3 apply.

15.4 Regulations for bunkering and liquefied gas fuel tank monitoring

15.4.1 *(1/5/2021)*

The requirements in IGF Code 15.4 apply.

15.5 Regulations for bunkering control

15.5.1 *(1/5/2021)*

The requirements in IGF Code 15.5 apply.

15.6 Regulations for gas compressor moni- toring

15.6.1 *(1/5/2021)*

The requirements in IGF Code 15.6 apply.

15.7 Regulations for gas engine monitoring

15.7.1 *(1/5/2021)*

The requirements in IGF Code 15.7 apply.

15.8 Regulations for gas detection

15.8.1 *(1/5/2021)*

The requirements in IGF Code 15.8 apply, with the following departures.

15.8.2 *(1/5/2021)*

Permanently installed gas detectors are also to be fitted:

a) at ventilation inlets to service spaces, ro-ro spaces, special category spaces and other machinery spaces if required based on the risk assessment required in [4.2];

b) in bunker stations.

15.8.3 *(1/5/2021)*

Gas detection equipment is to be designed, installed and tested in accordance with IEC 60079-29-1 or an equivalent recognized standard acceptable to the Society.

15.8.4 *(1/5/2021)*

On NH3 fuelled ships, audible and visible alarm is to be activated at a gas vapour concentration of 20% of the permissible exposure limit (PEL). The safety system is to be activated at 40% of the immediately dangerous to life of health limit (IDLH).

15.8.5 *(1/5/2021)*

Audible and visible alarms from the gas detection equipment are to be located on the navigation bridge or in the continuously manned central control station or safety centre.

15.9 Regulations for fire detection

15.9.1 *(1/5/2021)*

The requirements in IGF Code 15.9 apply.

15.10 Regulations for ventilation

15.10.1 *(1/5/2021)*

The requirements in IGF Code 15.10 apply.

15.11 Regulations on safety functions of fuel supply systems

15.11.1 *(1/5/2021)*

The requirements in IGF Code 15.11 apply.

Table 2 : Monitoring of NH3 supply system to engines *(1/5/2021)*

No	Parameter	Alarm	Automatic shutdown of tank valve (4)	Automatic shutdown of gas supply to machinery space containing NH3-fuelled engines	Comments
1	Gas detection in tank connection space at 20% PEL	x			
2	Gas detection on two detectors **(1)** in tank connection space at 40% IDLH	x	x		
3	Gas detection in duct between tank and machinery space containing NH3-fuelled engines at 20% PEL	x			
4	Gas detection on two detectors **(1)** in duct between tank and machinery space containing NH3-fuelled engines at 40% IDLH	x	x **(2)**		
5	Gas detection in fuel preparation room at 20% PEL	x			
6	Gas detection on two detectors **(1)** in fuel preparation room at 40% IDLH	x	x **(2)**		
7	Gas detection in duct inside machinery space containing NH3-fuelled engines at 20% PEL	x			If double pipe fitted in machinery space containing NH3-fuelled engines
8	Gas detection on two detectors **(1)** in duct inside machinery space containing NH3-fuelled engines at 40% IDLH	x		x **(3)**	If double pipe fitted in machinery space containing NH3-fuelled engines
9	Gas detection in ESD protected machinery space containing NH3-fuelled engines at 20% PEL	x			
10	Gas detection on two detectors **(1)** in ESD protected machinery space containing NH3-fuelled engines at 40% IDLH	x		x	
11	Gas detection in the vent line from crankcase of NH3-fuelled engines per [10.3.1]a) at 40% IDLH	x			
12	Gas detection in auxiliary system media vent line of NH3-fuelled engines at 40% IDLH	x			

(1) Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of self-monitoring type the installation of a single gas detector can be permitted

(2) If the tank is supplying gas to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

(3) If the gas is supplied to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing gas-fuelled engines, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

(4) Valves referred to in IGF Code 9.4.1.

16 Manufacture workmanship and testing

IGF CODE REFERENCE: Ch. 16

16.1 General

16.1.1 *(1/5/2021)*

The manufacture, testing, inspection and documentation are to be in accordance with recognized standards and the regulations given in this Appendix.

16.1.2 *(1/5/2021)*

Where post-weld heat treatment is specified or required, the properties of the base material are to be determined in the heat treated condition, in accordance with the applicable Tables of IGF Code Ch 7 and the weld properties are to be determined in the heat treated condition in accordance with IGF Code 16.3. In cases where a post-weld heat treatment is applied, the test regulations may be modified at the discretion of the Society.

16.2 General test regulations and specifications

16.2.1 **Tensile test** *(1/5/2021)*

The requirements in IGF Code 16.2 apply.

16.3 Welding of metallic materials and non-destructive testing for the fuel containment system

16.3.1 General *(1/5/2021)*

The requirements in IGF Code 16.3 apply.

16.4 Other regulations for construction in metallic materials

16.4.1 General *(1/5/2021)*

The requirements in IGF Code 16.4 apply.

16.5 Testing

16.5.1 General *(1/5/2021)*

The requirements in IGF Code 16.5 apply.

16.5.2 Testing and inspections during construction *(1/5/2021)*

a) Process pressure vessels containing NH3 and LPG are categorized as class 1 for the application of the requirements in Sec 3, irrespective of their design pressure and design temperature.

b) The fuel containment system for low temperature LPG or NH3 is to be inspected for cold spots during or immediately following the first LPG or NH3 bunkering, when steady thermal conditions are reached. Inspection of the integrity of thermal insulation surfaces that cannot be visually checked is to be carried out in accordance with the requirements of the Society.

16.6 Welding, post-weld heat treatment and non-destructive testing

16.6.1 General *(1/5/2021)*

The requirements in IGF Code 16.6 apply.

16.7 Testing regulations

16.7.1 *(1/5/2021)*

The requirements in IGF Code 16.7 apply.

APPENDIX 14 HYDROGEN FUELLED SHIPS

1 General

1.1 Scope

1.1.1 Application *(1/10/2021)*

The provisions of this Appendix apply to the arrangement, installation, control and monitoring of machinery, equipment and systems of ships using hydrogen as fuel (hereinafter named "hydrogen fuelled ships").

1.1.2 Acceptance by the flag Administration *(1/10/2021)*

The use of hydrogen as fuel in ships requires acceptance by the Administration of the State whose flag the ship is entitled to fly on the basis of the alternative design approach as required in IGF Code 2.3.

1.1.3 IGF Code requirements and the Society's rules *(1/10/2021)*

For hydrogen fuelled ships, the requirements of the latest version of the International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels, as amended (hereinafter named "IGF Code") are to be applied as class requirements as specified and with the deviations given in this Appendix. For the scope of classification, when reference is made to paragraphs of the IGF Code where the wording:

a) “LNG" and "gas" are used, they are to be regarded as referring to hydrogen; and

b) "Administration" is used, it is to be regarded as referring to the "Society".

In general, this Appendix applies to machinery, equipment and systems of ships using hydrogen as fuel and to their interfaces with the other ship systems. Unless otherwise specified, the machinery, equipment and systems of ships using hydrogen as fuel are also to com ply with the requirements given in Part C.

1.1.4 IGF Code requirements not within the scope of classification *(1/10/2021)*

The following requirements of the IGF Code are not within the scope of classification:

- Chapter 11 - Fire Safety
- Chapter 17 - Drills and emergency exercises
- Chapter 18 - Operation
- Chapter 19 - Training

These requirements are applied by the Society when acting on behalf of the flag Administration, within the scope of delegation (see [1.1.6]).

1.1.5 Correspondence of the IGF Code with the Rules *(1/10/2021)*

All the requirements of this Appendix are cross referenced to the applicable Chapters, Sections or paragraphs of the IGF Code, as appropriate.

1.1.6 Certificate of Fitness *(1/10/2021)*

The responsibility for interpretation of the IGF Code requirements for the purpose of issuing an International Certificate of Fitness for the Gas-fuelled Ships lies with the Administration of the State whose flag the ship is entitled to fly.

Whenever the Society is authorised by an Administration to issue on its behalf the "Certificate of Fitness for the Gas-Fuelled ships", or where the Society is authorised to carry out investigations and surveys on behalf of an Administration on the basis of which the "Certificate of Fitness for the Gas-Fuelled ships" will be issued by the Administration, or where the Society is requested to certify compliance with the IGF Code, the full compliance with the requirements of the IGF Code, including the operative requirements mentioned in [1.1.4], will be granted by the Society, subject to [1.1.2].

1.2 Documentation to be submitted

1.2.1 *(1/10/2021)*

Tab 1 lists the plans, information, analysis, etc. which are to be submitted in addition to the information required in the other Parts of the Rules, for the portion of the ship not involved in the hydrogen handling.

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.

Table 1 : Documents to be submitted *(1/10/2021)*

No.	A/I **(1)**	Document
1	I	Propulsion system general arrangement - Design philosophy including information on the machinery configuration, engine room arrangements, fuel arrangements, shutdown philosophy (if applicable), redundancy considerations etc. are to be submitted before other documentation
2	I	Fuel system Risk assessment
3	A	Fuel system arrangement plan - including: • gas tanks and gas containment systems with indication of distances required in [5.4] and calculations per [5.4.1], if applicable • tank connection spaces • fuel storage hold spaces • fuel preparation rooms • bunkering stations and other shore connections • machinery and boiler spaces, service and control station spaces • doors and openings to fuel preparation rooms and other hazardous areas
4	I	Fuel gas system operational manual including procedures for: • bunkering, including filling limits curve • gas freeing and inerting • normal operation • emergency operation
5	A	Fuel gas tanks including drawings of: • tanks • supports and stays • secondary barriers • insulation • marking plates • tank hatches, pipes and any other openings to gas tanks Fuel gas tank design analysis: • specification of design loads and structural analysis of gas tanks • complete stress analysis for independent tanks type B and type C. Fuel gas tanks production process including: • fuel gas tank non-destructive testing (NDT) plan including: • information about strength and tightness testing • specification of stress relieving procedures for independent tanks type C (thermal or mechanical). • fuel gas tank welding procedures • fuel gas tank material specifications including connected pipes
6	A	Fuel gas tank safety relief valves and associated vent piping specification, piping capacity analysis including back pressure
7	A	Fuel gas tank gas freeing and purging system piping diagram
8	A	Fuel gas tank control and monitoring system
9	A	Fuel gas piping system: Pipe routing sketch Piping diagram (including bunkering lines and vent lines for safety relief valves or similar piping, vent mast, and secondary enclosure for gas pipes)
10	I	Fuel gas piping system - Specification of valves, flanges and fittings including offsets, loops, bends, expansion elements such as bellows and slip joints. For valves intended for service with a design temperature below -55°C, documentation of leak test and functional test at design temperature (type test) is to be included
11	A	Fuel gas system drip trays - System arrangement plan - Hull protection beneath liquid piping where leakages may be anticipated, such as at shore connections and at pump seals. Including specification

(1) A = to be submitted for approval, in four copies
I = to be submitted for information, in duplicate.

No.	A/I (1)	Document
12	I	Electrical bonding of piping - Specification
13	A	Cooling system - Piping diagram in connection with fuel gas system
14	A	Heating system - Piping diagram in connection with fuel gas system
15	A	Fuel gas system control, monitoring and safety systems, including a test program for safety functions
16	A	Fuel gas driven engines - Failure mode and effect analysis
17	A	Exhaust gas system - Piping diagram
18	A	Hazardous area classification drawing, including air-lock location, construction details and alarm equipment
19	A	Gastight bulkhead penetrations - Detailed drawing
20	A	Ventilation of gas fuel system spaces - Ducting diagram for spaces containing gas installations, such as gas pipe ducts led through enclosed spaces, storage tanks below deck. Including capacity and location of fans and their motors
21	I	Explosion protection • System arrangement plan of electrical equipment in hazardous areas • Single line diagrams for all intrinsically safe circuits, for each circuit, including data for verification of the compatibility between the barrier and the field components • Documentation to demonstrate the fulfilment of [4.3] • List of certified safe type equipment/instruments (Ex) • Certificates of the safe type (Ex) equipment/instrumentation as per [1.3.2]
22	A	Fixed gas detection system arrangement plan Detectors, call points and alarm devices specification
23	I	FMEA of the whole gas-fuelled system
24	A	Test procedures of safety-critical items, in particular those related to the gas system as ascertained by the FMEA
25	I	Documentation of alternative design as per [2], as applicable
(1) A = to be submitted for approval, in four copies I = to be submitted for information, in duplicate.		

1.3 Definitions

1.3.1 *(1/10/2021)*

IGF CODE REFERENCE: Ch. 2, 2.1

Unless otherwise stated below, definitions are as defined in SOLAS chapter II-2 and IGF Code 2.2.

1.3.2 *(1/10/2021)*

IGF CODE REFERENCE: Ch. 2, 2.2

Certified safe type means electrical equipment that is certified safe by the relevant recognized authorities for operation in a flammable atmosphere based on a recognized standard.

Note 1: Refer to IEC 60079 series, Explosive atmospheres and IEC 60092-502:1999 Electrical Installations in Ships - Tankers - Special Features.

1.3.3 *(1/10/2021)*

LH2 means liquefied hydrogen gas, but it also means hydrogen vapours.

1.3.4 *(1/10/2021)*

Fuel, Gas and Gas Fuel in the context of this appendix in general mean either hydrogen in liquefied or vapour form (except specified otherwise, like "inert gas" or "liquid gas").

1.3.5 *(1/10/2021)*

High pressure means a maximum working pressure greater than 2.0 MPa.

2 Alternative design

IGF CODE REFERENCE: Ch. 2, 2.3

2.1 Deviation, equivalence and operational measures

2.1.1 *(1/10/2021)*
Appliances and arrangements may deviate from those set out in this Appendix provided that they meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant paragraphs.

2.1.2 *(1/10/2021)*
The equivalence of the alternative design is to be demonstrated as specified in SOLAS regulation II-1/55, and approved by the Society. Operational methods or procedures will not be allowed as an alternative to a particular fitting, material, appliance, apparatus, item of equipment, or type thereof which is prescribed by this Appendix.

3 Goal and functional requirements

IGF CODE REFERENCE: Ch. 3

3.1 Goal

3.1.1 *(1/10/2021)*
The goal of this Appendix is to provide for safe and environmentally-friend design, construction and operation of ships and in particular their installations of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery using gas as fuel.

3.2 Functional requirements

3.2.1 *(1/10/2021)*
The safety, reliability and dependability of the systems is to be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery. A FMEA consistent with the "TASNEEF Guide for FMEA" is to be carried out for the whole gas-fuelled system, including process system, electrical power supplies and control system, to check the potential existence of failure modes that can jeopardize the ship's safety. The results of the FMEA are then to be used to establish a trial program.

3.2.2 *(1/10/2021)*
The probability and consequences of fuel-related hazards are to be limited to a minimum through arrangement and system design, such as ventilation, detection and safety actions. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions are to be initiated.

3.2.3 *(1/10/2021)*
The design philosophy is to ensure that risk reducing measures and safety actions for the gas fuel installation do not lead to an unacceptable loss of power.

3.2.4 *(1/10/2021)*
Hazardous areas are to be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment.

3.2.5 *(1/10/2021)*
Equipment installed in hazardous areas are to be minimized to that required for operational purposes and are to be suitably and appropriately certified.

3.2.6 *(1/10/2021)*
Unintended accumulation of explosive, flammable or toxic gas concentrations are to be prevented.

3.2.7 *(1/10/2021)*
System components are to be protected against external damages.

3.2.8 *(1/10/2021)*
Sources of ignition in hazardous areas are to be minimized to reduce the probability of explosions.

3.2.9 *(1/10/2021)*
It is to be arranged for safe and suitable fuel supply, storage and bunkering arrangements capable of receiving and containing the fuel in the required state without leakage. Other than when necessary for safety reasons, the system is to be designed to prevent venting under all normal operating conditions including idle periods.

3.2.10 *(1/10/2021)*
Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application are to be provided.

3.2.11 *(1/10/2021)*
Machinery, systems and components are to be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.

3.2.12 *(1/10/2021)*
Fuel containment system and machinery spaces containing source that might release gas into the space are to be arranged and located such that a fire or explosion in either will not lead to an unacceptable loss of power or render equipment in other compartments inoperable.

3.2.13 *(1/10/2021)*
Suitable control, alarm, monitoring and shutdown systems are to be provided to ensure safe and reliable operation.

3.2.14 *(1/10/2021)*
Fixed gas detection suitable for all spaces and areas concerned are to be arranged.

3.2.15 *(1/10/2021)*
Fire detection, protection and extinction measures appropriate to the hazards concerned are to be provided.

3.2.16 *(1/10/2021)*
Commissioning, trials and maintenance of fuel systems and gas utilization machinery are to satisfy the goal in terms of safety, availability and reliability.

3.2.17 *(1/10/2021)*
The technical documentation is to permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.

3.2.18 *(1/10/2021)*
A single failure in a technical system or component is not to lead to an unsafe or unreliable situation.

4 General requirements

IGF CODE REFERENCE: Ch. 4, 4.1

4.1 Goal

4.1.1 *(1/10/2021)*
The goal of this paragraph is to ensure that the necessary assessments of the risks involved are carried out in order to eliminate or mitigate any adverse effect to the persons on board, the environment or the ship.

4.2 Risk assessment

IGF CODE REFERENCE: Ch. 4, 4.2

4.2.1 *(1/10/2021)*
A risk assessment is to be conducted to ensure that risks arising from the use of hydrogen as fuel and potentially affecting persons on board, the environment, the structural strength or the integrity of the ship are addressed. Considerations are to be given to the hazards associated with physical layout, operation and maintenance, following any reasonably foreseeable failure.

4.2.2 *(1/10/2021)*
For ships to which this Appendix applies, the risk assessment required by [4.2.1] need to be conducted:

a) where explicitly required by:
   - IGF Code paragraphs 5.10.5, 5.12.3, 6.4.1.1, 6.4.15.4.7.2, 8.3.1.1, 13.4.1, 13.7 and 15.8.1.10, and
   - paragraphs 4.4 and 6.8 of Annex to IGF Code, and
   - paragraphs 5.2.1, 5.4.1, 5.10.2, 5.12.2, 6.3.2, 6.6.2, 6.7.2, 6.9.2, 6.11.1, 8.3.1, 8.5.4, 12.5.2, 13.7.1 and 15.8.2 of this Appendix, and

b) when other potential hazards connected with the use of hydrogen as fuel are to be addressed.

4.2.3 *(1/10/2021)*

The risks are to be analysed using acceptable and recognized risk analysis techniques, and loss of function, component damage, fire, explosion and electric shock are as a minimum to be considered. The analysis is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as necessary. Details of risks, and the means by which they are mitigated, are to be documented to the satisfaction of the Society. Guidance on risk analysis techniques can be found in the "TASNEEF Guide on Risk Analysis".

4.2.4 *(1/10/2021)*

The assumptions for the risk assessment are to be agreed by a team of experts acceptable to the Society. It may include a representative of Class, Flag Administration, owner, builder or designer, and consultants having the necessary knowledge and experience in safety, design and/or operation as necessary for the specific evaluation at hand. Other members may include marine surveyors, ship operators, safety engineers, equipment manufacturers, human factors experts, naval architects and marine engineers, according to the problem under scope.

4.2.5 *(1/10/2021)*

The risk assessment can be qualitative or quantitative and is to cover the following aspects:

- Accidental release and dispersion (scenario for hydrogen leakages due to piping rupture and permeability, hydrogen effects on material e.g. embrittlement or permeation, calculation methods for hydrogen diluition in enclosed space)
- Ignition (spontaneous ignition of hydrogen during sudden release, minimum energy for ignition)
- Deflagration and detonation (hydrogen explosion hazards due to overpressure)
- Fires (jet fire, radiative heat fluxes, fire resistance of hydrogen system)
- Impact on people, asset and environment (severity of hydrogen incidents)
- Mitigation techniques (detection method, barriers, ventilation level)
- Emergency operation (strategy control of incident)
- Oxyigen enrichment due to cryogenic hydrogen temperature

The risk assessment is to include the following hazards:

- Creation of explosive atmosphere (hydrogen concentration in air)
- High flammability
- Back firing in pipes
- Chemical reaction with oxidant agents
- Asphyxiation at high hydrogen concentration and at high inert gas concentration
- Hydrogen accumulation on the upper part of spaces
- Invisible and very hot flame during H2 burning
- Hydrogen embrittlement of metals at high pressure

4.3 Limitation of explosion consequences

IGF CODE REFERENCE: Ch. 4, 4.3

4.3.1 *(1/10/2021)*

The preferred safety policy is to be the elimination of either any source of release or any source of ignition, or both. Only in case this is demonstrated not to be feasible, the following applies.

An explosion in any space containing any potential sources of release (note 1) and potential ignition sources is not to:

a) cause damage to or disrupt the proper functioning of equipment/systems located in any space other than that in which the incident occurs;

b) damage the ship in such a way that flooding of water below the main deck or any progressive flooding occurs;

c) damage work areas or accommodation in such a way that persons who stay in such areas under normal operating conditions are injured;

d) disrupt the proper functioning of control stations and switchboard rooms necessary for power distribution;

e) damage life-saving equipment or associated launching arrangements;

f) disrupt the proper functioning of fire-fighting equipment located outside the explosion-damaged space;

g) affect other areas of the ship in such a way that chain reactions involving, inter alia, cargo, gas and bunker oil may arise; or

h) prevent persons access to life-saving appliances or impede escape routes.

Note 1: Double wall fuel pipes are not considered as potential sources of release.

The aforesaid points are to be demonstrated in a way acceptable to the Society.

5 Ship design and arrangement

IGF CODE REFERENCE: Ch. 5

5.1 Goal

IGF CODE REFERENCE: Ch. 5, 5.1

5.1.1 *(1/10/2021)*

The goal of this paragraph [5] is to provide for safe location, space arrangements and mechanical protection of power generation equipment, fuel storage systems, fuel supply equipment and refuelling systems.

5.2 Functional requirements

IGF CODE REFERENCE: Ch. 5, 5.2

5.2.1 *(1/10/2021)*

This paragraph [5] is related to functional requirements in IGF Code paragraphs 3.2.1 to 3.2.3, 3.2.5, 3.2.6, 3.2.8, 3.2.12 to 3.2.15 and 3.2.17. In particular the following apply:

a) location of the fuel tank(s) on open deck or under deck is subject to risk assessment; in both cases, the tank(s) is (are) to be *located in such a way that the probability for the tank(s) to be damaged following a collision or grounding is reduced to a minimum taking into account the safe operation of the ship and other hazards that may be relevant to the ship;*

b) fuel containment systems, fuel piping and other sources of release of fuel are to be so located and arranged that released gas is lead to a safe location in the open air;

c) the access or other openings to spaces containing fuel sources of release are to be so arranged that flammable, asphyxiating or toxic gas cannot escape to spaces that are not designed for the presence of such gases;

d) fuel piping is to be protected against mechanical damage;

e) the propulsion and fuel supply system are to be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power; and

f) the probability of a gas explosion in a machinery space with gas or low-flashpoint fuelled machinery is to be minimized.

5.3 Regulations - General

IGF CODE REFERENCE: Ch. 5, 5.3

5.3.1 *(1/10/2021)*

The requirements in IGF Code 5.3 apply.

5.4 Machinery space concepts

IGF CODE REFERENCE: Ch. 5, 5.4

5.4.1 *(1/10/2021)*

In a machinery space with hydrogen fuelled machinery, only gas safe machinery concept is allowed, such that the spaces are considered gas safe under all conditions, normal as well as abnormal conditions, i.e. inherently gas safe.

In a gas safe machinery space, a single failure cannot lead to release of fuel gas into the machinery space.

Special consideration may be given to the arrangement of the fuel cell space.

Consideration may be given to accept an ESD protected machinery space on ships below 100 GT, provided that the arrangement is considered in the risk assessment in [4.2].

5.5 Regulations for gas safe machinery space

IGF CODE REFERENCE: Ch. 5, 5.5

5.5.1 *(1/10/2021)*

The requirements in IGF Code 5.5 apply.

5.6 Regulations for ESD-protected machinery spaces

5.6.1 *(1/10/2021)*
ESD protected Machinery spaces are generally not acceptable and [5.4.1] applies.

5.7 Regulations for location and protection of fuel piping

IGF CODE REFERENCE: Ch. 5, 5.7

5.7.1 *(1/10/2021)*
The requirements in IGF Code 5.7 apply.

5.8 Regulations for fuel preparation room design

IGF CODE REFERENCE: Ch. 5, 5.8

5.8.1 *(1/10/2021)*
The requirements in IGF Code 5.8 apply.

5.9 Regulations for bilge systems

IGF CODE REFERENCE: Ch. 5, 5.9

5.9.1 *(1/10/2021)*
The requirements in IGF Code 5.9 apply.

5.10 Regulations for drip trays

IGF CODE REFERENCE: Ch. 5, 5.10

5.10.1 *(1/10/2021)*
The requirements in IGF Code 5.10 apply.

5.10.2 *(1/10/2021)*
The risk assessment is to follow the steps outlined below.

a) The team of experts is to conduct a Hazard Identification (HAZID) to agree on the scenarios to be subjected to the risk assessment, and on the assumptions regarding the most critical events (typically, connection failures causing an hydrogen release) considering also available internationally recognized standard (e.g. ISO/TR 15916) for the identification of hazards and risks.

b) Reasonable assumptions on the extent of connection failures or other selected events and the process parameters of the hydrogen are to be made by the team of experts, preferably on the basis of statistics available in the public domain or provided and documented by stakeholders.

c) Reasonable assumptions on the operation of ventilation system are to be made according to layout and procedures of the affected space.

d) In order to verify that the hydrogen release will not create flammable concentrations and to demonstrate the drip tray capacity for a hydrogen cryogenic spill, a specific simulation is to be set up, aimed at evaluating the maximum amount of hydrogen spilled and its cloud, the evaporation rate and the possibility to fully accommodate the liquid hydrogen in the drip tray. The dispersion of vapors resulting from hydrogen evaporation in the affected space is also to be ascertained in respect of explosive atmosphere.

e) The simulation is to be conducted by commercially available and validated tools (typically, by CFD tools). It is to focus on the calculation of the amount of hydrogen spilled before the stop of hydrogen flow. Other calculation methods (e.g. empirical formulas based on literature) will be subject to special consideration.

f) As a precaution, in order to maximize the accumulation of hydrogen into the drip tray, hydrogen release is to be assumed as directed downward, impinging on the drip tray, and ambient temperature is to be set to the minimum credible winter temperature. Equipment and space surfaces and drip tray are to be considered adiabatic, to conservatively minimize the heat exchange with the hydrogen droplets, and to increase the amount of liquid accumulated in the drip tray.

g) Reasonable assumptions are to be made by the expert team regarding detection time, hydrogen flow stop time and human reaction time, in case operators are credited in the emergency.

h) If the simulation demonstrates that the drip tray cannot accommodate the hydrogen spill, mitigating measures are to be provided and subjected to the same simulation process, to appreciate the risk reduction.

5.11 Regulations for arrangement of entrances and other openings in enclosed spaces

IGF CODE REFERENCE: Ch. 5, 5.11

5.11.1 *(1/10/2021)*
The requirements in IGF Code 5.11 apply.

5.12 Regulations for airlocks

IGF CODE REFERENCE: Ch. 5, 5.12

5.12.1 *(1/10/2021)*
The requirements in IGF Code 5.12 apply.

5.12.2 *(1/10/2021)*
In the context of the risk assessment required in IGF Code 5.12.3, the team of experts is to conduct a Hazard Identification (HAZID) to agree on the worst scenario for hydrogen release including the configuration of the airlocks.

In order to assess the structural integrity of the room and the suitability of the designed airlock, the maximum pressure within the spaces identified by the HAZID has to be evaluated, considering the effectiveness of the ventilation system. This calls for a simulation by means of the tools mentioned in [5.10.2]. The following steps, as a minimum, are to be performed.

a) Representative accidental scenarios of loss of hydrogen from failures in process or containment systems are to be selected by the team of experts in the identified spaces. The simulation is to focus on the calculation of the amount of hydrogen spilled before the stop of the hydrogen flow

b) Reasonable assumptions on the extent of containment failure and the process parameters of the hydrogen are to be made by the team of experts, preferably based on statistics available in the public domain or provided and documented by stakeholders.

c) Reasonable assumptions on the operation of ventilation system are to be made according to layout and procedures of the selected spaces.

d) As a precaution, in order to maximize the accumulation of hydrogen onto the space floor, hydrogen release is to be directed downward, impinging on the floor, and ambient temperature is to be set to the maximum credible summer temperature in the space. The surfaces are to be considered isothermal at ambient temperature, to conservatively increase the evaporation rate and, consequently, the pressure buildup.

e) Reasonable assumptions are to be made by the team of experts regarding detection time, hydrogen flow stop time and human reaction time, in case operators are credited in the emergency.

If the simulation demonstrates that the analysed airlocks cannot prevent gas release in safe space, mitigating measures are to be provided and subjected to the same simulation process, to appreciate the risk reduction.

6 Fuel containment system

IGF CODE REFERENCE: Ch. 6

6.1 Goal

6.1.1 *(1/10/2021)*
The goal of this paragraph [6] is to provide that gas storage is adequate so as to minimize the risk to personnel, the ship and the environment to a level that is equivalent to a conventional oil fuelled ship.

6.2 Functional requirements

6.2.1 *(1/10/2021)*
This paragraph [6] relates to functional requirements in IGF Code 3.2.1, 3.2.2, 3.2.5 and 3.2.8 to 3.2.17. In particular the following apply:

a) the fuel containment system is to be so designed that a leak from the tank or its connections does not endanger the ship, persons on board or the environment. Potential dangers to be avoided include:

1) exposure of ship materials to temperatures below acceptable limits;

2) flammable fuels spreading to locations with ignition sources;

3) toxicity potential and risk of oxygen deficiency due to fuels and inert gases;

4) restriction of access to assembly stations, escape routes and life-saving appliances (LSA); and

5) *reduction in availability of LSA.*

b) *the pressure and temperature in the fuel tank are to be kept within the design limits of the containment system and possible carriage requirements of the fuel;*

c) *the fuel containment arrangement is to be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power; and*

d) *if portable tanks are used for fuel storage, the design of the fuel containment system is to be equivalent to permanent installed tanks as described in this paragraph.*

6.3 Regulations - General

6.3.1 *(1/10/2021)*

The requirements in IGF Code 6.3 apply, with the following deviations from IGF Code 6.3.1 and 6.3.4.

6.3.2 *(1/10/2021)*

Hydrogen in a liquid state may be stored with a maximum allowable relief valve setting (MARVS) of up to 1.0 MPa. Higher values are subject to special consideration on the basis of the risk assessment aimed to assess all related risks.

6.3.3 *(1/10/2021)*

All tank connections, fittings, flanges and tank valves are to be enclosed in a tank connection space able to safely contain leakage from the tank connections.

When the fuel storage tank is in an enclosed space, the tank connection space is to be gastight toward other spaces.

6.3.4 *(1/10/2021)*

The vacuum insulation capability is to be evaluated for the upper limit of cold vacuum pressure (CVP), and loss of vacuum is to be defined with respect to the CVP upper limit. Accordingly, cargo containment systems and piping are to be designed and tested taking into account the effect of vacuum pressure. Supporting structure and adjacent hull structure are to be designed taking into account the cooling owing to loss of vacuum insulation.

6.4 Regulations for liquefied gas fuel containment

6.4.1 *(1/1/2025)*

The requirements in IGF Code 6.4 apply, taking into account the provisions in [6.4.4] to [6.4.11] of App 7.

6.4.2 Materials and construction *(1/10/2021)*

Austenitic stainless steel - such as AISI 304, 316, 304L and 316L - is to be used for materials in contact with hydrogen. Other materials may be approved after special consideration and/or testing, in accordance to an international recognized standard (e.g. EN 13445-2) and subject to the submission of the relevant documentation including material specification with chemical and mechanical properties, material test report as base material and as welded with reference to IMO guideline in MSC.1/Circ.1622.

Materials having a melting point below 925°C are not to be used for piping outside the fuel tanks (ref. chapter 7.4.1.2 of the IGF Code), with a possible exception for short lengths of pipes attached to, or in the close proximity of, the fuel tanks. In such case the low melting point materials are to be protected by A-60 rating insulation.

When applying IGF Code 6.4.13.1.1.1.5, loss of vacuum for vacuum insulated tanks is also to be considered.

6.4.3 *(1/10/2021)*

Where minimum design temperature is lower than -196°C, property testing for insulation materials is to be carried out with the appropriate medium, over a range of temperatures expected in service. The testing or inspection record of previous satisfactory applications with relevant technical analysis and simulations may be acceptable as an alternative.

6.5 Regulations for portable liquefied gas fuel tanks

6.5.1 *(1/10/2021)*

The requirements in IGF Code 6.5 apply.

6.6 Regulations for high compressed hydrogen containment system and chemical containment system using metal hydrides

6.6.1 *(1/10/2021)*

The high compressed hydrogen containment system consists of a group of pressure vessels supported by rack whereby the hydrogen gas is kept under pressure to increase the storage capacity at ambient temperature. The following requirements are applicable to systems with maximum allowable working pressure up to 90 MPa. Special considerations will be given to systems with design pressure above 90 MPa.

The chemical containment system using metal hydrides consists of a group of pressure vessels supported by rack whereby the hydrogen is absorbed in the metal hydrides (metal powder). The following requirements are applicable to systems with design pressure up to 10 MPa.

6.6.2 *(1/10/2021)*

The requirements in IGF Code 6.6 apply.

Special consideration mentioned in IGF Code 6.6.4 is to be intended as risk assessment according to [4.2].

6.6.3 *(1/10/2021)*

The pressure vessels (cylinders) are to be designed and tested according to international recognized standards with loads and allowable stress to be preliminary agreed with the Society.

6.6.4 *(1/10/2021)*

The rack supporting the pressure vessels and its connection to adjacent structure are to be designed taking into account at least the following loads as defined in IGF code 6.4.9.3.3 and 6.4.9.4:

- thermally induced loads if any
- vibration
- hull interaction
- weight of containment system
- static heel
- wind impact, wave impact, green sea effects and ice for installations on open deck
- loads due to ship motion
- collision load.

6.7 Regulations for pressure relief system

6.7.1 General *(1/10/2021)*

The requirements in IGF Code 6.7 apply with the following deviations.

6.7.2 Pressure relief systems for gas fuel tanks *(1/10/2021)*

The distances given in IGF Code 6.7.2.7.3 and 6.7.2.8 are to be replaced with proper values established by suitable techniques, in the context of the risk assessment required in [4.2], considering the physical properties of the released gas and relevant dispersion.

For containment system other than liquefied gas fuel tanks, the sizing of pressure relief systems is to be determined according to international recognized standard where the discharge conditions are to be defined during the risk assessment taking into account the arrangement and location of containment system.

Pressure-relief devices and the inlet and discharge piping are to be designed and installed to minimize moisture accumulation and ice build up from atmospheric condensation, that could cause them to fail to function properly.

6.8 Regulations on loading limit for liquefied gas fuel tanks

6.8.1 *(1/10/2021)*

The requirements in IGF Code 6.8 apply.

6.9 Regulations for the maintaining of fuel storage condition

6.9.1 *(1/10/2021)*

The requirements in IGF Code 6.9 apply except for IGF Code 6.9.1 which is replaced by [6.9.2] below.

6.9.2 Control of liquefied gas fuel tank pressure and temperature *(1/10/2021)*

With the exception of liquefied gas fuel tanks designed to withstand the full gauge vapor pressure of the fuel under conditions of the upper ambient design temperature, liquefied gas fuel tanks' pressure and temperature are to be maintained at all times within their design range by means acceptable to the Society, e.g. by one of the following methods:

a) reliquefaction of vapours;

b) thermal oxidation of vapours;

c) pressure accumulation in a separate tank; or

d) liquefied gas fuel cooling.

The method chosen is to be capable of maintaining tank pressure below the set pressure of the tank pressure relief valves for a period of 15 days assuming full tank at normal service pressure, a tank valve closed by the safety system and the ship in idle condition, i.e. only power for domestic load is generated.

e) Venting of fuel vapor for control of the tank pressure, subject to risk assessment [4.2].

6.10 Regulations on atmospheric control within the fuel containment system

6.10.1 *(1/10/2021)*

The requirements in IGF Code 6.10 apply.

6.11 Regulations on atmosphere control within fuel storage hold spaces (Fuel containment systems other than type C independent tanks)

6.11.1 *(1/10/2021)*

Interbarrier and fuel storage hold spaces associated with liquefied gas fuel containment systems requiring full or partial secondary barriers are to be arranged to prevent fire risk due to hydrogen leakage and the arrangement is subject to risk assessment according to [4.2].

6.12 Regulations on environmental control of spaces surrounding type C independent tanks

6.12.1 *(1/10/2021)*

Spaces surrounding liquefied gas fuel tanks are to be filled with suitable gas and be maintained in this condition with a suitable gas provided by shipboard storage, which is to be sufficient for normal consumption for at least 30 days. This is only applicable for liquefied gas fuel tanks where condensation and icing due to cold surfaces is an issue.

For vacuum insulated tanks the above requirement is not applicable if the insulation arrangement is made to prevent condensation of oxygen and of water vapor on the outer tank and it can be demonstrated through thermal analysis.

6.12.2 *(1/10/2021)*

The spaces surrounding gas fuel tanks (in gaseous form at ambient temperature) are to have a mechanical exhaust ventilation having a capacity of at least 30 air changes per hour. The fan motors are to comply with the required explosion protection in the installation area. The ventilation outlet is to be covered by a protection screen and placed in a position where no flammable gas-air mixture may be ignited.

6.13 Regulations on inerting

6.13.1 *(1/10/2021)*

The requirements in IGF Code 6.13 apply.

6.13.2 *(1/10/2021)*

The spaces where the inert gas double block and bleed valves and closable non-return valve are fitted are to be classified as a Zone 1 hazardous spaces.

6.14 Regulations on inert gas production and storage on board

6.14.1 *(1/10/2021)*

The requirements in IGF Code 6.14 apply.

7 Material and general pipe design

IGF CODE REFERENCE: Ch. 7

7.1 Goal

7.1.1 *(1/10/2021)*

The goal of this paragraph [7] is to ensure the safe handling of fuel, under all operating conditions, to minimize the risk to the ship, personnel and to the environment, having regard to the nature of the products involved.

7.2 Functional requirements

7.2.1 *(1/10/2021)*

This paragraph [7] relates to functional requirements in IGF Code 3.2.1, 3.2.5, 3.2.6, 3.2.8, 3.2.9 and 3.2.10. In particular the following apply:

a) Fuel piping is to be capable of absorbing thermal expansion or contraction caused by extreme temperatures of the fuel without developing substantial stresses.

b) Provision is to be made to protect the piping, piping system and components and fuel tanks from excessive stresses due to thermal movement and from movements of the fuel tank and hull structure.

c) If the fuel gas contains heavier constituents that may condense in the system, means for safely removing the liquid are to be fitted.

d) Low temperature piping is to be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material.

e) Oxygen condensation on the surface of low temperature piping is to be prevented.

7.3 Regulations for general pipe design

7.3.1 General *(1/10/2021)*

The requirements in IGF Code 7.3 apply.

Fuel pipes in spaces made gas safe are not to include expansion joints, flexible hoses, bellows or other pipe components with poorer strength, fatigue or leakage properties than the fully welded pipe. The use of metallic flexible components can be only allowed if of double walled type, designed and tested in accordance with international recognized standard and where the sufficient flexibility of piping system cannot be granted with other methods.

7.3.2 **Prevention of oxygen condensation** *(1/10/2021)*

For fuel pipes containing liquid hydrogen and cold hydrogen vapor, measures are to be taken to prevent the exposed surfaces from reaching -183°C. For places where preventive measures against low surface temperature are not sufficiently effective, other appropriate measures such as ventilation which avoids the formation of highly enriched oxygen and the installation of trays recovering liquid air may be permitted in lieu of the preventive measures. Insulation on liquid hydrogen piping systems exposed to air is to be of non-combustible material and is to be designed to have a seal in the outer covering to prevent the condensation of air and subsequent oxygen enrichment within the insulation.

7.3.3 **Joining of piping** *(1/10/2021)*

Butt welded connections of piping are to be used.

Bolted flange connections of piping may be used where welded connections are not feasible.

Threaded connections complying with recognized standards may only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less. The threaded connections are to have an increased pipe thickness and higher nominal pressure (PN). For external diameters exceeding 25 mm and up to 50 mm the use will be case by case evaluated by the Society considering the arrangement and the rupture risks.

In any case, threaded connections are to be in accordance with standards approved by the Society, and the use will be specially evaluated by the Society.

Heat treatment post-welding is to be required for all butt welds of pipes made of carbon, carbon-manganese and low-alloy steels. The Society may waive the recommendation for thermal stress relieving of pipes having wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system.

7.4 Regulations for materials

7.4.1 **Metallic materials** *(1/10/2021)*

The requirements in IGF Code 7.4 apply.

7.4.2 *(1/10/2021)*

The materials whose design temperature is lower than -165°C, are to be in accordance with international recognized standards.

Materials which according to EN 13480-2 may be used up to -270°C are allowed, subject to having 60 J impact energy of base material and 40 J for welding material at -196°C.

Other alternative proposals to demonstrate the suitability of selected material (e.g. use of test data for samples of base material alloys and welding material impact tested at -269°C with liquefied helium) will be evaluated case by case basis by the Society.

It is to be ensured that deterioration (ageing) of material will not affect its resistance capacity to hydrogen embrittlement.

7.4.3 *(1/10/2021)*

Materials of construction and ancillary equipment such as insulation are to be resistant to the effects of high oxygen concentrations caused by condensation and enrichment at the low temperatures attained in parts of the hydrogen containment system and piping working at cryogenic temperature. Due consideration is to be given to ventilation in areas where condensation might occur, to avoid the stratification of oxygen-enriched atmosphere.

8 Bunkering

IGF CODE REFERENCE: Ch. 8

8.1 Goal

8.1.1 *(1/10/2021)*

The goal of this paragraph [8] is to provide for suitable systems on board the ship to ensure that bunkering can be conducted without causing danger to persons, the environment or the ship.

8.2 Functional requirements

8.2.1 *(1/10/2021)*

This paragraph [8] relates to functional requirements in IGF Code 3.2.1 to 3.2.11 and 3.2.13 to 3.2.17. In particular the following apply.

The piping system for transfer of fuel to the storage tank is to be designed such that any leakage from the piping system cannot cause danger to personnel, the environment or the ship.

8.3 Regulations for bunkering station

8.3.1 General *(1/10/2021)*

The requirements in IGF Code 8.3 apply, with the following additions:

a) The bunkering station is to be under direct view from a bunkering control station, if any, or from the bridge; as an alternative a CCTV system may be considered.

b) For bunkering of hydrogen, a risk assessment is to be carried out, following the steps outlined below:

   1) The team of experts is to conduct a Hazard Identification (HAZID) to agree on the scenarios to be subjected to the risk assessment, and on the assumptions regarding the most critical events (typically, connection failures causing an hydrogen spill). The effects in the bunker station and above and below it are to be simulated by means of the tools mentioned in [5.10.2].

   2) As a minimum, a scenario to be assumed is the failure of the presentation flange on the bunkering line. The simulation is to focus on the calculation of the amount of hydrogen released before the intervention of ESD and the stop of the bunkering pumps. After the stop of the pumps, the amount of the discharge of the residual inventory of the hose or loading arm is to be calculated according to the bunkering configuration, to estimate whether it is significant; in this case, it is to be taken into account in the simulation.

   3) Reasonable assumptions on the extent of connection failures or other selected events and the parameters of the hydrogen process are to be made by the team of experts, preferably on the basis of statistics available in the public domain or provided and documented by stakeholders or using industry safety standards.

   4) Reasonable assumptions on the operation of ventilation system are to be made according to layout and procedures of the bunker station.

   5) For the case of liquified hydrogen, in order to verify the release cloud and drip tray capacity, a specific simulation is to be set up, aimed at evaluating the maximum amount of hydrogen released and spilled onto the drip tray, the

evaporation rate, and the possibility to fully accommodate the hydrogen in the drip tray avoiding any over-board disposal.

6) In particular, the dispersion of hydrogen resulting from leakage and/or evaporation in the bunker station and from the bunker station to the upper decks, if realistically possible, is to be simulated.

7) In case a double walled bayonet coupling is used instead of a single presentation flange, the hydrogen release scenario is to be adapted accordingly.

c) Low temperature steel shielding is to be considered if the escape of cold jets impinging on surrounding hull structure is possible.

8.4 Regulations for manifold

8.4.1 *(1/10/2021)*

The requirements in IGF Code 8.4 apply.

8.5 Regulations for bunkering system

8.5.1 *(1/10/2021)*

An arrangement for purging fuel bunkering lines with inert gas is to be provided.

8.5.2 *(1/10/2021)*

A manually operated stop valve and a remote operated shut-down valve in series, or a combined manually operated and remote valve is to be fitted in every bunkering line close to the connecting point. It is to be possible to operate the remote valve in the control location for bunkering operations and/or from another safe location.

8.5.3 *(1/10/2021)*

Means are to be provided for draining any fuel from the bunkering pipes upon completion of operation, unless these are arranged for a permanent containment of hydrogen.

8.5.4 *(1/10/2021)*

Bunkering lines are to be arranged for inerting and gas freeing. When not engaged in bunkering, the bunkering pipes are to be free of gas, unless these are arranged for a permanent containment of hydrogen and the consequences of not gas freeing are evaluated in the risk assessment according to [4.2].

8.5.5 *(1/10/2021)*

In case bunkering lines are arranged with a cross-over it is to be ensured by suitable isolation arrangements that no fuel is transferred inadvertently to the ship side not in use for bunkering, unless the lines are arranged for a permanent containment of hydrogen.

8.5.6 *(1/10/2021)*

A ship-shore link (SSL) or an equivalent means for automatic and manual ESD communication to the bunkering source is to be fitted.

8.5.7 *(1/10/2021)*

If not demonstrated to be required at a higher value due to pressure surge considerations a default time as calculated in accordance with IGF Code 16.7.3.7 from the trigger of the alarm to full closure of the remote operated valve required by [8.5.3] is to be adjusted.

8.5.8 *(1/10/2021)*

Means are to be provided to manage the vapors generated during the bunkering, either by vapor return to the bunkering manifold or by one of the systems required in [6.9.2].

9 Fuel supply to consumers

IGF CODE REFERENCE: Ch. 9

9.1 Goal

9.1.1 *(1/10/2021)*

The goal of this paragraph [9] is to ensure safe and reliable distribution of fuel to the consumers.

9.2 Functional requirements

9.2.1 *(1/10/2021)*

This paragraph [9] is related to functional requirements in IGF Code 3.2.1 to 3.2.6, 3.2.8 to 3.2.11 and 3.2.13 to 3.2.17. In particular the following apply:

a) the fuel supply system is to be so arranged that the consequences of any release of fuel will be minimized, while providing safe access for operation and inspection;

b) the piping system for fuel transfer to the consumers is to be designed in a way that a failure of one barrier cannot lead to a leak from the piping system into the surrounding area causing danger to the persons on board, the environment or the ship; and

c) fuel lines outside the machinery spaces are to be installed and protected so as to minimize the risk of injury to personnel and damage to the ship in case of leakage.

9.3 Regulations on redundancy of fuel supply

9.3.1 *(1/10/2021)*

The requirements in IGF Code 9.3 apply.

9.4 Regulations on safety functions of gas supply system

9.4.1 *(1/10/2021)*

The requirements in IGF Code 9.4 apply with the following deviations from IGF Code 9.4.7.

9.4.2 *(1/10/2021)*

In cases where the master gas fuel valve is automatically shut down, the complete gas supply branch downstream of the double block and bleed valve is to be automatically vented to the vent mast; the requirements in [6.7.2] i) apply.

9.5 Regulations for fuel distribution outside of machinery space

9.5.1 *(1/10/2021)*

Fuel pipes are to be protected by a secondary enclosure.

This enclosure can be a ventilated duct or a double wall piping system. The duct or double wall piping system is to be mechanically under pressure ventilated with 30 air changes per hour, and gas detection as required in IGF Code 15.8 is to be provided. In case of low temperatures in the annular space of piping, the ventilation is to be made by dry air. *Other solutions providing an equivalent safety level may also be accepted by the Society* (e.g. use of pressurized inert gas in the double wall annular space).

9.5.2 *(1/10/2021)*

The requirement in [9.5.1] need not be applied for fully welded open ended *fuel gas vent pipes led through mechanically ventilated spaces* nor for fully welded fuel gas pipes on the open deck.

9.6 Regulations for fuel supply to consumers in gas-safe machinery spaces

9.6.1 *(1/10/2021)*

The requirements in IGF Code 9.6 apply.

9.6.2 *(1/10/2021)*

The fuel is to be supplied to machinery spaces at a temperature higher than -183°C (90 K), to prevent oxygen condensation on the pipes.

9.7 Regulations for gas fuel supply to consumers in ESD-protected machinery spaces

9.7.1 *(1/10/2021)*

ESD protected Machinery spaces are generally not acceptable and [5.4.1] applies.

9.8 Regulations for the design of ventilated duct, outer pipe against inner pipe gas leakage

9.8.1 *(1/10/2021)*

The design pressure of the outer pipe or duct of fuel systems is not to be less than the maximum working pressure of the inner pipe.

Alternatively for fuel piping systems with a working pressure greater than 1.0 MPa, the design pressure of the outer pipe or duct is not to be less than the maximum built-up pressure arising in the annular space considering the higher between:

- maximum built-up pressure as the static pressure in way of the rupture resulting from the gas flowing in the annular space.
- the local instantaneous peak pressure in way of any rupture considering the ventilation arrangements.

The tangential membrane stress of a straight pipe is not to exceed the tensile strength divided by 1,5 (Rm/1,5) when subjected to the above pressures. The pressure ratings of all other piping components are to reflect the same level of strength as straight pipes.

9.8.2 *(1/10/2021)*

Verification of the strength is to be based on calculations demonstrating the duct or pipe integrity. As an alternative to calculations, the strength can be verified by representative tests.

9.8.3 *(1/10/2021)*

The duct is to be pressure tested to show that it can withstand the expected maximum pressure at fuel pipe rupture.

9.9 Regulations for compressors and pumps

9.9.1 *(1/10/2021)*

The requirements in IGF Code 9.9 apply.

9.9.2 *(1/10/2021)*

Motors driving hydrogen compressors and pumps are to be of a type certified as suitable for operation in an explosive atmosphere (Hazardous area Zone 1) due to the presence of hydrogen, even when placed in a motor room separated from the compressors by a gastight bulkhead or deck, unless the motor room is equipped with a ventilation system having a capacity of 30 air changes per hour being continuously operated when the motors are energized. Suitable interlocks and alarms are to be provided to stop and prevent the start of the motors in case of loss of ventilation. Avoidance of unacceptable loss of power as defined in IGF Code 2.2.40 is anyway to be ensured by automatically starting a stand-by motor.

10 Power generation including propulsion and other gas consumers

IGF CODE REFERENCE: Ch. 10

10.1 Goal

10.1.1 *(1/10/2021)*

The goal of this paragraph [10] is to provide safe and reliable delivery of mechanical, electrical or thermal energy.

10.2 Functional requirements

10.2.1 *(1/10/2021)*

This paragraph [10] is related to functional requirements in IGF Code 3.2.1, 3.2.11, 3.2.13, 3.2.16 and 3.2.17. In particular the following apply:

a) the exhaust systems are to be configured to prevent any accumulation of unburnt gaseous fuel;

b) unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, engine components or systems containing or likely to contain an ignitable gas and air mixture are to be fitted with suitable pressure relief systems. Dependent on the particular engine design this may include the air inlet manifolds and scavenge spaces;

c) the explosion venting is to be led away from where personnel may normally be present; and

d) all gas consumers are to have a separate exhaust system.

10.3 Regulations for internal combustion engines of piston type

10.3.1 General *(1/10/2021)*

The requirements in IGF Code 10.3 apply with the following additions to IGF Code 10.3.1.2 and 10.3.1.4:

a) for hydrogen fuelled engines where the space below the piston is in direct communication with the crankcase, a crankcase forced ventilation is required, having the inlet from open areas that, in the absence of the considered inlet, would be non-hazardous and going to a dedicated duct having a hydrogen detection system;

b) *the gas extracted from auxiliary systems media is to be vented to a safe location in the atmosphere.* In the vent line a gas detection is to be installed for monitoring/alarm function.

10.4 Regulations for main and auxiliary boilers

10.4.1 *(1/10/2021)*

The requirements in IGF Code 10.4 apply.

10.5 Regulations for gas turbines

10.5.1 *(1/10/2021)*

The requirements in IGF Code 10.5 apply.

10.6 Regulations for Fuel cells

10.6.1 *(1/10/2021)*

The requirements available in TASNEEF Rules for fuel cell installation in ships (FC-Ships) apply to the installation of fuel cells.

11 Fire safety

11.1 Application

11.1.1 *(1/10/2021)*

This paragraph is void, as the provisions of IGF Code Ch 11 are not within the scope of classification.

These provisions are applied by the Society when acting on behalf of the flag Administration, within the scope of delegation (see [1.1.6]).

12 Explosion prevention

IGF CODE REFERENCE: Ch. 12

12.1 Goal

12.1.1 *(1/10/2021)*

The goal of this paragraph [12] is to provide for the prevention of explosions and for the limitation of effects from explosion.

12.2 Functional requirements

12.2.1 *(1/10/2021)*

This paragraph [12] is related to functional requirements in IGF Code 3.2.2 to 3.2.5, 3.2.7, 3.2.8, 3.2.12 to 3.2.14 and 3.2.17. In particular the following apply.

The probability of explosions is to be reduced to a minimum by:

a) reducing number of sources of ignition; and

b) reducing the probability of formation of ignitable mixtures.

12.3 Regulations - General

12.3.1 *(1/10/2021)*

The requirements in IGF Code 12.3 apply.

12.4 Regulations on area classification

12.4.1 *(1/10/2021)*
The requirements in IGF Code 12.4 apply.

12.5 Hazardous area zones

12.5.1 *(1/10/2021)*
The requirements in IGF Code 12.5 apply, with the following deviations.

12.5.2 *(1/10/2021)*
The extensions and types (Zone 0, Zone 1, Zone 2) of hazardous areas in way of outlet from the pressure relief valves are to be evaluated in the context of the risk assessment required in [4.2].

12.5.3 Fuel storage hold space categorization *(1/10/2021)*

a) Fuel storage hold spaces containing Type C tanks with all potential leakage sources in a tank connection space and having no access to any hazardous area, are to be considered as non-hazardous.

b) Where the fuel storage hold spaces include potential leak sources, e.g. tank connections, they are to be considered hazardous area zone 1.

c) Where the fuel storage hold spaces included bolted access to the tank connection space, they are to be considered hazardous are zone 2.

13 Ventilation

IGF CODE REFERENCE: Ch. 13

13.1 Goal

13.1.1 *(1/10/2021)*
The goal of this paragraph [13] is to provide for the ventilation required for safe operation of gas-fuelled machinery and equipment.

13.2 Functional requirements

13.2.1 *(1/10/2021)*
This paragraph [13] is related to functional requirements in IGF Code 3.2.2, 3.2.5, 3.2.8, 3.2.10, 3.2.12 to 3.2.14 and 3.2.17.

13.3 Regulations - General

13.3.1 *(1/10/2021)*
The requirements in IGF Code 13.3 apply.

13.3.2 *(1/10/2021)*
Areas where fuel covered by this Appendix can be present are to be provided with suction points of the mechanical exhaust system fitted in the high part of the space, where hydrogen is likely to accumulate.

13.4 Regulations for tank connection space

13.4.1 *(1/10/2021)*
The requirements in IGF Code 13.4 apply.

13.5 Regulations for machinery spaces

13.5.1 *(1/10/2021)*
The requirements in IGF Code 13.5 apply.

13.6 Regulations for fuel preparation room

13.6.1 *(1/10/2021)*
The requirements in IGF Code 13.6 apply.

13.7 Regulations for bunkering station

13.7.1 *(1/10/2021)*

Bunkering station are to be suitably ventilated to ensure that any vapour being released during bunkering operations will be removed. *If the natural ventilation is not sufficient, mechanical ventilation is to be provided in accordance with the risk assessment required by [4.2].*

13.8 Regulations for ducts and double pipes

13.8.1 *(1/10/2021)*

The requirements in IGF Code 13.8 apply with the following deviations from IGF Code 13.8.2 and 13.8.3.

13.8.2 *(1/10/2021)*

The ventilation system for double piping and for gas valve unit spaces in gas safe engine-rooms is to be independent of all other ventilation systems except other fuel supply ventilation systems.

13.8.3 *(1/10/2021)*

The ventilation inlet for the double wall piping or duct is always to be located in a non-hazardous area in open air *away from ignition sources. The inlet opening is to be fitted with a suitable wire mesh guard and protected from ingress of water.*

14 Electrical installations

IGF CODE REFERENCE: Ch. 14

14.1 Goal

14.1.1 *(1/10/2021)*

The goal of this paragraph [14] is to provide for electrical installations that minimize the risk of ignition in the presence of a flammable atmosphere.

14.2 Functional requirements

14.2.1 *(1/10/2021)*

This paragraph [14] is related to functional requirements in IGF Code 3.2.1, 3.2.2, 3.2.4, 3.2.7, 3.2.8, 3.2.11, 3.2.13 and 3.2.16 to 3.2.18. In particular the following apply.

Electrical generation and distribution systems, and associated control systems, are to be designed such that a single fault will not result in the loss of ability to maintain fuel tank pressures and hull structure temperature within normal operating limits.

14.3 Regulations - General

14.3.1 *(1/10/2021)*

The requirements in IGF Code 14.3 apply.

15 Control monitoring and safety systems

IGF CODE REFERENCE: Ch. 15

15.1 Goal

15.1.1 *(1/10/2021)*

The goal of this paragraph [15] is to provide for the arrangement of control, monitoring and safety systems that support an efficient and safe operation of the gas-fuelled installation as covered in the other paragraphs of thisAppendix.

15.2 Functional requirements

15.2.1 *(1/10/2021)*

This paragraph [15] is related to functional requirements in IGF Code 3.2.1, 3.2.2, 3.2.11, 3.2.13 to 3.2.15, 3.2.17 and 3.2.18. In particular the following apply:

a) the control, monitoring and safety systems of the gas-fuelled installation are to be so arranged that the remaining power for propulsion and power generation is in accordance with IGF Code 9.3.1 in the event of single failure;

b) a gas safety system is to be arranged to close down the gas supply system automatically, upon failure in systems as described in IGF Code Table 1 and upon other fault conditions which may develop too fast for manual intervention;

c) the safety functions are to be arranged in a dedicated gas safety system that is independent of the gas control system in order to avoid possible common cause failures. This includes power supplies and input and output signal;

d) the safety systems including the field instrumentation are to be arranged to avoid spurious shutdown, e.g. as a result of a faulty gas detector or a wire break in a sensor loop; and

e) where two or more gas supply systems are required to meet the regulations, each system is to be fitted with its own set of independent gas control and gas safety systems.

15.3 Regulations - General

15.3.1 *(1/10/2021)*

The requirements in IGF Code 15.3 apply.

15.4 Regulations for bunkering and liquefied gas fuel tank monitoring

15.4.1 *(1/10/2021)*

The requirements in IGF Code 15.4 apply.

15.5 Regulations for bunkering control

15.5.1 *(1/10/2021)*

The requirements in IGF Code 15.5 apply.

15.6 Regulations for gas compressor moni- toring

15.6.1 *(1/10/2021)*

The requirements in IGF Code 15.6 apply.

15.7 Regulations for gas engine monitoring

15.7.1 *(1/10/2021)*

The requirements in IGF Code 15.7 apply.

15.8 Regulations for gas detection

15.8.1 *(1/10/2021)*

The requirements in IGF Code 15.8 apply, with the following deviations.

15.8.2 *(1/10/2021)*

Permanently installed gas detectors are also to be fitted:

a) at ventilation inlets to service spaces, ro-ro spaces, special category spaces and other machinery spaces if required based on the risk assessment required in [4.2];

b) in bunker stations.

15.8.3 *(1/10/2021)*

Gas detection equipment is to be designed, installed and tested in accordance with IEC 60079-29-1 or an equivalent recognized standard acceptable to the Society.

15.8.4 *(1/10/2021)*

Audible and visible alarms from the gas detection equipment are to be located on the navigation bridge or in the continuously manned central control station or safety centre.

15.9 Regulations for fire detection

15.9.1 *(1/10/2021)*

The requirements in IGF Code 15.9 apply.

15.10 Regulations for ventilation

15.10.1 *(1/10/2021)*

The requirements in IGF Code 15.10 apply.

15.11 Regulations on safety functions of fuel supply systems

15.11.1 *(1/10/2021)*

The requirements in IGF Code 15.11 apply.

16 Manufacture workmanship and testing

IGF CODE REFERENCE: Ch. 16

16.1 General

16.1.1 *(1/10/2021)*

The manufacture, testing, inspection and documentation are to be in accordance with recognized standards and the regulations given in this Appendix.

16.1.2 *(1/10/2021)*

Where post-weld heat treatment is specified or required, the properties of the base material are to be determined in the heat treated condition, in accordance with the applicable Tables of IGF Code Ch 7 and the weld properties are to be determined in the heat treated condition in accordance with IGF Code 16.3. In cases where a post-weld heat treatment is applied, the test regulations may be modified at the discretion of the Society.

16.2 General test regulations and specifications

16.2.1 **Tensile test** *(1/10/2021)*

The requirements in IGF Code 16.2 apply.

16.3 Welding of metallic materials and non-destructive testing for the fuel containment system

16.3.1 General *(1/10/2021)*

The requirements in IGF Code 16.3 apply.

16.4 Other regulations for construction in metallic materials

16.4.1 General *(1/10/2021)*

The requirements in IGF Code 16.4 apply.

16.5 Testing

16.5.1 General *(1/10/2021)*

The requirements in IGF Code 16.5 apply.

16.5.2 Testing and inspections during construction *(1/10/2021)*

a) Process pressure vessels containing hydrogen are categorized as class 1 for the application of the requirements in Sec 3, irrespective of their design pressure and design temperature.

b) The fuel containment system for low temperature hydrogen is to be inspected for cold spots during or immediately following the first hydrogen bunkering, when steady thermal conditions are reached. Inspection of the integrity of thermal insulation surfaces that cannot be visually checked is to be carried out in accordance with the requirements of the Society.

16.6 Welding, post-weld heat treatment and non-destructive testing

16.6.1 General *(1/10/2021)*
The requirements in IGF Code 16.6 apply.

16.7 Testing regulations

16.7.1 *(1/10/2021)*
The requirements in IGF Code 16.7 apply.

APPENDIX 15 METHYL/ETHYL ALCOHOL FUELLED SHIPS

1 General

1.1 Scope

1.1.1 Application *(1/1/2022)*

The provisions of this Appendix apply to the arrangement, installation, control and monitoring of machinery, equipment and systems of ships using methyl/ethyl alcohol as fuel (hereinafter named "methyl/ethyl alcohol fuelled ships").

1.1.2 Acceptance by the flag Administration *(1/1/2022)*

The use of methyl/ethyl alcohol as fuel in ships requires acceptance by the Administration of the State whose flag the ship is entitled to fly on the basis of the alternative design approach as required in MSC.1/Circ.1621 para 2.3.

1.1.3 MSC.1/Circ.1621 requirements and the Society's rules *(1/1/2022)*

For methyl/ethyl alcohol fuelled ships, the requirements of the IMO Interim Guidelines for the Safety of Ships using Methyl/Ethyl Alcohol as Fuel set out in the annex of IMO circular MSC.1/Circ.1621 (hereinafter named "MSC.1/Circ.1621") are to be applied as class requirements as specified and with the deviations given in this Appendix.

For the scope of classification, when reference is made to paragraphs of MSC.1/Circ.1621 where the wording "Administration" is used, it is to be regarded as referring to the "Society".

In general, this Appendix applies to machinery, equipment and systems of ships using methyl/ethyl alcohol as fuel and to their interfaces with the other ship systems. Unless otherwise specified, the machinery, equipment and systems of ships using methyl/ethyl alcohol as fuel are also to comply with the requirements given in Part C.

1.1.4 MSC.1/Circ.1621 requirements not within the scope of classification *(1/1/2022)*

The following requirements of MSC.1/Circ.1621 are not within the scope of classification:

- Section 11 - Fire Safety
- Section 16 - Training, drills and emergency exercises
- Section 17 - Operation

These requirements are applied by the Society when acting on behalf of the flag Administration, within the scope of delegation (see [1.1.6]).

1.1.5 Correspondence of the MSC.1/Circ.1621 with the Rules *(1/1/2022)*

All the requirements of this Appendix are cross referenced to the applicable paragraphs of MSC.1/Circ.1621, as appropriate.

1.1.6 Statutory certificates *(1/1/2022)*

The responsibility for interpretation of the MSC.1/Circ.1621 requirements for the purpose of issuing statutory certificates for methyl/ethyl alcohol fuelled ships lies with the Administration of the State whose flag the ship is entitled to fly.

Whenever the Society is authorized by an Administration to issue on its behalf the statutory certificates for methyl/ethyl alcohol fuelled ships, or where the Society is authorized to carry out investigations and surveys on behalf of an Administration on the basis of which the statutory certificates for methyl/ethyl alcohol fuelled ships will be issued by the Administration, or where the Society is requested to certify compliance with MSC.1/Circ.1621, the full compliance with the requirements of MSC.1/Circ.1621, including the operative requirements mentioned in [1.1.4], will be granted by the Society, subject to [1.1.2].

1.2 Documentation to be submitted

1.2.1 *(1/1/2022)*

Tab 1 lists the plans, information, analysis, etc. which are to be submitted in addition to the information required in the other Parts of the Rules, for the portion of the ship not involved in the methyl/ethyl alcohol handling.

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.

Table 1 : Documents to be submitted *(1/1/2022)*

No.	A/I **(1)**	Document
1	I	Propulsion system general arrangement - Design philosophy including information on the machinery configuration, engine room arrangements, fuel arrangements, shutdown philosophy (if applicable), redundancy considerations etc.
2	I	Methyl/ethyl alcohol fuel system risk assessment
3	A	Methyl/ethyl alcohol fuel system arrangement plan - including: • methyl/ethyl alcohol storage and service tanks • tank connection spaces and cofferdams • fuel storage hold spaces • fuel preparation rooms • bunkering stations and other shore connections • engines and other consumers, service and control station spaces • doors and openings to fuel preparation rooms and other hazardous areas • vent mast
4	I	Methyl/ethyl alcohol fuel system operational manual including procedures for: • bunkering, including filling limits curve • gas freeing and inerting • normal operation • emergency operation
5	A	Detailed drawings of methyl/ethyl alcohol fuel service and storage tanks including: • materials, • internal structure with coating, • supporting structure, • heat insulation (if any), • connections, nozzles, manholes, hatches. • strength analysis of fuel tanks with expected maximum allowable pressure.
6	A	Methyl/ethyl alcohol fuel tank pressure and vacuum relief arrangements and associated vent piping specification. Calculation for the discharge capacity of pressure relief valves and discharge piping.
7	A	Methyl/ethyl alcohol fuel tank freeing and purging system piping diagram with connections to inerting, venting and ventilation systems
8	A	Methyl/ethyl alcohol fuel system control, monitoring and safety systems, including a test program for safety functions (ESD - Cause and Effect Matrix)
9	A	Methyl/ethyl alcohol fuel piping system: Pipe routing sketch Piping diagram with supply lines, bunkering lines, vent lines, double wall pipes or ducts arrangement
10	I	Methyl/ethyl alcohol fuel piping system - Specification of valves, flanges and fittings including offsets, loops, bends, expansion elements such as bellows and slip joints.
11	A	Methyl/ethyl alcohol fuel system drip trays - System arrangement plan
12	I	Electrical bonding of piping - Specification
13	A	Heating, cooling and water injection systems - Piping diagrams in connection with methyl/ethyl alcohol fuel system (if any)
14	A	Inerting system - Piping diagram in connection with methyl/ethyl alcohol fuel system
15	A	Exhaust system - Piping diagram including arrangement of explosion relief (if any)
16	A	Hazardous area classification drawing, including air-lock location, construction details and alarm equipment
17	A	Gastight bulkhead penetrations - Detailed drawing

(1) A = to be submitted for approval
I = to be submitted for information.

No.	A/I **(1)**	Document
18	A	Ventilation of methyl/ethyl alcohol fuel system spaces including capacity and location of fans and their motors - Ducting diagram
19	I	Explosion protection • System arrangement plan of electrical equipment in hazardous areas • Single line diagrams for all intrinsically safe circuits, for each circuit, including data for verification of the compatibility between the barrier and the field components • Documentation to demonstrate the fulfilment of [4.3] • List of certified safe type equipment/instruments (Ex) • Certificates of the safe type (Ex) equipment/instrumentation as per [1.3.2] • Maintenance and inspection plan
20	A	Fixed methyl/ethyl alcohol detection system arrangement plan Detectors, call points and alarm devices specification
21	I	FMEA of the whole methyl/ethyl alcohol fuelled system
22	A	Test procedures of safety-critical items, in particular those related to the methyl/ethyl alcohol fuel system as ascertained by the FMEA
23	I	Documentation of alternative design as per [2], as applicable

(1) A = to be submitted for approval
I = to be submitted for information.

1.3 Definitions

MSC.1/Circ.1621 REFERENCE: para. 2.2

1.3.1 *(1/1/2022)*

The terms used in this Appendix have the meanings defined in MSC.1/Circ.1621 para. 2.2.

Terms not defined have the same meaning as in SOLAS chapter II-2 and the IGF Code.

1.3.2 *(1/1/2022)*

"Certified safe type" means electrical equipment that is certified safe by the relevant recognized authorities for operation in a flammable atmosphere based on a recognized standard.

Note 1: Refer to IEC 60079 series, Explosive atmospheres and IEC 60092-502:1999 Electrical Installations in Ships - Tankers - Special Features.

1.3.3 *(1/1/2022)*

"Cofferdam" is the isolating space between two adjacent steel bulkheads or decks. This space may be a void space or a ballast space.

1.3.4 *(1/1/2022)*

"High pressure" in MSC.1/Circ.1621 para. 7.3.6 and 7.3.12.6 means a maximum working pressure greater than 2.0 MPa.

2 Alternative design

MSC.1/Circ.1621 REFERENCE: para. 2.3

2.1 Deviation, equivalence and operational measures

2.1.1 *(1/1/2022)*

Appliances and arrangements may deviate from those set out in this Appendix provided that they meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant paragraphs.

2.1.2 *(1/1/2022)*

The equivalence of the alternative design is to be demonstrated as specified in SOLAS regulation II-1/55, and approved by the Society. Operational methods or procedures will not be allowed as an alternative to a particular fitting, material, appliance, apparatus, item of equipment, or type thereof which is prescribed by this Appendix.

3 Goal and functional requirements

MSC.1/Circ.1621 REFERENCE: para. 3

3.1 Goal

3.1.1 *(1/1/2022)*

The goal of this Appendix is to provide for safe and environmentally friendly design, construction and operation of ships and in particular their installations of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery using methyl/ethyl alcohol as fuel.

3.2 Functional requirements

3.2.1 *(1/1/2022)*

The safety, reliability and dependability of the systems is to be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery.

A FMEA consistent with the "TASNEEF Guide for FMEA" is to be carried out for the whole methyl/ethyl alcohol-fuelled system, including process system, electrical power supplies and control system, to check the potential existence of failure modes that can jeopardize the ship's safety. The results of the FMEA are then to be used to establish a trial program.

3.2.2 *(1/1/2022)*

The probability and consequences of fuel-related hazards are to be limited to a minimum through arrangement and system design, such as ventilation, detection and safety actions. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions are to be initiated.

3.2.3 *(1/1/2022)*

The design philosophy is to ensure that risk reducing measures and safety actions for the gas fuel installation do not lead to an unacceptable loss of power.

3.2.4 *(1/1/2022)*

Hazardous areas are to be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment.

3.2.5 *(1/1/2022)*

Equipment installed in hazardous areas are to be minimized to that required for operational purposes and are to be suitably and appropriately certified.

3.2.6 *(1/1/2022)*

Unintended accumulation of explosive, flammable or toxic gas concentrations are to be prevented.

3.2.7 *(1/1/2022)*

System components are to be protected against external damage.

3.2.8 *(1/1/2022)*

Sources of ignition in hazardous areas are to be minimized to reduce the probability of explosions.

3.2.9 *(1/1/2022)*

Safe and suitable fuel supply, storage and bunkering arrangements are to be provided, capable of receiving and containing the fuel in the required state without leakage.

3.2.10 *(1/1/2022)*

Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application are to be provided.

3.2.11 *(1/1/2022)*

Machinery, systems and components are to be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.

3.2.12 *(1/1/2022)*

Suitable control, alarm, monitoring and shutdown systems are to be provided to ensure safe and reliable operation.

3.2.13 *(1/1/2022)*
Fixed fuel vapour and/or leakage detection suitable for all spaces and areas concerned is to be arranged.

3.2.14 *(1/1/2022)*
Fire detection, protection and extinction measures appropriate to the hazards concerned are to be provided.

3.2.15 *(1/1/2022)*
Commissioning, trials and maintenance of fuel systems and fuel utilization machinery are to satisfy the goal in terms of safety, availability and reliability.

3.2.16 *(1/1/2022)*
The technical documentation is to permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.

3.2.17 *(1/1/2022)*
A single failure in a technical system or component is not to lead to an unsafe or unreliable situation.

4 General provisions

MSC.1/Circ.1621 REFERENCE: para. 4

4.1 Goal

4.1.1 *(1/1/2022)*
The goal of this paragraph [4] is to ensure that the necessary assessments of the risks involved are carried out in order to eliminate or mitigate any adverse effect to the persons on board, the environment or the ship.

4.2 Risk assessment

4.2.1 *(1/1/2022)*
A risk assessment is to be conducted to ensure that risks arising from the use of methyl/ethyl alcohol fuels and potentially affecting persons on board, the environment, the structural strength or the integrity of the ship are addressed. Considerations are to be given to the hazards associated with physical layout, operation and maintenance, following any reasonably foreseeable failure.

4.2.2 *(1/1/2022)*
The risks are to be analysed using acceptable and recognized risk analysis techniques, and loss of function, component damage, fire, explosion, toxicity and electric shock are as a minimum to be considered. The analysis is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as necessary. Details of risks, and the means by which they are mitigated, are to be documented to the satisfaction of the Society.

The risk assessment can be carried out using the techniques (HAZID, FMECA, HAZOP) described in the "TASNEEF Guide on Risk Analysis".

4.2.3 *(1/1/2022)*
For ships to which this Appendix applies, the risk assessment required by [4.2.1] needs to be conducted:

a) where required by paragraphs 5.4.4, 5.5.2, 5.6.3, 5.10.2, 6.3.2, 6.4.2, 6.5.2, 8.3.3, 10.3.3, 10.6.3 of this Appendix;

b) in the context of the requirements in MSC.1/Circ.1621 paragraphs 3.2.17, 5.6.1, 5.10.2, 8.3.1.1, 8.5.2, 9.3.2, 10.2.2, 13.5, 15.2.1, 15.7.1.8; and

c) when other potential hazards connected with the use of methyl/ethyl alcohol fuels as fuel are to be addressed.

4.2.4 *(1/1/2022)*
The assumptions for the risk assessment are to be agreed by a team of experts acceptable to the Society. It may include a representative of Class, Flag Administration, owner, builder or designer, and consultants having the necessary knowledge and experience in safety, design and/or operation as necessary for the specific evaluation at hand. Other members may include marine surveyors, ship operators, safety engineers, equipment manufacturers, human factors experts, naval architects and marine engineers, according to the problem under scope.

4.2.5 *(1/1/2022)*
The risk assessment can be qualitative or quantitative and is to cover the following aspects:

- Accidental release and dispersion (scenario for methyl/ethyl alcohol leakages due to piping rupture)

- Deflagration and detonation
- Fires (radiative heat fluxes, fire resistance of methyl/ethyl alcohol system)
- Impact on people, asset and environment (severity of methyl/ethyl alcohol incidents)
- Mitigation techniques (detection method, barriers, ventilation level)
- Emergency operation (strategy control of incident)

The risk assessment is to include the following hazards:

- Creation of explosive atmosphere (methyl/ethyl alcohol concentration in air)
- High flammability
- Chemical reaction with oxidant agents
- Invisible and very hot flame during methyl/ethyl alcohol burning
- Toxicity of vapours
- Corrosion.

4.3 Limitation of explosion consequences

4.3.1 *(1/1/2022)*

The preferred safety policy is to be the elimination of either any source of release or any source of ignition, or both. Only in case this is demonstrated not to be feasible, the MSC.1/Circ.1621 para. 4.3 applies. In this case an explosion analysis is to be carried out to demonstrate that, for the worst case scenario, the maximum pressure built-up in case of explosion does not exceed the design pressure of the space, enclosure, air lock, tank, taking into account the venting arrangement and the explosion pressure relief devices, where provided. The scenario for the explosion analysis shall be evaluated during the risk assessment

5 Ship design and arrangement

MSC.1/Circ.1621 REFERENCE: para. 5

5.1 Goal

5.1.1 *(1/1/2022)*

The goal of this paragraph [5] is to provide for safe location, space arrangements and mechanical protection of power generation equipment, fuel storage system, fuel supply equipment and refuelling systems.

5.2 Functional requirements

5.2.1 *(1/1/2022)*

This paragraph [5] is related to functional requirements in 3.2.1, 3.2.2, 3.2.3, 3.2.4, 3.2.5, 3.2.6, 3.2.7, 3.2.12, 3.2.14 and 3.2.16 of MSC.1/Circ.1621. In particular, the following applies:

a) the fuel tank(s) is(are) be located in such a way that the probability of the tank(s) being damaged following a collision or grounding is reduced to a minimum taking into account the safe operation of the ship and other hazards that may be relevant to the ship;

b) fuel containment systems, fuel piping and other fuel release sources are to be located and arranged such that released fuel, either as vapour or liquid, is led to safe locations;

c) the access or other openings to spaces containing potential sources of fuel release are to be arranged such that flammable, asphyxiating or toxic vapours or liquids cannot escape to spaces that are not designed for the presence of such substances;

d) fuel piping is to be protected against mechanical damage;

e) the propulsion and fuel supply system is to be designed such that safety actions after any fuel leakage do not lead to an unacceptable loss of power; and

f) the probability of a fire or explosion in a machinery space as a result of a fuel release is to be minimized in the design, with special attention to the risk of leakage from pumps, valves and connections.

5.3 General provisions

5.3.1 *(1/7/2025)*

The requirements in MSC.1/Circ.1621 para. 5.3 and the relevant interpretations in IACS UI GF20 apply.

5.3.2 *(1/1/2022)*

Where cofferdams surrounding integral fuel storage tanks are water filled, they are to be specially considered as ballast tanks in terms of corrosion addition and scantling as indicated in Pt B, Ch 4, Sec 2 and Pt B, Ch 7, Sec 1 to Pt B, Ch 7, Sec 3.

5.3.3 *(1/1/2022)*

In case the fuel tanks are surrounded with cofferdam this one is to be arranged with dedicated mechanical forced ventilation system according to [5.11] or filled with water. Bilging/draining of the cofferdams is to be done by a separate bilge/drainage system with possibility for discharge overboard and collection in dedicated holding tank which can be portable or fixed.

5.4 Independent fuel tanks

5.4.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 5.4 apply.

5.4.2 *(1/1/2022)*

For single fuel installations with methyl/ethyl alcohol as primary fuel or where fuel oil is only used as pilot, two methyl/ethyl alcohol fuel service tanks are to be fitted, each having a capacity of at least 8 h at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant.

5.4.3 *(1/1/2022)*

For single fuel installations with methyl/ethyl alcohol as primary fuel or where fuel oil is only used as pilot, two methyl/ethyl alcohol fuel storage tanks are to be fitted so that, in the event of any one tank becoming unavailable, the remaining tank(s) will provide sufficient fuel to enable the ship to operate within its service. These tanks are to be located in separate spaces. If those spaces are adjacent, the insulation between both spaces is to be at least A-60.

5.4.4 *(1/1/2022)*

For dual fuel installations, where oil fuel is considered as primary fuel and in case of failure of methyl/ethyl alcohol fuel system the engine is capable to switch to fuel oil without loss of propulsion the service tank may be omitted. The risks and hazards of the configuration are to be evaluated in the risk assessment as required in [4.2] and the fuel supply system is to comply with Sec 10, [11.9].

5.4.5 *(1/1/2022)*

The arrangement for supporting and fixing the tanks are to be designed for the maximum expected static, dynamic inclinations and accidental loads according to Sec 1, [2.4] and Ch 2, Sec 2, [1.6], as well as the accelerations according to Pt B, Ch 5, Sec 3 taking into account the ship's characteristics and the position of the tanks.

5.5 Portable Tanks

5.5.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 5.5 apply.

5.5.2 *(1/1/2022)*

The hazards and risks about the location and mobilization of the portable tanks on board shall be evaluated in the risk assessment as required in [4.2].

5.5.3 *(1/1/2022)*

Portable fuel tanks are to be secured to the deck or hold space while connected to the ship systems. The arrangement for supporting and fixing the tanks are to be designed for the maximum expected static and dynamic inclinations according to Pt C, Ch 1, Sec 1, Tab 1 and Pt C, Ch 2, Sec 2, Tab 4, as well as the accelerations according to Pt B, Ch 5, Sec 3 taking into account the ship's characteristics and the position of the tanks.

5.6 Provisions for machinery space

5.6.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 5.6 apply.

5.6.2 *(1/1/2022)*

The double wall pipes and enclosure according to [5.6.3] are not to be considered as source of release.

5.6.3 *(1/1/2022)*
Enclosure used for the containment of methyl/ethyl alcohol piping (e.g. valves, pumps, filters etc..) excluding annular space of double wall pipes are to be provided with means for draining and for inspection. The layout of inspection openings and connections for draining is to be evaluated in the risk assessment as required in [4.2].

5.7 Provisions for location and protection of fuel piping

5.7.1 *(1/1/2022)*
The requirements in MSC.1/Circ.1621 para. 5.7 apply.

5.7.2 *(1/1/2026)*
In case of double wall pipes the annular space between inner and outer pipe is to be provided either with:

a) an independent mechanical underpressure ventilation having a capacity of minimum 30 air changes per hour and be routed to open air, or

b) filled with inert gas at a pressure greater than the methyl/ethyl alcohol fuel pressure, or

c) filled with inert gas at a pressure greater than piping installation space pressure.

For cases b) and c) above, suitable alarms are to be provided to indicate a loss of inert gas pressure between the pipes.

Appropriate means for detecting leakage into the annular space are to be provided. The double wall enclosure is to be fitted with means for safe draining to a suitable fixed or portable tank allowing the collection and the detection of any possible leakage.

5.7.3 *(1/1/2022)*
The outer pipe in the double walled fuel pipes is to be designed for a design pressure not less than the maximum working pressure of the methyl/ethyl alcohol fuel pipes.

5.8 Provisions for fuel preparation spaces design

5.8.1 *(1/1/2022)*
The requirements in MSC.1/Circ.1621 para. 5.8 apply.

5.8.2 *(1/1/2022)*
The enclosures required in [5.6.3] are to be considered as fuel preparation space with reference to MSC.1/Circ.1621 para. 2.2.4. Those enclosures which, due their dimensions, cannot be entered during operation of methyl/ethyl alcohol fuel supply system are to be fitted with inspection means to be used only after the space can be assumed as safe.

5.9 Provisions for bilge systems

5.9.1 *(1/1/2022)*
The requirements in MSC.1/Circ.1621 para. 5.9 apply.

5.9.2 *(1/1/2022)*
The bilge systems installed in areas where leaked methyl/ethyl alcohol fuel can be present are to be fitted with sampling points for possible detection of explosive atmosphere.

5.10 Provisions for drip trays

5.10.1 *(1/1/2022)*
The requirements in MSC.1/Circ.1621 para. 5.10 apply.

5.10.2 *(1/1/2022)*
The capacity of drip trays is to be evaluated through the risk assessment taking into account the following steps:

a) The team of experts is to conduct a Hazard Identification (HAZID) to agree on the scenarios to be subjected to the risk assessment, and on the assumptions regarding the most critical events (e.g. instrument connection failure causing methyl/ethyl alcohol fuel leakage) considering also available internationally recognized standard (e.g. ISO/TR 15916) for the identification of hazards and risks.

b) Reasonable assumptions on the extent of connection failures or other selected events and the process parameters of the methyl/ethyl alcohol fuel are to be made by the team of experts, preferably on the basis of statistics available in the public domain or provided and documented by stakeholders.

c) Reasonable assumptions on the operation of ventilation system are to be made according to layout and procedures of the affected space.

d) In order to verify that the methyl/ethyl alcohol fuel release will not create flammable concentrations and to demonstrate the drip tray capacity for a methanol spill, if needed a specific simulation is to be set up, aimed at evaluating the maximum amount of methanol spilled and its cloud, the evaporation rate and the possibility to fully accommodate the methyl/ethyl alcohol fuel in the drip tray. The dispersion of vapors resulting from methyl/ethyl alcohol fuel evaporation in the affected space is also to be ascertained in respect of explosive atmosphere.

e) The simulation is to be conducted by commercially available and validated tools (typically, by CFD tools). It is to focus on the calculation of the amount of methyl/ethyl alcohol fuel spilled before the stop of methanol flow. Other calculation methods (e.g. empirical formulas based on literature) may be also acceptable.

f) As a precaution, in order to maximize the accumulation of methyl/ethyl alcohol fuel into the drip tray, methyl/ethyl alcohol release is to be assumed as directed downward, impinging on the drip tray and effects of spill protection arrangement can be taken into account.

g) Reasonable assumptions are to be made by the expert team regarding detection time, methyl/ethyl alcohol flow stop time and human reaction time, in case operators are credited in the emergency.

h) If the simulation or calculation demonstrates that the drip tray cannot accommodate the methyl/ethyl alcohol spill, mitigating measures are to be provided and to be evaluated during the risk assessment.

5.11 Provisions for arrangement of entrances and other openings in enclosed spaces

5.11.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 5.11 apply.

5.11.2 *(1/1/2022)*

Passageways between the surface to be inspected, flat or curved, and structural elements such as deck beams, stiffeners, frames, girders etc., are to have a distance between that surface and the free edge of the structural elements of at least 380 mm. The distance between the surface to be inspected and the surface to which the above structural elements are fitted, e.g. deck, bulkhead or shell, is to be at least 450 mm in case of a curved tank surface or 600 mm in case of a flat tank surface.

5.12 Provisions for airlocks

5.12.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 5.12 apply.

5.12.2 *(1/1/2022)*

The air locks are not to be used as control station for the methyl/ethyl alcohol fuel system.

5.12.3 *(1/1/2022)*

In case an explosion analysis is performed according to [4.3] the air lock door is to be designed taking into account the built up pressure as result of explosion.

6 Fuel containment system

MSC.1/Circ.1621 REFERENCE: para. 6

6.1 Goal

6.1.1 *(1/1/2022)*

The goal of this paragraph [6] is to provide for a fuel containment system where the risk to the ship, its crew and to the environment is minimized to a level that is at least equivalent to a conventional oil-fuelled ship.

6.2 Functional requirements

6.2.1 *(1/1/2022)*

This paragraph [6] refers to functional requirements in 3.2.1, 3.2.2, 3.2.5 and 3.2.8 to 3.2.16 of MSC.1/Circ.1621.

6.2.2 *(1/1/2022)*

The fuel tanks are to be designed such that a leakage from the fuel tank or its connections does not endanger the ship, persons on board or the environment. Potential dangers to be avoided include:

- *flammable fuels spreading to locations with ignition sources;*
- *toxicity potential and risk of oxygen deficiency or other negative impacts on crew health due to fuels and inert gases;*
- *restriction of access to muster stations, escape routes or LSAs; and*
- *reduction in availability of LSAs.*

6.2.3 *(1/1/2022)*

The fuel containment system and the fuel supply system are to be designed such that safety actions after any leakage, irrespective of in liquid or vapour phase, do not lead to an unacceptable loss of power.

6.2.4 *(1/1/2022)*

If portable tanks are used for fuel storage, the design of the fuel containment system is to be equivalent to permanent installed tanks as described in this paragraph.

6.3 Provisions for fuel tanks venting and gas freeing system

6.3.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 6.3 apply.

6.3.2 *(1/1/2022)*

Fuel tank vent outlets with vapour discharge arranged:

- directed horizontally on shell side under water line
- directed horizontally on shell side above water line

may be accepted if the risks and the hazards are evaluated during the risk assessment as required in [4.2] considering the dispersion property and density of methyl/ethyl alcohol fuel vapour.

6.4 Inerting and atmospheric control within the fuel storage system

6.4.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 6.4 apply.

6.4.2 *(1/1/2022)*

Gas freeing operations with discharge arranged:

- directed horizontally on shell side under water line
- directed horizontally on shell side above water line

may be accepted if the risks and the hazards are evaluated during the risk assessment as required in [4.2] considering the dispersion property and density of methyl/ethyl alcohol fuel vapour.

6.4.3 *(1/1/2022)*

Pressure and vacuum relief valves and the devices for the prevention of flame propagation into the fuel containment system are to be type approved by the Society.

6.5 Inert gas availability on board

6.5.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 6.5 apply.

6.5.2 *(1/1/2022)*

In case the inert gas for the gas freeing is provided externally to the ship (e.g. yard, bunkering ships, terminals) the risks and hazards of the transfer operation are to be evaluated during the risk assessment as required in [4.2].

7 Material and general pipe design

MSC.1/Circ.1621 REFERENCE: para. 7

7.1 Goal

7.1.1 *(1/1/2022)*

The goal of this paragraph [7] is to ensure the safe handling of fuel, under all operating conditions, to minimize the risk to the ship, personnel and to the environment, having regard to the nature of the products involved.

7.2 Functional requirements

7.2.1 *(1/1/2022)*

This paragraph [7] relates to functional requirements in 3.2.1, 3.2.6, 3.2.8, 3.2.9 and 3.2.10 of MSC.1/Circ.1621. In particular, all materials used are to be suitable for the fuel under the maximum working pressure and temperature.

7.3 Provisions for general pipe design

7.3.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 7.3 apply.

7.3.2 *(1/1/2025)*

Piping systems are subdivided into three classes, denoted as class I, class II and class III (as defined in Sec 10, Tab 3), for the purpose of acceptance of materials, selection of joints, heat treatment, welding, pressure testing and the certification of fittings.

Due to the toxicity of the methyl/ethyl alcohol fuel:

- single wall pipes and inner pipes of double wall arrangements are to be class I piping systems,
- outer pipes of double wall piping arrangements are to be class II piping systems, and
- vent and bleed lines conveying methyl/ethyl alcohol fuel vapours connected to open atmosphere are to be class III piping systems.

7.3.3 *(1/1/2022)*

Junction of pipes are to comply additionally with requirements defined in Sec 10, [2.1]

Design and installation of flexible hoses and expansion joints are to comply additionally with requirements defined in Sec 10, [2.6].

7.4 Provisions for materials

7.4.1 **Metallic materials** *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 7.4 apply.

7.4.2 *(1/1/2022)*

Use of metallic materials is stipulated in Sec 10, [2.1].

Plastic pipes for conveying the methyl/ethyl alcohol fuel are not allowed.

8 Bunkering

MSC.1/Circ.1621 REFERENCE: para. 8

8.1 Goal

8.1.1 *(1/1/2022)*

The goal of this paragraph [8] is to provide for suitable systems on board the ship to ensure that bunkering can be conducted without causing danger to persons, the environment or the ship.

8.2 Functional requirements

8.2.1 *(1/1/2022)*

This paragraph [8] relates to functional requirements in 3.2.1, 3.2.2, 3.2.3, 3.2.4, 3.2.5, 3.2.6, 3.2.7, 3.2.8, 3.2.9, 3.2.10, 3.2.11, 3.2.13, 3.2.14, 3.2.15 and 3.2.16 of MSC.1/Circ.1621. In particular, the following applies:

The piping system for transfer of fuel to the storage tank is to be designed such that any leakage from the piping system cannot cause danger to persons, the environment or the ship.

8.3 Provisions for bunker station

8.3.1 *(1/1/2022)*
The requirements in MSC.1/Circ.1621 para. 8.3 apply.

8.3.2 *(1/1/2022)*
Bunkering hoses, quick connect/disconnect couplings and emergency release couplings are to be type approved by the Society.

8.3.3 *(1/1/2022)*
The bunkering procedure including the steady transfer, topping, inerting, and ESD operations are to be considered in the risk assessment required in [4.2].

8.4 Provisions for manifold

8.4.1 *(1/1/2022)*
The requirements in MSC.1/Circ.1621 para. 8.4 apply.

8.4.2 *(1/1/2022)*
The manifold flanges and supports are to be designed to withstand the maximum allowable forces acting on the worst scenario where emergency release coupling or break way coupling is activated.

8.5 Provisions for bunkering system

8.5.1 *(1/1/2022)*
The requirements in MSC.1/Circ.1621 para. 8.5 apply.

9 Fuel supply to consumers

MSC.1/Circ.1621 REFERENCE: para. 9

9.1 Goal

9.1.1 *(1/1/2022)*
The goal of this paragraph [9] is to ensure safe and reliable distribution of fuel to the consumers.

9.2 Functional requirements

9.2.1 *(1/1/2022)*
This paragraph [9] is related to functional requirements in 3.2.1, 3.2.2, 3.2.3, 3.2.4, 3.2.5, 3.2.6, 3.2.8, 3.2.9, 3.2.10, 3.2.11 and 3.2.13 to 3.2.17 of MSC.1/Circ.1621.

9.3 General provisions for fuel supply system

9.3.1 *(1/1/2022)*
The requirements in MSC.1/Circ.1621 para. 9.3 apply.

9.4 Provisions for fuel distribution

9.4.1 *(1/1/2022)*
The requirements in MSC.1/Circ.1621 para. 9.4 apply.

9.4.2 *(1/1/2022)*
Where fuel pipes excluding vent and bleed lines pass through enclosed spaces in the ship, they are to be protected by a secondary enclosure.

9.4.3 *(1/1/2022)*
In multi-consumers installations which are supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines, are to be provided. The means of isolation are not to affect the operation of the other consumers and are to be operable from a position not rendered inaccessible by a fire on any of the consumers.

9.5 Redundancy of fuel supply

9.5.1 *(1/1/2022)*
The requirements in MSC.1/Circ.1621 para. 9.5 apply

9.6 Safety functions of the fuel supply system

9.6.1 *(1/1/2022)*
The requirements in MSC.1/Circ.1621 para. 9.6 apply.

9.7 Provisions for fuel preparation spaces and pumps

9.7.1 *(1/1/2022)*
The requirements in MSC.1/Circ.1621 para. 9.7 apply.

10 Power generation including propulsion and other energy converters

MSC.1/Circ.1621 REFERENCE: para. 10

10.1 Goal

10.1.1 *(1/1/2022)*
The goal of this paragraph [10] is to provide safe and reliable delivery of mechanical, electrical or thermal energy.

10.2 Functional requirements

10.2.1 *(1/1/2022)*
This paragraph [10] is related to functional requirements in 3.2.1, 3.2.11, 3.2.13, 3.2.14, 3.2.15, 3.2.16 and 3.2.17 of MSC.1/Circ.1621. In particular the following applies:

a) the exhaust systems are to be designed to prevent any accumulation of unburnt fuel;

b) each fuel consumers is to have a separate exhaust system.

10.2.2 *(1/1/2022)*
One single failure in the fuel system is not to lead to an unacceptable loss of power.

10.3 Provisions for internal combustion engines

10.3.1 *(1/1/2022)*
The requirements in MSC.1/Circ.1621 para. 10.3 apply.

10.3.2 *(1/1/2022)*
Methyl/ethyl alcohol engines are to be type approved according to Sec 2.

10.3.3 *(1/1/2022)*
A risk assessment of the engine is to be carried out using the HAZID or FMECA methods and reflected in the safety concept of the engine. The risk assessment is to cover at least the following hazards:

- accumulation of methyl/ethyl alcohol fuel vapors in the charge air system or in the crankcase leading to explosive atmosphere
- condensation of methyl/ethyl alcohol vapours
- leakage of methyl/ethyl alcohol liquid fuel from high pressure system (if applicable)
- unburnt methyl/ethyl alcohol vapours in the exhaust duct
- single failure of a methyl/ethyl alcohol fuel admission valve or injection valve
- single failure of the ignition system (sparking plug or pilot injection)
- leakage of the methyl/ethyl alcohol fuel system into the auxiliary systems (cooling and lubricating)
- single failure of the purging system
- effects of methyl/ethyl alcohol characteristics associated with its composition (density, flashpoint, heat value, flammability range).

10.4 Provision for dual-fuel engines

10.4.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para.10.4 apply.

10.4.2 *(1/1/2022)*

The dual fuel engines are to comply with App 12, as applicable.

10.5 Provision for single fuel engines

10.5.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 10.5 apply.

10.6 Requirements for dual fuel boilers

10.6.1 *(1/1/2022)*

Boiler arrangements are to comply with the requirements of Sec 3 and Sec 10.

10.6.2 *(1/1/2022)*

Combustion chambers and uptakes are to be designed to prevent any accumulation of unburned methyl/ethyl alcohol fuel.

10.6.3 *(1/1/2022)*

In case of dual fuel boilers essential for the ship main propulsion, an automatic system is to be provided for a fast changeover from methyl/ethyl alcohol fuel operation to oil fuel operation giving relevant alarm.

10.6.4 *(1/1/2022)*

A risk assessment of the dual fuel boiler is to be carried out using the HAZID or FMECA methods and reflected in the safety concept of the boiler. The risk assessment is to cover at least the following hazards:

- condensation of methyl/ethyl alcohol vapours
- unburnt methyl/ethyl alcohol vapours in the exhaust duct
- single failure of a methyl/ethyl alcohol fuel supply valve
- single failure of the burner and flame scanner
- single failure of the purging system
- effects of methyl/ethyl alcohol characteristics associated with its composition (density, flashpoint, heat value, flammability range).

11 Fire safety

MSC.1/Circ.1621 REFERENCE: para. 11

11.1 Application

11.1.1 *(1/1/2026)*

This paragraph is void, as the provisions of MSC.1/Circ.1621 para. 11 are not within the scope of classification.

These provisions are applied by the Society when acting on behalf of the flag Administration, within the scope of delegation (see [1.1.6]), together with the relevant interpretations in IACS UI GF21, unless instructed otherwise by the flag Administration.

12 Explosion prevention and area classification

MSC.1/Circ.1621 REFERENCE: para. 12

12.1 Goal

12.1.1 *(1/1/2022)*

The goal of this paragraph [12] is to provide for the prevention of explosions and for the limitation of effects of a fire and explosion.

12.2 Functional requirements

12.2.1 *(1/1/2022)*

This paragraph [12] is related to functional requirements in 3.2.1, 3.2.2, 3.2.3, 3.2.4, 3.2.5, 3.2.6, 3.2.8 and 3.2.11 to 3.2.17 of MSC.1/Circ.1621. The probability of explosions is to be reduced to a minimum by:

a) reducing number of sources of ignition; and

b) reducing the probability of formation of ignitable mixtures, and

c) using certified safe type electrical equipment suitable for the hazardous zone where the use of electrical equipment in hazardous areas is unavoidable.

12.3 General provisions

12.3.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para.12.3 apply.

12.4 Area classification

12.4.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 12.4 apply.

12.5 Hazardous area zones

12.5.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 12.5 apply.

13 Ventilation

MSC.1/Circ.1621 REFERENCE: para. 13

13.1 Goal

13.1.1 *(1/1/2022)*

The goal of this paragraph [13] is to provide for the ventilation required for safe working conditions for personnel and the safe operation of machinery and equipment where methyl/ethyl alcohol is used as fuel.

13.2 Functional requirements

13.2.1 *(1/1/2022)*

This paragraph [13] is related to functional requirements in 3.2.1, 3.2.2, 3.2.4, 3.2.6 and 3.2.11 to 3.2.17 of MSC.1/Circ.1621.

13.3 Previsions - General

13.3.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 13.3 apply.

13.3.2 *(1/1/2022)*

Loss or reduction of required ventilation capacity in a hazardous area is to give an audible and visual alarm on the navigation bridge and in a continuously manned central control station or safety center and locally as applicable.

13.3.3 *(1/1/2022)*

An approved type fail-safe automatic closing fire damper is to be fitted in each ventilation duct serving tank connection spaces, fuel preparation rooms or other hazardous enclosed spaces.

13.4 Provisions for fuel preparation spaces

13.4.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 13.4 apply.

13.5 Provisions for bunkering station

13.5.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 13.5 apply.

13.6 Provisions for ducts and double wall pipes

13.6.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 13.6 apply.

14 Electrical installations

MSC.1/Circ.1621 REFERENCE: para. 14

14.1 Goal

14.1.1 *(1/1/2022)*

The goal of this paragraph [14] is to provide for electrical installations that minimize the risk of ignition in the presence of a flammable atmosphere.

14.2 Functional requirements

14.2.1 *(1/1/2022)*

This paragraph [14] is related to functional requirements in 3.2.1, 3.2.2, 3.2.3, 3.2.5, 3.2.8, 3.2.11, 3.2.13, 3.2.15, 3.2.16 and 3.2.17 of MSC.1/Circ.1621.

14.3 Provisions - General

14.3.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 14.3 apply.

15 Control monitoring and safety systems

MSC.1/Circ.1621 REFERENCE: para. 15

15.1 Goal

15.1.1 *(1/1/2022)*

The goal of this paragraph [15] is to provide for the arrangement of control, monitoring and safety systems that support an efficient and safe operation of the fuel installations as covered in the other paragraphs of this Appendix.

15.2 Functional requirements

15.2.1 *(1/1/2022)*

This paragraph [15] is related to functional requirements in 3.2.1, 3.2.2, 3.2.3, 3.2.9, 3.2.10, 3.2.11, 3.2.13, 3.2.14 and 3.2.17 of MSC.1/Circ.1621. In particular, the following applies:

a) the control, monitoring and safety systems of the methyl/ethyl alcohol installations are to be arranged such that there is not an unacceptable loss of power in the event of a single failure;

b) a fuel safety system is to be arranged to close down the fuel supply system automatically, upon failure in systems as described in table 1 of MSC.1/Circ.1621 and upon other fault conditions which may develop too fast for manual intervention;

c) the safety functions are to be arranged in a dedicated fuel safety system that is independent of the fuel control system in order to avoid possible common cause failures; this includes power supplies and input and output signal;

d) the safety systems including the field instrumentation are to be arranged to avoid spurious shutdown, e.g. as a result of a faulty vapour detector or a wire break in a sensor loop; and

e) where two fuel supply systems are required to meet the provisions, each system is to be fitted with its own set of independent fuel control and safety systems.

15.3 General provisions

15.3.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 15.3 apply.

15.4 Provisions for bunkering and fuel tank monitoring

15.4.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 15.4 apply.

15.5 Provisions for bunkering control

15.5.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 15.5 apply.

15.5.2 *(1/1/2022)*

The bunkering station is to be under direct view from a bunkering control station, if any, or from the bridge; as an alternative a CCTV system may be considered.

15.6 Provisions for engine monitoring

15.6.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 15.6 apply.

15.7 Provisions for gas detection

15.7.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 15.7 apply.

15.8 Provisions for fire detection

15.8.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 15.8 apply.

15.9 Provisions for ventilation

15.9.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 15.9 apply.

15.10 Provisions on safety functions of fuel supply systems

15.10.1 *(1/1/2022)*

The requirements in MSC.1/Circ.1621 para. 15.10 apply.

16 Manufacture workmanship and testing

16.1 General

16.1.1 *(1/1/2022)*

The manufacture, testing, inspection and documentation are to be in accordance with recognized standards and the Society Rules, in particular those in Sec 3 and Sec 10.

APPENDIX 16 BIOFUEL

1 General

1.1 Application

1.1.1 Engines *(1/7/2023)*

The following internal combustion engines are to comply with the requirements of this Appendix when using biofuels:

- main propulsion engines
- engines driving electric generators
- engines driving other auxiliaries essential for safety and navigation and cargo pumps in tankers, when they develop a power of 110 kW and over.

1.1.2 Engines for emergency services *(1/1/2025)*

The use of biodiesel or biodiesel blends (with a biodiesel percentage above 7%) is not permitted to supply engines driving emergency generators and or other emergency services (e.g. emergency fire pumps) as well as engines of lifeboats, rescue boats and similar.

Special considerations may be given to the use of HVO or HVO blends upon examination of the fuel properties as reported in the fuel data sheets or fuel check analysis, and execution of a dedicated risk analysis.

1.1.3 Fuel Cell Modules *(1/7/2023)*

The following fuel cell modules are to comply with the requirements of this Appendix when using biofuels:

- fuel cell modules used to power at least one of the essential services defined in Ch 2, Sec 1, [3.2.1] necessary to ensure the compliance of the main source of electrical power to the requirements in Ch 2, Sec 3, [2.2.3]
- fuel cell modules used to power only services not falling under the definition of essential services in Ch 2, Sec 1, [3.2.1] when they develop a power of 110 kW and over.

1.2 Documentation to be submitted

1.2.1 *(1/7/2023)*

The documents listed in Tab 1 are to be submitted.

The list of documents requested is intended as a guidance for the complete set of information to be submitted, rather than an actual list of titles.

The Society reserves the right to request additional documents in the case of non-conventional design or if it is deemed necessary for the evaluation of the system, equipment or components.

1.3 Definitions and abbreviations

1.3.1 *(1/7/2023)*

Bioammonia is produced from various raw materials such as corn and woody biomass. It is colorless compound and it may be generated from biological degradation of organic matter.

1.3.2 *(1/7/2023)*

Biodiesel means a fuel oil which is derived from biomass and hence includes, but is not limited to, processed used cooking oils, fatty-acid-methyl-esters (FAME) or fatty-acid-ethyl-esters (FAEE), straight vegetable oils (SVO), hydrotreated vegetable oils (HVO), glycerol or other biomass to liquid (BTL) type products.

1.3.3 *(1/7/2023)*

Bioethanol is an alcohol made by fermentation, mostly from carbohydrates produced in sugar or starch crops such as maize, sugarcane, or sweet sorghum. Cellulosic biomass, derived from non-food sources, such as trees and grasses, may be as a feedstock for ethanol production.

1.3.4 *(1/7/2023)*

Biofuel blend means a blend of biofuel and fossil fuel oil.

1.3.5 *(1/7/2023)*

Biohydrogen is produced by steam reforming of methane (biogas) given by anaerobic digestion of organic waste. It may also be produced by fermentation of renewable materials by bacteria which may take place in light (photofermentation) or in the absence of light (dark fermentation).

1.3.6 *(1/1/2025)*

BioMethane (**BioCNG or BioLNG**) is a non-fossil gas, consisting of almost 100% methane, locally produced, gained from the biogas from waste streams such as organic household waste, sludge, manure or agricultural waste. This biogas is upgraded to BioMethane, compressed or liquefied into BioCNG or BioLNG respectively.

1.3.7 *(1/7/2023)*

Biomethanol is an alcohol produced by either gasification or pyrolysis from biomass like forage grasses, trees, and crop residues.

1.3.8 *(1/7/2023)*

Blend ratio means the mass percentage of biofuel in a biofuel blend.

1.3.9 *(1/7/2023)*

BTL (Biomass to Liquid) fuels are synthetic fuels that are produced from biomass by means of thermo-chemical conversion using the Fischer-Tropsch process or the methanol to gasoline process. International recognized standards applicable for the biofuel BTL may be EN 16709, EN 15940.

1.3.10 *(1/7/2025)*

FAME (Fatty Acid Methyl Ester) biofuel is produced from vegetable oils, animal fats or waste cooking oils by transesterification, where various oils (triglycerides) are converted to methyl esters. It is considered a type of biodiesel which can be often blended with conventional marine diesel oils. International recognized standards applicable for the biofuel FAME may be ISO 8217:2024, EN 14214, ASTM D6751, EN 590.

1.3.11 *(1/7/2023)*

HVO/HDRD (Hydrogen Vegetable Oil/Hydrogenation Derived Renewable Diesel) is the product of fats or vegetable oils alone or blended with petroleum refined by a hydrotreating process known as fatty acids-to-hydrocarbon hydrotreatment. Diesel produced using this process is often called renewable diesel to differentiate it from FAME biodiesel. International recognized standard applicable for the biofuel HVO/HDRD may be ASTM D 975.

1.3.12 *(1/7/2023)*

SVO/PPO (Straight Vegetable Oil/Pure Plant Oil) is produced from seeds or fruits of oil plants (colza, oil palm, jatropha curcas, etc.).

Table 1 : Documents to be submitted *(1/7/2025)*

No.	A/I **(1)**	Document	TOXIC or F.P.< 60°C	FAME>30%	FAME<30%	HVO	OTHER
1	I	Biofuel Technical File including the technical specification, material safety data sheet with chemical composition, properties, hazards, blending ratio (if mixed with conventional fuel)	X	X	X	X	X
2	I	Risk Assessment report, as per [2.2.1]	X				
3	I	Technical report as per [2.2.2]		X			X
4	I	Engine/fuel cell maker statement about general suitability for use with the proposed biofuel or biofuel blend as per [2.2.3] **(2)**	X	X	X	X	X

(1) A = to be submitted for approval
I = to be submitted for information.

(2) The engine/fuel cell maker statement may apply to an engine/fuel cell type or series and does not need to be specific to the considered engine/fuel cell and ship.

Note 1: X = submission is required.

No.	A/I **(1)**	Document	TOXIC or F.P.< 60°C	FAME>30%	FAME<30%	HVO	OTHER
5	I	Operational manual for the safe bunkering, storage and supply of the biofuel	X	X	X	X	X
6	A	Structure drawings of fuel service and storage tanks	X	X	X	X	X
7	A	Biofuel piping system	X	X	X	X	X

(1) A = to be submitted for approval
I = to be submitted for information.

(2) The engine/fuel cell maker statement may apply to an engine/fuel cell type or series and does not need to be specific to the considered engine/fuel cell and ship.

Note 1: X = submission is required.

2 General Provisions

2.1 Biofuel Technical File

2.1.1 *(1/7/2025)*

A technical file of the biofuel is to be made available on board. The document is to include all information relevant to the biofuel given by the producer as follows and not limited to:

- brief description of the biofuel production process
- example of bunkering delivery note
- material safety data sheet
- general chemical composition and physical properties, including applicable limits (e.g. viscosity, oxidation stability, Cloud Point (CP) and Cold Filter Plugging Point (CFPP))
- blending ratio with fossil fuels.

2.2 Risk Assessment

2.2.1 *(1/7/2025)*

For all biofuels (including biofuel blends) with low flash points or specific toxic hazards for humans, a risk assessment is to be conducted to ensure that risks arising from the use of such biofuels are below acceptable limits. The following risks are to be analyzed as a minimum, using acceptable and recognized risk analysis techniques:

- loss of function (propulsion and generation of electrical power)
- component damage
- fire
- explosion
- toxicity
- environmental impact in case of spillage.

The analysis is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as necessary. Details of risks and mitigation means, are to be documented to the satisfaction of the Society.

The risk assessment can be carried out using the techniques (HAZID, FMECA, HAZOP) described in the "TASNEEF Guide on Risk Analysis".

2.2.2 *(1/7/2025)*

For biofuels (including biofuel blends) not presenting toxicity or flammability hazards, the risk assessment may be replaced by a technical report where the risks to the ship propulsion and power generation systems are duly assessed by engine/fuel cell module maker, design company and yard, addressing at least the following issues:

- loss of function (propulsion and generation of electrical power)
- performance of engines and fuel cell modules
- reliability of biofuel supply, injection system and storage system considering possible clogging, fuel change over contamination, chemical reaction with other stored fuels or with water, ageing due to oxidation and microbial growth
- suitability of fire extinguishing system for the biofuel
- special adjustments and setting of parameters for the correct functioning of engines and fuel cells.

2.2.3 *(1/7/2025)*
For HVO and blends having low FAME Biofuel content (i.e. B30 or less), a technical report may be replaced by a statement issued by the relevant maker concerning general suitability of the engines/fuel cell and systems with the proposed biofuel or blend.

2.3 Biodiesel specification

2.3.1 *(1/7/2025)*
In case the biodiesel or biodiesel blend is complying with ISO 8217:2024, the relevant Category (e.g: "ISO-F-DFA") is to be specified in the biofuel technical file.

In case the biodiesel or biodiesel part of the blend is complying with a specific biodiesel standard, e.g. EN14214 for FAME or EN15940 for HVO, this is to be specified in the biofuel technical file.

For other biofuels, the requirements in [2.1.1] apply.

2.3.2 *(1/7/2023)*
The biodiesel or biodiesel blend specification is to comply with the requirements of the engine manufacturer.

2.3.3 *(1/7/2025)*
The flashpoint (determined using the closed cup test according to ISO 2719:2016) of the biodiesel or biodiesel blend is to be not less than 60°C unless specially addressed in the risk assessment.

APPENDIX 17 TYPE TESTING PROCEDURE OF EXPLOSION RELIEF DEVICES FOR COMBUSTION AIR INLET AND EXHAUST GAS MANIFOLDS OF I.C. ENGINES USING GAS AS FUEL

1 General

1.1 Scope

1.1.1 *(1/7/2024)*

Aim of this Appendix is to specify testing procedure for explosion relief devices for combustion air inlet manifold and exhaust gas manifold of internal combustion engines using gas as fuel.

1.2 Definitions

1.2.1 *(1/7/2024)*

Definitions addressing gas as fuel as given in the App 12.

Explosion relief device (ERD) means a device to protect a component against a determined overpressure in the event of a gas explosion. The device is fitted with a flame arrester and may be a valve, a rupture disc or other, as applicable.

1.3 Documents

1.3.1 *(1/7/2024)*

Prior to testing, the following documentation for the ERD is to be submitted for approval:

- drawings (sectional drawings, details, assembly etc.)
- specification data sheet including operating conditions and design limits such as:
  - maximum permissible operating pressure, resulting from maximum charging air or exhaust gas back pressure
  - maximum permissible operating temperature, resulting from maximum charging air or exhaust gas temperature
  - static opening pressure, resulting from maximum charging air or exhaust gas back pressure
  - maximum explosion pressure, i.e. maximum pressure that the device can withstand
  - geometric relief area
- product marking
- installation and operation manual
- test program
- specification of test vessel.

2 Tests

2.1 Test specimens

2.1.1 *(1/7/2024)*

The ERD used for the explosion test is to be selected from the manufacturer’s production line by a representative of the Society:

- as a finished certified component itself, or
- on samples taken from earlier stages in the production of the component, when applicable.

If necessary, an additional ERD may need to be selected for the demonstration of the opening pressure. The selected ERD has to be clearly marked.

If applicable, the selected ERD is to be representative for the type range and operating conditions, for example:

- kind of ERD (valve, rupture disc, etc.),
- mounting orientation (vertical, horizontal)

- design of ERD (e.g., spring design, sealing)
- design of flame arrester
- ERD intended to be fitted to the air inlet or exhaust gas manifold of an engine having a turbocharger with characteristics as per the testing conditions in [2.3.2].

The selection of the representative ERD is subject to approval by the Society.

2.2 Demonstration of opening pressure

2.2.1 *(1/7/2024)*

The ERD which has been selected is to be subjected to a pressure test at the manufacturer's works to demonstrate that the static opening pressure is kept within the manufacturer's specification and that the ERD is air tight at the maximum permissible operating pressure for at least 30 seconds.

2.3 Explosion test

2.3.1 Test facility *(1/7/2024)*

The test facilities are to be accredited to a national or international standard, e.g. ISO/IEC 17025:2017, and are to be acceptable to the Society.

The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.

The test facilities are to have equipment for controlling and measuring a methane gas concentration within a test vessel to an accuracy of ± 0.1%.

The test facilities are to be capable of effective point-located ignition of a methane/air mixture.

The test facility arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognizing the speed of the events during an explosion (10 kHz or above).

The explosion test (see [2.3.5]) is to be documented by high speed (250 frames/s or above) video recording. The video recording is to be provided with a time stamp.

2.3.2 Test vessel *(1/7/2024)*

The test vessel is a simplified model of the air inlet or exhaust gas manifold. The free area of the connected turbo charger (compressor or turbine wheel) is to be considered.

The test vessel is to comply with the following requirements:

- The shape of the test vessel is to correspond to a pipe with $L/D \geq 10$.
- The test vessel is to be equipped with a rupture disc at one front end to simulate the turbo charger. The relief area of the rupture disc is to be in relationship to the test vessel diameter based on turbocharger manufacturer data for an equivalent free area of compressor or turbine wheel. The opening pressure is to be ±10% of the static opening pressure of the ERD.
- The volume of the test vessel is to comply with the specific relief area of the ERD of 700 cm^2/m^3 ±15%.
- The test vessel is to be provided with all necessary flanges and connection to mount the ERD in the intended position, to mount a rupture disc as turbo charger simulation, to connect the Methane-air mixture supply and the measurement equipment.
- The ignition is to be made at the middle of the test vessel.
- The test vessel is to be designed to verify a homogeneous air / methane mixture inside the vessel.
- The test vessel is to have connections for measuring the pressure in the test vessel in at least two positions, one at the ERD and the other at the test vessel center.
- The test vessel is to have a design pressure of not less than the maximum explosion pressure of a stoichiometric air / methane mixture at test conditions in [2.3.6].
- The test vessel configuration is subject to approval by the Society.

Typical test vessel configurations:

All test vessel configurations to be equipped with a rupture disc (1) (turbo charger simulation) at one front end. The ignition is in the centre of the test vessel (ϟ). The pressure sensors are mounted at the valve flanges (p1) and at the test vessel centre (p2). The measuring of the methane concentration to verify a homogeneous air / methane mixture can be performed at both ends of the test vessel, e.g. (c1) and (c2).

2.3.3 Explosion test process *(1/7/2024)*

The explosion testing is to be performed in two stages according to [2.3.4] and [2.3.5] for each ERD that is required to be approved as type tested.

The explosion testing is to be witnessed by a Society surveyor.

Calibration records for the instrumentation used to collect data are to be presented to, and reviewed by, the attending surveyor.

2.3.4 Reference test – Explosion test without ERD *(1/7/2024)*

Two explosion tests are to be carried out in the test vessel without ERD. The test vessel configuration is shown in Fig 1.

The aim of this test is to establish a reference pressure level in the test vessel which can be used for determination of the capability of a relief valve in terms of pressure relief.

2.3.5 ERD test – Explosion test with ERD *(1/7/2024)*

Two explosion tests are to be carried out in the test vessel with the same ERD at the required position. If the ERD is a rupture disc with flame arrester, the rupture disc is to be replaced.

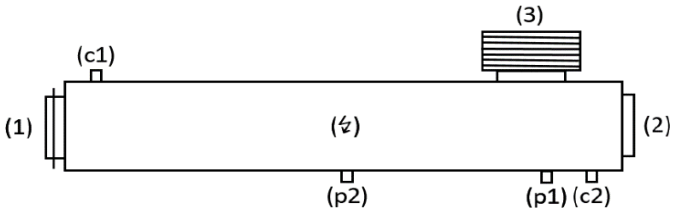
If shielding arrangements to deflect the emission of explosion combustion products at the ERD are intended, the ERD are to be tested with the shielding arrangements fitted

The test vessel configuration is shown in Fig 2 or Fig 3.

Figure 1 : Configuration without ERD (flanges for ERDs closed (2)) *(1/7/2024)*

Figure 2 : Configuration with ERD (3) mounted at the front end of the test vessel *(1/7/2024)*

Figure 3 : Configuration with ERD (3) mounted on top of the test vessel *(1/7/2024)*



2.3.6 Explosion test method *(1/7/2024)*

The test conditions are to comply with the intended use of the ERD, such as:

- pipe diameter
- operating pressure
- operating temperature
- installation orientation.

All explosion tests are to be carried out using an air and methane mixture with a volumetric methane concentration of 9.5% ± 0.5%. A homogeneous air / methane mixture inside the test vessel is to be verified. The concentration of methane is not to differ by more than 0.5%.

The initial pressure in the test vessel is to be the specified maximum operating pressure of the ERD.

The initial temperature in the test vessel is to be the specified maximum operating temperature of the ERD.

If the initial pressure and/or initial temperature deviate from the design limits, the ERD manufacturer is to prove the acceptability of this deviation either using standards or generally applicable calculation methods.

The ignition is to be made using an explosive charge of 50 - 100 Joule.

Successive explosion testing to establish an ERD functionality is to be carried out as quickly as possible during stable weather conditions.

The pressure rise and decay during all explosion testing is to be recorded.

The effect of an ERD in terms of pressure relief following an explosion is ascertained from maximum pressure recorded at the centre of the test vessel during the two stages. The pressure relief within the test vessel due to the installation of an ERD is the difference between average pressure of the two explosions of the reference test (see [2.3.4]) and the average of the two explosions of the ERD test (see [2.3.5]).

For acceptance of correct functioning of the flame arrester, there is to be no indication of flame or combustion outside of the ERD during its testing (see [2.3.5]). This is to be monitored by a high-speed video camera (see [2.3.1]), for which ambient light conditions are to be considered to maximise the potential for flame/combustion detection. The use of a dark, ideally matt finish, background and an avoidance of direct light onto the video camera monitored area are recommended.

After each ERD test (see [2.3.5]), the external condition of the flame arrester to be examined for signs of damage and/or deformation that may affect the operation of the ERD.

2.4 Check of ERD components

2.4.1 *(1/7/2024)*

After completing the explosion tests, the ERDs are to be dismantled and the condition of all components are to be ascertained and documented.

3 Report, Assessment and Approval

3.1 Test report

3.1.1 *(1/7/2024)*

A complete test report has to be submitted to the Society for

- the demonstration of opening pressure (see [2.2]) and
- the explosion test (see [2.3]).

The reports is to include respective information according to the requirements in [2], as applicable:

- test specimens
- test facility, including measuring equipment and test vessel
- measuring results (pressures, temperatures, flame velocities, volumetric methane concentration, ambient conditions etc.)
- video documentation of explosion tests
- photo documentation of ERD components

3.2 Assessment

3.2.1 *(1/7/2024)*

To verify compliance with this requirement the assessment has to address the following:

- Function and mechanical integrity of the ERD.
  - After dismantling of the ERD, the flame arrester is not to show signs of damage or any deformation that may affect the operation of the ERD.
  - If a valve is used any indication of valve sticking or uneven opening during the explosion that may affect subsequent operation of the valve has to be considered.
  - The mechanical integrity of the ERD is proven up to a maximum explosion pressure (as average of the two explosions) of the ERD tests in [2.3.5].
- The functioning of the flame arresters is considered satisfactory if there is no indication of flame or combustion outside the ERD during the explosion tests.

3.3 Approval

3.3.1 *(1/7/2024)*

The approval of an ERD is at the discretion of the Society based on the appraisal of plans and particulars and the test report of type testing.

The type approval is valid only for an ERD fitted to the air inlet or exhaust gas manifold of an engine having a turbocharger with compressor or turbine wheel characteristics corresponding to those required in [2.3.2] for the test vessel rupture disc in terms of free area.

APPENDIX 18 REQUIREMENTS CONCERNING THE USE OF CRUDE OIL OR SLOPS AS FUEL FOR TANKERS BOILERS

1 General

1.1 Application

1.1.1 *(1/1/2025)*

This Appendix applies to tankers where crude oil or slops are used as fuel for boilers, except for the requirement(s) in this Appendix which create conflict with the statutory requirements related to alternative design and arrangements required by SOLAS II-1/55 that do not need to be complied with (i.e statutory requirements take precedence over this Appendix).

1.1.2 *(1/1/2025)*

This Appendix is to be applied in conjunction with the applicable statutory requirements.

In case the crude oil or slops intended to be used as fuel have a flashpoint below 60°C, the applicable statutory requirements are typically those of the International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code) (for ships subject to SOLAS Regulation II-1/57), and the other requirements established by the national authority.

1.2 Documentation to be submitted

1.2.1 *(1/1/2025)*

In tankers crude oil or slops may be used as fuel for main or auxiliary boilers according to the following requirements. For this purpose all arrangement drawings of a crude oil installation with pipeline layout and safety equipment are to be submitted to the Society for approval in each case.

2 Design and construction

2.1 General

2.1.1 *(1/1/2025)*

Crude oil or slops may be taken directly from cargo tanks or flow slop tanks or from other suitable tanks. These tanks are to be fitted in the cargo tank area and are to be separated from non-gas-dangerous areas by means of cofferdams with gas-tight bulkheads.

2.1.2 *(1/1/2025)*

The construction and workmanship of the boilers and burners are to be proved to be satisfactory in operation with crude oil.

The whole surface of the boilers is to be gas-tight separated from the engine room. The boilers themselves are to be tested for gas-tightness before being used. The whole system of pumps, strainers, separators and heaters, if any, is to be fitted in the cargo pump room or in another room, to be considered as dangerous, and separated from engine and boiler room by gas-tight bulkheads. When crude oil is heated by steam or hot water the outlet of the heating coils should be led to a separate observation tank installed together with above mentioned components. This closed tank is to be fitted with a venting pipe led to the atmosphere in a safe position according to the rules for tankers and with the outlet fitted with a suitable flame proof wire gauze of corrosion resistant material which is to be easily removable for cleaning.

2.1.3 *(1/1/2025)*

Electric, internal combustion and steam (when the steam temperature is higher than 220°C) prime movers of pumps, of separators (if any), etc., are to be fitted in the engine room or in another non-dangerous room.

Where drive shafts pass through pump room bulkhead or deck plating, gas-tight glands are to be fitted.

The glands are to be efficiently lubricated from outside the pump room.

2.1.4 *(1/1/2025)*

Pumps are to be fitted with a pressure relief bypass from delivery to suction side and it is to be possible to stop them by a remote control placed in a position near the boiler fronts or machinery control room and from outside the engine room.

2.1.5 *(1/1/2025)*

When it is necessary to preheat crude oil or slops, their temperature is to be automatically controlled and a high temperature alarm is to be fitted.

2.1.6 *(1/1/2025)*

The piping for crude oil or slops and the draining pipes for the tray defined in [2.1.8] are to have a thickness as specified in Tab 1:

Table 1 : *(1/1/2025)*

External diameter of pipes, d_e	thickness, t
$d_e \leq 82,5$ mm	$t \geq 6,3$ mm
88,9 mm < $d_e \leq 108$ mm	$t \geq 7,1$ mm
114,3 mm < $d_e \leq 139,7$ mm	$t \geq 8$ mm
152,4 mm $\leq d_e$	$t \geq 8,8$ mm

Their connections (to be reduced to a minimum) are to be of the heavy flange type. Within the engine room and boiler room these pipes are to be fitted within a metal duct, which is to be gas-tight and tightly connected to the fore bulkhead separating the pump room and to the tray. This duct (and the enclosed piping) is to be fitted at a distance from the ship's side of at least 20% of the vessel's beam amidships and be at an inclination rising towards the boiler so that the oil naturally returns towards the pump room in the case of leakage or failure in delivery pressure. It is to be fitted with inspection openings with gas-tight doors in way of connections of pipes within it, with an automatic closing drain-trap placed on the pump room side, set in such a way as to discharge leakage of crude oil into the pump room.

In order to detect leakages, level position indicators with relevant alarms are to be fitted on the drainage tank defined in [2.1.8]. Also a vent pipe is to be fitted at the highest part of the duct and is to be led to the open in a safe position. The outlet is to be fitted with a suitable flame proof wire gauze of corrosion-resistant material which is to be easily removable for cleaning.

The duct is to be permanently connected to an approved inert gas system or steam supply in order to make possible:

- injection of inert gas or steam in the duct in case of fire or leakage purging of the duct before carrying out work on the piping in case of leakage.

2.1.7 *(1/1/2025)*

In way of the bulkhead to which the duct defined in [2.1.6] is connected, delivery and return oil pipes are to be fitted on the pump room side, with shut-off valves remotely controlled from a position near the boiler fronts or from the machinery control room. The remote control valves should be interlocked with the hood exhaust fans (defined in [2.1.9]) to ensure that whenever crude oil is circulating the fans are running.

2.1.8 *(1/1/2025)*

Boilers are to be fitted with a tray or gutterway of a height to the satisfaction of the Society and be placed in such a way as to collect any possible oil leakage from burners, valves and connections.

Such a tray or gutterway is to be fitted with a suitable flame proof wire gauze, made of corrosion resistant material and easily dismountable for cleaning. Delivery and return oil pipes are to pass through the tray or gutterway by means of a tight penetration and are then to be connected to the oil supply manifolds.

A quick closing master valve is to be fitted on the oil supply to each boiler manifold. The tray or gutterway is to be fitted with a draining pipe discharging into a collecting tank in pump room. This tank is to be fitted with a venting pipe led to the open in a safe position and with the outlet fitted with wire gauze made of corrosion resistant material and easily dismountable for cleaning.

The draining pipe is to be fitted with arrangements to prevent the return of gas to the boiler or engine room.

2.1.9 *(1/1/2025)*

Boilers are to be fitted with a suitable hood placed in such a way as to enclose as much as possible of the burners, valves and oil pipes, without preventing, on the other side, air inlet to burner register.

The hood, if necessary, is to be fitted with suitable doors placed in such a way as to enable inspection of and access to oil pipes and valves placed behind it. It is to be fitted with a duct leading to the open in a safe position, the outlet of which is to be fitted with a suitable flame wire gauze, easily dismountable for cleaning. At least two mechanically driven exhaust fans having spark proof impellers are to be fitted so that the pressure inside the hood is less than that in the boiler room. The exhaust fans are to be connected with automatic change over in case of stoppage or failure of the one in operation.

The exhaust fan prime movers are to be placed outside the duct and a gas-tight bulkhead penetration is to be arranged for the shaft.

Electrical equipment installed in gas dangerous areas or in areas which may become dangerous (i.e. in the hood or duct in which crude-oil piping is placed) is to be of certified safe type as required in Ch 2, Sec 2, [6].

2.1.10 *(1/1/2025)*

When using fuel oil for delivery to and return from boilers fuel oil burning units in accordance with Sec 3 are to be fitted in the boiler room. Fuel oil delivery to, and returns from, burners are to be effected by means of a suitable mechanical interlocking device so that running on fuel oil automatically excludes running on crude oil or vice versa.

2.1.11 *(1/1/2025)*

The boiler compartments are to be fitted with a mechanical ventilation plant and are to be designed in such a way as to avoid the formation of gas pockets.

Ventilation is to be particularly efficient in way of electrical plants and machinery and other plants which may generate sparks. These plants are to be separated from those for service of other compartments and are to be in accordance with Ch 4, Sec 1, [5.2.3] and [5.3].

2.1.12 *(1/1/2025)*

A gas detector plant is to be fitted with intakes in the duct defined in [2.1.6], in the hood duct (downstream of the exhaust fans in way of the boilers) and in all zones where ventilation may be reduced. An optical warning device is to be installed near the boiler fronts and in the machinery control room. An acoustical alarm, audible in the machinery space and control room, is to be provided.

2.1.13 *(1/1/2025)*

Means are to be provided for the boiler to be automatically purged before firing.

2.1.14 *(1/1/2025)*

Independent of the fire extinguishing plant as required by SOLAS, Chapter II-2 and by TASNEEF Rules for Fire Protection, Detection and Extinction for the Issue and Maintenance of Statutory Certificates other than SOLAS Certificates, an additional fire extinguishing plant is to be fitted in the engine and boiler rooms in such a way that it is possible for an approved fire extinguishing medium to be directed on to the boiler fronts and on to the tray defined in [2.1.8]. The emission of extinguishing medium should automatically stop the exhaust fan of the boiler hood (see [2.1.7]).

2.1.15 *(1/1/2025)*

A warning notice is to be fitted in an easily visible position near the boiler front. This notice is to specify that when an explosive mixture is signalled by the gas detector plant defined in [2.1.12] the watchkeepers are to immediately shut off the remote controlled valves on the crude oil delivery and return pipes in the pump room, stop the relative pumps, inject inert gas into the duct defined in [2.1.6] and turn the boilers to normal running on fuel oil.

2.1.16 *(1/1/2025)*

One pilot burner in addition to the normal burning control is required.

APPENDIX 19 TYPE APPROVAL TESTING OF SYNTHETIC MATERIALS FOR AFTMOST PROPELLER SHAFT BEARINGS

1 Scope

1.1 *(1/1/2026)*

This Appendix gives the requirements for the Type Approval testing of synthetic materials for aftmost propeller shaft bearings.

1.2 *(1/1/2026)*

The procedures and requirements of this Appendix are applicable to Type Approval obtained for the synthetic material required by Sec 7, [2.4].

1.3 *(1/1/2026)*

The qualification for design and application of aftmost propeller shaft bearings is to be provided and guaranteed by the manufacturer.

1.4 *(1/1/2026)*

Testing and inspection is to be carried out in accordance with the specific requirements given in this Appendix.

2 Documentation

2.1 *(1/1/2026)*

The manufacturer is to submit request of approval, test programme (see [3.1]) and information including the following contents to the Society:

a) product name

b) name and address of the manufacturer, including details for all relevant production places

c) reference of applicable rules and standards which the product is to comply with

d) product description:
   - material type
   - lubrication type
   - isotropic or anisotropic behaviour
   - elastomeric or non-elastomeric type

e) limitations of the product

f) product specification, technical data sheet, and installation manual including:
   1) maximum nominal surface pressure
   2) product dimensions:
      - minimum and maximum dimensions
      - other, if relevant
   3) commonly acceptable mating material (type of shaft material, roughness, hardness, etc.)
   4) running clearance
   5) maximum operating temperature

g) safety data sheet.

h) description of production processes

i) description of quality assurance system or copy of ISO 9001 certificate

j) in-service experience, if available

k) list of tests and measuring equipment including calibration certificate.

3 Type Approval testing

3.1 Test program

3.1.1 *(1/1/2026)*

Test program is to include following items:

a) description of products to be approved

b) description of the selected test samples

c) content of tests (test items, test standard, test conditions, acceptance criteria, etc.)

d) description of the wear testing stands and the test conditions.

3.1.2 *(1/1/2026)*

The extent of the test program is to test the material properties of [3.3].

In particular a reduction or complete suppression of the approval tests may be accepted by the Society taking into account:

a) documentation of approval tests performed

b) a proven track record.

3.2 Wear testing procedure

3.2.1 *(1/1/2026)*

Unless otherwise specified in this Appendix, the requirements for the wear test should refer to ASTM G77-17 or other national or international equivalent standards, with the following data:

- material of the shaft used in the test and its properties are to be specified and are to be equivalent to typical mating material e.g. alloyed steel or stainless steel or copper alloy
- diameter of shaft: the shaft diameter depends on the bearing size. The running clearance should be considered in the wear test
- motion of shaft: continuous rotation
- circumferential velocity should be 6 m/s for oil or water lubrication and should be 3 m/s for grease lubrication
- lubrication: sea water or substitute ocean water (23°C ± 2°C), or mineral oil (80°C ± 2°C), or grease (80°C ± 2°C) according to the applicable lubrication type
- surface roughness of test shaft: Ra is not to exceed 0,5 μ m for stainless steel and Ra is not to exceed 0,8 μ m for copper alloy
- interface pressure: maximum nominal surface pressure ± 10%
- duration of test: until the coefficient of friction and wear rate remains constant at least 192h. Wear of bushings is to be measured continuously or regularly. If regularly, wear to be measured by disassembling every 48 hours until a constant wear rate has been achieved (minimum of four points of measurements).

3.2.2 *(1/1/2026)*

Parameters to be recorded:

- dimensions of test specimen
- wear vs. time
- coefficient of friction vs. time
- temperature of test specimen during test cycle
- deviation of load from the maximum nominal surface pressure.

3.3 Material properties

3.3.1 *(1/1/2026)*

The properties of non-elastomeric materials for aftmost propeller shaft bearings are to comply with the requirements of Tab 1. The properties of elastomeric materials for aftmost propeller shaft bearings are to comply with the requirements of Tab 2.

Table 1 : Type testing for non-elastomeric materials for aftmost propeller shaft bearings *(1/1/2026)*

Test items	Test standard **(1)**	Number of specimens for each sample **(2)**, at least	Test conditions	Acceptance criteria
Compressive strength [N/mm^2]	ISO 604: 2002; ASTM D695-2015	5 **(3)**		Min.85 N/mm^2 in the case of isotropic materials. Min.85 N/mm^2 for specimens parallel to sheet plane in the case of anisotropic materials. Min.100 N/mm^2 for specimens normal to sheet plane in the case of anisotropic materials.
Compressive modulus [N/mm^2]	ISO 604: 2002; ASTM D695-2015	5 **(3)**		Min.850 N/mm^2 in the case of isotropic materials. Min.850 N/mm^2 for specimens parallel to sheet plane in the case of anisotropic materials. Min.1000 N/mm^2 for specimens normal to sheet plane in the case of anisotropic materials.
Water swelling [volume, %], only required for water lubrication	ISO 175: 2010	3	Four weeks in substitute ocean water (ASTM D1141-98(2021)) at (20°C ± 2°C) and maximum temperature ((60°C ± 2°C or advised maximum working temperature by manufacturer, whichever is higher). At least three specimens with dimension:50x50xt mm, t is min. 4 mm or the min. thickness of the bushing product. Testing immediately after extraction (wetcondition).	Volumetric swelling ≤ 3%
Oil swelling (for oil lubricated system) [volume, %], only required for oil lubrication	ISO 175: 2010	3	Four weeks -in oil No.3(ISO 1817:2022)at 20°C ± 2°C. At least three specimens with dimension: 50x50xt mm, t is min. 4 mm or the min. thickness of the bushing product. Testing immediately after extraction (wet condition).	Volumetric swelling ≤ 3%
Compressive strength and modulus change when immersed in water, only required for water lubrication	ISO 604: 2002; ASTM D695- 2015	5 **(3)**	Four weeks in substitute ocean water (ASTM D1141) at 20°C ± 2°C.	Min. 80% retention of minimum specified compressive strength and modulus before water immersion
Temperature resistance	ISO 604: 2002; ASTM D695- 2015	5 **(3)**	Compressive strength and compressive modulus at maximum temperature (60°C ± 2°C or advised maximum working temperature by manufacturer, whichever is higher).	Min. 80% retention of minimum specified compressive strength and modulus at 20°C ± 2°C

Test items	Test standard **(1)**	Number of specimens for each sample **(2)**, at least	Test conditions	Acceptance criteria
Wear test	See [3.2]	1		

(1) Other testing standards may also be accepted, provided that they are suitable for testing of the synthetic material selected for application in aftmost propeller shaft bearings.

(2) The number of specimens is to be prepared for each sample.

(3) Test at least five specimens for each sample in the case of isotropic materials. Test at least ten specimens, five normal to and five parallel to sheet plane, for each sample in the case of anisotropic materials.

Table 2 : Type testing for elastomeric materials for aftmost propeller shaft bearings *(1/1/2026)*

Test items	Test standard **(1)**	Number of specimens **(2)**, at least	Test conditions	Acceptance criteria
Tensile strength [N/mm^2]	ISO 37:2017; Method A of ASTM D412-16(2021); ASTM D638-22	3		Min.10 N/mm^2 for rubber bearing, and min.30 N/mm^2 for other elastomeric bearing
Elongation (%)	ISO 37:2017; Method A of ASTM D412-16(2021); ASTM D638-22	3		Min.150% for rubber bearing, and min.60% for other elastomeric bearing
Hardness	ISO 48-4:2018; ASTM D2240-15(2021)	3		
Water swelling [volume, %], only required for water lubrication	ISO 1817: 2022	3	Four weeks in substitute ocean water (ASTM D1141) at 20°C ± 2°C and maximum temperature (60°C ± 2°C or advised maximum working temperature by manufacturer, whichever is higher). At least three specimens with dimension:50x50xt mm, t is min. 4 mm or the min. thickness of the bushing product. Testing immediately after extraction (wetcondition).	Volumetric swelling ≤ 3%
Oil swelling (for oil lubricated system) [volume, %], only required for oil lubrication	ISO 1817: 2022	3	Four weeks in oil No.3(ISO 1817) at 20°C ± 2°C. At least three specimens with dimension: 50x50xt mm, t is min. 4 mm or the min. thickness of the bushing product. Testing immediately after extraction (wetcondition).	Volumetric swelling ≤ 3%
Tensile strength and elongation change when immersed in water, only required for water lubrication	ISO 37:2017; Method A of ASTM D412-16(2021); ASTM D638-22	3	Four weeks in substitute ocean water (ASTM D1141) at 20°C ± 2°C.	Min. 80% retention of minimum specified tensile strength and elongation before water immersion

Test items	Test standard **(1)**	Number of specimens **(2)**, at least	Test conditions	Acceptance criteria
Temperature resistance	ISO 37:2017; ISO 7743:2017; Method A of ASTM D412-16(2021); ASTM D638-22	3	Tensile strength and elongation at maximum temperature (60°C ± 2°C or advised maximum working temperature by manufacturer, whichever is higher).	Min. 80% retention of minimum specified tensile strength and elongation at 20°C ± 2°C
Adhesion to metals (except those not to be adhered to metals) [N/mm^2]	ISO 813:2019; ISO 1827:2022	3		
Change of properties due to aging [%]	ISO 37:2017; ISO 7743:2017; Method A of ASTM D412-16(2021); ASTM D638-22	3	After oven aging for tension and elongation tests. Test specimens are to be subjected to circulating air at maximum temperature (60°C ± 2°C or advised maximum working temperature by manufacturer, whichever is higher) for 96 hours. Tension and elongation tests are to be performed not less than 20 hours and not more than 48 hours after removal from the aging environment.	Min. 75% retention of Tensile strength and elongation before aging
Wear test	See [3.2]	1		

(1) Other testing standards may also be accepted, provided that they are suitable for testing of the synthetic material selected for application in aftmost propeller shaft bearings.

(2) The number of specimens is to be prepared for each sample.

3.4 Test products

3.4.1 *(1/1/2026)*

At least three representative diameter products of each kind of product are to be selected for type approval testing, except for the wear test where one representative product may be selected.

Each kind of product means:

- same chemical composition range
- same reinforcement, only applicable to composite materials
- same production process

The test products used for type approval testing are to be selected from the manufacturer's production line or stock by a Surveyor of the Society as a:

- finished certified component itself; or
- on samples taken from earlier stages in the production of the component, when applicable.

3.5 Test laboratories

3.5.1 *(1/1/2026)*

The selected test facility are to have accreditation according to ISO/IEC 17025 for carrying out and recording of the material property tests required by this Appendix. The test facility and the testing arrangements are to be to the satisfaction of the Society. If the test laboratory does not have the relevant accreditation, then specified testing will need to be witnessed by a Surveyor of the Society.

4 Type Approval certificate

4.1 General

4.1.1 *(1/1/2026)*

The Society issues a Type Approval Certificate based on the test reports and manufacturer's technical documentation e.g., installation/ engineering manuals.

The Type Approval Certificate is to contain the general information as defined by Society Rules. As minimum, the following information is specifically applicable to products relevant to this document and are to be included on the relevant Type Approval Certificate:

a) Product description and properties in accordance with paragraph [3.3] above

b) Maximum nominal surface pressure

c) Maximum operating temperature.

Chapter 2
ELECTRICAL INSTALLATIONS

SECTION 1 GENERAL

1 Application

1.1 General

1.1.1 The requirements of this Chapter apply to electrical installations on ships. In particular, they apply to the components of electrical installations for:

- primary essential services
- secondary essential services
- essential services for special purposes connected with ships specifically intended for such purposes (e.g. cargo pumps on tankers, cargo refrigerating systems, air conditioning systems on passenger ships)
- services for habitability.

The other parts of the installation are to be so designed as not to introduce any risks or malfunctions to the above services.

1.1.2 *(1/7/2007)*
As stated in Note 1 to Pt A, Ch 1, Sec 1, [1.1.2], the statutory requirements of the SOLAS Convention and/or national safety regulations, as applicable, regarding fire protection, detection and extinction (hereinafter referred to as "fire protection statutory requirements") are no longer mandatory for the purpose of classification, except where the Society carries out surveys relevant to fire protection statutory requirements on behalf of the flag Administration. In such cases, fire protection statutory requirements are considered a matter of class and therefore compliance with these requirements is also verified by the Society for classification purposes.

1.1.3 *(1/7/2019)*
The Society may consider modified requirements for installations of ships having navigation notation "sheltered area" or "special navigation" in an area at not more than 6 miles from the shore.

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, are those currently in force at the date of agreement for ship classification.

2 Documentation to be submitted

2.1 Standard list of documents and additional documents

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.

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.

2.1.2 *(1/7/2021)*
In addition to the documentation listed in Tab 1, a FMEA, carried out according to the TASNEEF "Guide for Failure mode and Effect Analysis" or other equivalent methods, and a Test Program, identifying the tests to be carried out in order to

verify the assumptions and conclusions of the FMEA, may be requested for approval for the following systems where applicable (see Note 1):

- control and power systems to power-operated fire doors and status indication for all fire doors;
- control and power systems to power-operated watertight doors and their status indication;
- steering gear control system;
- electric propulsion control system;
- public address and general alarm system;
- remote emergency stop/shutdown arrangements for systems which may support the propagation of fire and/or explosion;
- control and power system and position indication circuits for bow doors, stern doors, side doors, inner doors.

The FMEA may be requested by the Society for other systems on a case by case basis, depending on their influence on the overall ship safety.

Note 1: where the modes of failure and their consequences are clearly identifiable from the relevant drawings the Society may waive this request.

2.1.3 *(1/7/2021)*

Where the Society carries out surveys relevant to fire protection statutory requirements on behalf of the flag Administration (see [1.1.2]) the additional documents listed in Tab 2 are to be submitted.

2.1.4 *(1/7/2021)*

When an alteration or addition to an existing installation is proposed, updated plans are to be submitted for approval. As a minimum a technical specification, schematic diagrams and a proposed list of tests to be carried out onboard at the presence of the TASNEEF Surveyor are to be included.

2.1.5 *(1/7/2021)*

Where computer based systems are implemented and used to control the electrical installation, or to provide safety functions in accordance with the requirements of this Chapter (e.g. electric propulsion, steering gear, emergency safety systems etc.), the arrangements are to satisfy the applicable requirements of Chapter 3.

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 those services essential for propulsion and steering, and the safety of the ship, and services to ensure minimum comfortable conditions of habitability and necessary for special purposes connected with ships specifically intended for such purposes (e.g. cargo pumps on tankers, cargo refrigerating systems, air conditioning systems on passenger ships).

Table 1 : Documents to be submitted *(1/1/2023)*

No.	I/A **(1)**	Documents to be submitted	Notes
GENERAL			
1	A	Operation description of main, emergency and transitional electrical power systems (if applicable) under normal and foreseeable abnormal operating conditions.	
(1) A: to be submitted for approval I: to be submitted for information			

No.	I/A **(1)**	Documents to be submitted	Notes
2	A	Single line diagram of main and emergency power and lighting systems.	The drawing is to include the single line diagram of: • the main switchboard and all the feeders connected to the main switchboard • the emergency switchboard and all feeders connected to the emergency switchboard • interconnector feeder between main switchboard and emergency switchboard • the main and emergency source of electrical power (i.e. generators and/or batteries and any additional source of power) • any distribution boards and motor control centers (MCC) • the main and emergency lighting distribution • transformers, converters and similar appliance which constitute an essential part of the electrical supply system • uninterruptible power system units (UPS) when providing an alternative power supply to essential services and/or when providing an alternative power supply or transitional power supply, if any, to the emergency services.
3	A	Electrical power balance (main and emergency supply).	The load balance of the main supply is to include the operating modes in which the ship is intended to operate.
4	I	Calculation of short-circuit currents for 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.	The calculation is to include the short circuit currents at: • the main switchboard(s) • the emergency switchboard • all the distribution boards and MCC including those fed from transformers. Document is to include details of circuit breaker and fuse operating times and discrimination curves.
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.	Main switchboard, emergency switchboards, each distribution board, motor control centers (MCC) and UPS and/or battery distribution.
6	A	Single line diagram and detailed functional diagram of the main switchboard	
7	A	Single line diagram and detailed functional diagram of the emergency switchboard.	
8	A	Single line diagram and detailed functional diagram of distribution boards, and 100kW and over motor control centers and single starters.	Main distribution boards are intended as distribution boards which are supplied directly or through transformer by main or emergency switchboard
9	A	Diagram and arrangement of main and emergency lighting	
10	A	Diagram and arrangement of the general emergency alarm system, the public address system and other intercommunication systems.	
11	A	A functional diagram of the distribution board specially reserved for the navigation lights.	

(1) A: to be submitted for approval
I: to be submitted for information

No.	I/A (1)	Documents to be submitted	Notes
12	I	Schedule for recording of the type, location and maintenance cycle of batteries used for essential and emergency services.	Reference is to be made to the requirements of Sec 3, [11.1.1].
13	A	Single line diagram for electric propulsion installation, including power supply circuits.	For control alarm and safety system see Chapter 3.
14	A/I	For BATTERY POWERED SHIP documents required by App 2, Tab 1 and for FUEL CELL POWERED SHIP, documents required by App 3, Tab 1.	
15	A	A functional diagram of the electric power circuits for steering gear	Reference is to be made to the requirements of Ch 1, Sec 11, [2.3], [2.4], [3] & [4]. For control alarm and safety system see Chapter 3
16	A	Electrical diagram of local application fixed gas fire-extinguishing systems.	Reference is to be made to the requirements of Ch 4, Sec 1, [7.1.2]
17	A	Electrical diagrams of power control and position indication circuits of watertight doors	Reference is to be made to the requirements of: • Pt B, Ch 2, Sec 1, [6] • Pt E, Ch 11, Sec 2
18	I	General arrangement plan of the ship showing location of main items of the electrical system	The plan is to include: • main switchboard(s) and emergency switchboard • main source of power including battery rooms, if any • emergency source of power and transitional source of power (where required by the applicable rules) • distribution boards supplying primary and secondary essential services • UPS or batteries serving primary and secondary essential services and emergency services • major equipment serving propulsion (e.g. motors, transformers, converter, etc.)
19	A	A functional diagram of uninterruptible power supply (UPS) for primary essential services, emergency services and 50kVA and over secondary essential services.	Reference is to be made to Sec 7, [3].

(1) A: to be submitted for approval
I: to be submitted for information

No.	I/A **(1)**	Documents to be submitted	Notes
20	A	Plan of hazardous areas, where applicable	Reference is to be made to: - Sec 3, [10] and - service notations in relation to the type and/or service of the ship: • Pt E, Ch 1, Sec 4 for ro-ro cargo ships • Pt E, Ch 7, Sec 6 for oil tankers and fls tankers • Pt E, Ch 8, Sec 10 for chemical tankers • Pt E, Ch 9, Sec 10 for liquefied gas carrier • Pt E, Ch 12, Sec 5 for ro-ro passenger ships • Pt E, Ch 17, Sec 4 for oil recovery ships • Pt E, Ch 19, Sec 5 for barge oil-non propelled ship • Pt E, Ch 24, Sec 9 for Compressed Natural Gas Carrier • Pt E, Ch 25, Sec 6 for oil carrier-assisted propulsion • Pt E, Ch 26, Sec 5 for palm-oil carrier assisted propulsion • Pt E, Ch 28, Sec 4 for chemical recovery ship • Pt E, Ch 29, Sec 4 for well stimulation
DOCUMENTS REQUESTED IN RELATION TO THE TYPE AND SERVICES OF THE SHIP			
21	A	Diagram of alarm, monitoring and safety system of inert gas system, where applicable.	Reference is to be made to the requirements of Ch 4, Sec 1, [9]
22	A	Document giving certification details of types of cables and safety characteristics of the equipment installed in hazardous areas, as applicable.	Reference is to be made to Sec 3, [10].
23	A	Diagrams of tank level indicator systems, high level alarm systems and overflow control systems, where applicable.	Reference is to be made to the requirements of Pt E, Ch 7, Sec 4 and sec 5
24	A	Single line diagrams of the power supply to well stimulation equipment.	Reference is to be made to the requirements of Pt E, Ch 29, Sec 4.
25	A	Electrical diagrams of power control and position indication circuits for bow doors, stern doors, side doors, inner doors, television system and alarm systems for ingress of water.	Reference is to be made to the requirements of Pt E, Ch 1, Sec 2; Pt E, Ch 11, Sec 3; Pt E, Ch 12, Sec 2, Ch 12, Sec 2.
26	A	Diagrams of the supplies to the supplementary emergency lighting systems for ro-ro passenger ships.	Reference is to be made to the requirements of Pt E, Ch 12, Sec 5, [2]

(1) A: to be submitted for approval
I: to be submitted for information

Table 2 : Documents requested in relation to the type and services of the ship (2) *(1/7/2021)*

No.	**(1)**	Documents to be submitted
1	A	Electrical diagram of the automatic fire detection and alarm systems and manually operated call points.
2	A	Electrical diagram of the fixed gas fire-extinguishing systems.
3	A	Electrical diagram of the sprinkler systems.
4	A	Electrical diagram of power control and position indication circuits for fire doors.

(1) A: to be submitted for approval

(2) Reference is to be made to the requirements of "Rules for Fire Protection, Detection and Extinction for the Issue and Maintenance of SOLAS Certificates" or "Rules for Fire Protection, Detection and Extinction for the Issue and Maintenance of Statutory Certificates other than SOLAS Certificates", as applicable.

No.	(1)	Documents to be submitted
5	A	Diagram of the remote stop system (ventilation, fuel pumps, etc.).
6	A	Diagram of power, control and indication circuits for electrically operated low location lighting (LLL).

(1) A: to be submitted for approval

(2) Reference is to be made to the requirements of "Rules for Fire Protection, Detection and Extinction for the Issue and Maintenance of SOLAS Certificates" or "Rules for Fire Protection, Detection and Extinction for the Issue and Maintenance of Statutory Certificates other than SOLAS Certificates", as applicable.

3.3 Primary essential services

3.3.1 Primary essential services are those which need to be in continuous operation to maintain propulsion and steering.

Examples of equipment for primary essential services are the following:

- Steering gear
- Pumps for controllable pitch propellers
- Scavenging air blowers, fuel oil supply pumps, fuel valve cooling pumps, lubricating oil pumps and cooling water pumps for main and auxiliary engines and turbines necessary for the propulsion
- Forced draught fans, feed water pumps, water circulating pumps, condensate pumps, oil burning installations, for steam plants or steam turbines ship, and also for auxiliary boilers on ship where steam is used for equipment supplying primary essential services
- Azimuth thrusters which are the sole means for propulsion/steering with lubricating oil pumps, cooling water pumps
- Electrical equipment for electric propulsion plant with lubricating oil pumps and cooling water pumps
- Electric generators and associated power sources supplying the above equipment
- Hydraulic pumps supplying the above equipment
- Viscosity control equipment for heavy fuel oil
- Control, monitoring and safety devices/systems for equipment for primary essential services
- Speed regulators dependent on electrical energy for main or auxiliary engines necessary for propulsion.

The main lighting system for those parts of the ship normally accessible to and used by personnel and passengers is also considered (included as) a primary essential service.

3.4 Secondary essential services

3.4.1 Secondary essential services are those services which need not necessarily be in continuous operation to maintain propulsion and steering but which are necessary for maintaining the vessel’s safety.

Examples of equipment for secondary essential services are the following:

- Windlasses
- Fuel oil transfer pumps and fuel oil treatment equipment
- Lubrication oil transfer pumps and lubrication oil treatment equipment
- Preheaters for heavy fuel oil
- Sea water pumps
- Starting air and control air compressors
- Bilge, ballast and heeling pumps
- Fire pumps and other fire-extinguishing medium pumps
- Ventilation fans for engine and boiler rooms
- Services considered necessary to maintain dangerous cargo in a safe condition
- Navigation lights, aids and signals
- Internal safety communication equipment
- Fire detection and alarm systems
- Electrical equipment for watertight closing appliances
- Electric generators and associated power supplying the above equipment
- Hydraulic pumps supplying the above equipment
- Control, monitoring and safety for cargo containment systems
- Control, monitoring and safety devices/systems for equipment for secondary essential services.

3.4.2 Services for habitability are those which need to be in operation to maintain the vessel's minimum comfort conditions for people on board.

Examples of equipment for maintaining conditions of habitability:

- Cooking
- Heating
- Domestic refrigeration
- Mechanical ventilation
- Sanitary and fresh water
- Electric generators and associated power sources supplying the above equipment.

3.5 Safety voltage

3.5.1 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.

3.5.2 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.

3.6 Low-voltage systems

3.6.1 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.

3.7 High-voltage systems

3.7.1 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.

3.8 Basic insulation

3.8.1 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.

3.9 Supplementary insulation

3.9.1 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.

3.10 Double insulation

3.10.1 Insulation comprising both basic insulation and supplementary insulation.

3.11 Reinforced insulation

3.11.1 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 "single 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.

3.12 Earthing

3.12.1 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.

3.13 Normal operational and habitable condition

3.13.1 *A condition under which the ship as a whole, the machinery, services, means and aids ensuring propulsion, ability to steer, safe navigation, fire and flooding safety, internal and external communications and signals, means of*

escape, and emergency boat winches, as well as the designed comfortable conditions of habitability are in working order and functioning normally.

3.14 Emergency condition

3.14.1 *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.*

3.15 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 Dead ship condition

3.16.1 *The condition under which the main propulsion plant, boilers and auxiliaries are not in operation due to the absence of power.*

Note 1: Dead ship condition is a condition in which the entire machinery installation, including the power supply, is out of operation and the auxiliary services such as compressed air, starting current from batteries etc., for bringing the main propulsion into operation and for the restoration of the main power supply are not available.

3.17 Main generating station

3.17.1 *The space in which the main source of electrical power is situated.*

3.18 Main switchboard

3.18.1 *A switchboard which is directly supplied by the main source of electrical power and is intended to distribute electrical energy to the ship's services.*

3.19 Emergency switchboard

3.19.1 *A switchboard which in the event of failure of the main electrical power supply system is directly supplied by the emergency source of electrical power or the transitional source of emergency and is intended to distribute electrical energy to the emergency services.*

3.20 Emergency source of electrical power

3.20.1 *A source of electrical power, intended to supply the emergency switchboard in the event of failure of the supply from the main source of electrical power.*

3.21 Distribution board

3.21.1 *(1/1/2021)*

A switchgear and controlgear assembly which is supplied by the main or the emergency switchboard or distribution boards and is arranged for the distribution of electrical energy to other distribution boards, final distribution boards or final sub-circuits.

3.22 Final sub-circuit

3.22.1 That portion of a wiring system extending beyond the final required overcurrent protective device of a board.

3.23 Motor control centre (MCC)

3.23.1 *(1/1/2021)*

A switchgear and controlgear assembly which is supplied by main or emergency switchboards and is intended to control and distribute electrical energy.

Note 1: It is possible for the MCC to be a section or sections of the main switchboard.

3.24 Hazardous areas

3.24.1 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.

3.24.2 Hazardous areas are classified in zones based upon the frequency and the duration of the occurrence of explosive atmosphere.

3.24.3 *(1/7/2022)*

Hazardous areas for explosive gas atmosphere are classified in the following zones:

- Zone 0: an area in which ignitable concentrations of flammable gases or vapours are continuously present or present for long periods
- Zone 1: an area in which ignitable concentrations of flammable gases or vapours are likely to occur in normal operation
- Zone 2: an area in which ignitable concentrations of flammable gases or vapours are not likely to occur, or in which such a mixture, if it does occur, will exist for a short period only.

3.25 Certified safe-type equipment

3.25.1 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.

3.26 Environmental categories

3.26.1 *(1/7/2021)*

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 3

The first characteristic numeral indicates the temperature range in which the electrical equipment operates satisfactorily, as specified in Tab 4

The second characteristic numeral indicates the vibration level in which the electrical equipment operates satisfactorily, as specified in Tab 5.

3.26.2 The tests for verifying the additional and supplementary letters and the characteristic numeral of the environmental categories are defined in Ch 3, Sec 8.

3.27 Navigation Light (NL)

3.27.1 *(1/7/2015)*

Navigation Light (NL) means the following lights:

- *masthead light, sidelights, sternlight, towing light, all-round light, flashing light as defined in Rule 21 of COLREGs (see Note 1),*
- *all-round flashing yellow light required for air-cushion vessels by Rule 23 of COLREGs,*
- *manoeuvring light required by Rule 34(b) of COLREGs.*

Note 1:

COLREGs means Convention on the International Regulations for Preventing Collisions at Sea, 1972, including their annexes.

Table 3 : 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 4 : First characteristic numeral *(1/7/2017)*

First characteristic numeral	Brief description of location	Temperature range °C	
1	Air conditioned areas	+ 5	+ 40
2	Enclosed spaces	+ 5	+ 45
3a	Electronic equipment inside consoles, housing, etc..	+ 5	+ 55
3b	Close to combustion engines, boilers and similar	+ 5	+ 70
4	Exposed decks, masts	- 25	+ 45

Table 5 : 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, cargo spaces	from 2,0 to 13,2 from 13,2 to 100	1,0 -	- 0,7
2	Masts	from 2,0 to 13,2 from 13,2 to 50	3,0 -	- 2,1
3	On air compressors, on diesel engines and similar	from 2,0 to 25,0 from 25,0 to 100	1,6 -	- 4,0

SECTION 2 GENERAL DESIGN REQUIREMENTS

1 Environmental conditions

1.1 General

1.1.1 The electrical components of installations are to be designed and constructed to operate satisfactorily under the environmental conditions on board.

In particular, the conditions shown in the tables in this Article 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), biological conditions, 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.

1.2 Ambient air temperatures

1.2.1 *(1/7/2017)*

For ships classed for unrestricted navigation, the reference ambient air temperature ranges are shown in Tab 1 in relation to the various locations of installation.

1.2.2 *(1/7/2006)*

Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is to be suitable may be reduced from 45° and maintained at a value not less than 35° provided:

- the equipment is not for use for emergency services.
- temperature control is achieved by at least two cooling units so arranged that in the event of loss of one cooling unit, for any reason, the remaining unit(s) is (are) capable of satisfactorily maintaining the design temperature.
- the equipment is able to be initially set to work safely up to a 45° ambient temperature until such time as the lower ambient temperature is achieved; the cooling equipment is to be rated for a 45 ° ambient temperature.
- audible and visual alarms are fitted, at a continually manned control station, to indicate any malfunction of the cooling units.

1.2.3 *(1/7/2004)*

In accepting an ambient temperature less than 45° it is to be ensured that electrical cables are adequately rated throughout their length for the maximum ambient temperature to which they are exposed.

1.2.4 *(1/7/2004)*

The equipment used for cooling and maintaining the lower ambient temperature is to be classified for a secondary essential service.

1.2.5 For ships classed for service in specific zones, the Society may accept different ambient air temperature (e.g. for ships operating outside the tropical belt, the maximum ambient air temperature may be assumed as equal to + 40 °C instead of + 45 °C).

Table 1 : Ambient air temperature *(1/7/2017)*

Location	Temperature range, in °C	
Enclosed spaces	+ 5	+ 45
Electronic equipment inside console, housing, etc.	+ 5	+ 55
Fitted on combustion engines, boilers and similar	+ 5	+ 70
Exposed decks	- 25	+ 45

1.3 Humidity

1.3.1 For ships classed for unrestricted service, the humidity ranges shown in Tab 2 are applicable in relation to the various locations of installation.

Table 2 : Humidity

Location	Humidity
General	95% at 55 °C
Air conditioned areas	Different values may be considered on a case by case basis

1.4 Cooling water temperatures

1.4.1 The temperatures shown in Tab 3 are applicable to ships classed for unrestricted service.

1.4.2 For ships classed for service in specific zones, the Society may accept different values for the cooling water temperature (e.g. for ships operating outside the tropical belt, the maximum cooling water temperature may be assumed as equal to + 25 °C instead of + 32 °C).

Table 3 : Water temperature

Coolant	Temperature range, in °C	
Sea water	0	+ 32

1.5 Salt mist

1.5.1 The applicable salt mist content in the air is to be 1 mg/m^3.

1.6 Inclinations

1.6.1 The inclinations applicable are those shown in Tab 4.

The Society may consider deviations from these angles of inclination taking into consideration the type, size and service conditions of the ships.

1.7 Vibrations

1.7.1 In relation to the location of the electrical components, the vibration levels given in Tab 5 are to be assumed.

1.7.2 The natural frequencies of the equipment, their suspensions and their supports are to be outside the frequency ranges specified.

Where this is not possible using a suitable constructional technique, the equipment vibrations are to be dumped so as to avoid unacceptable amplifications.

2 Quality of power supply

2.1 Voltage and frequency variation

2.1.1 *(1/7/2006)*

All electrical appliances supplied from the main or emergency systems are to be so designed and manufactured that they are capable of operating satisfactorily under the normally occurring variations in voltage and frequency.

2.1.2 *(1/7/2006)*

Unless otherwise stated in national or international standards, all equipment is to operate satisfactorily with the variations from its rated value shown in Tab 6 to Tab 8 subject to the following conditions.

a) For alternating current components, the voltage and frequency variations shown in Tab 6 are to be assumed.

b) For direct current components supplied by d.c. generators or converted by rectifiers, the voltage variations shown in Tab 7 are to be assumed.

c) For direct current components supplied by electrical batteries, the voltage variations shown in Tab 8 are to be assumed.

2.1.3 *(1/7/2007)*
Any special system, e.g. electronic circuits, whose function cannot operate satisfactorily within the limits shown in Tab 6, Tab 7 and Tab 8 is not to be supplied directly from the system but by alternative means, e.g. through stabilised supply.

2.2 Harmonic distortions

2.2.1 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.

2.2.2 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 that
- the total harmonic distortion does not exceed 10%.

Table 4 : Inclination of ship *(1/7/2021)*

Type of machinery, equipment or component	Angles of inclination, in degrees **(1)**			
	Athwartship		Fore-and-aft	
	static	dynamic **(4)**	static	dynamic **(5)**
Machinery and equipment relative to main electrical power installation	15	22,5	5	7,5
Machinery and equipment relative to the emergency power installation and crew and passenger safety systems of the ship (e.g. emergency source of power, emergency fire pumps, etc.)	22,5 **(2)**	22,5 **(2)**	10	10
Switchgear and associated electrical and electronic components and remote control systems **(3)**	22,5	22,5	10	10

(1) Athwartship and fore-and-aft angles may occur simultaneously in their most unfavourable combination.
(2) In the case of gas carriers or chemical tankers, the emergency power supply must also remain operable with the ship flooded to a final athwartship inclination up to a maximum of 30°.
(3) No undesired switching operations or functional changes are to occur.
(4) The period of dynamic inclination may be assumed equal to 10 s.
(5) The period of dynamic inclination may be assumed equal to 5 s.

Table 5 : Vibration levels

Location	Frequency range Hz	Displacement amplitude mm	Acceleration amplitude g
Machinery spaces, command and control stations, accommodation spaces, exposed decks, cargo spaces	from 2,0 to 13,2 from 13,2 to 100	1,0 -	- 0,7
On air compressors, on diesel engines and similar	from 2,0 to 25,0 from 25,0 to 100	1,6 -	- 4,0
Masts	from 2,0 to 13,2 from 13,2 to 50	3,0 -	- 2,1

Figure 1

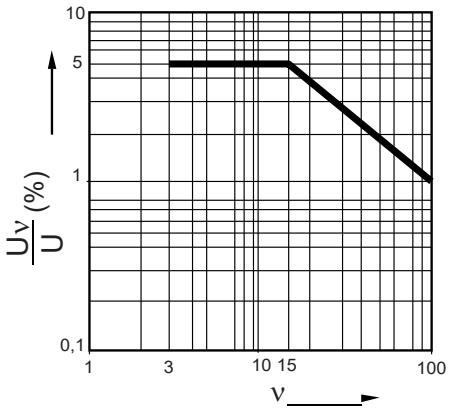


Table 6 : Voltage and frequency variations for a.c. distribution systems *(1/7/2004)*

Quantity in operation	Variations	
	Continuous	Transient
Voltage	+ 6% - 10%	± 20% (recovery time: 1,5 s)
Frequency	± 5%	± 10% (recovery time: 5 s)

Table 7 : Voltage variations for d.c. distribution systems

Parameters	Variations
Voltage tolerance (continuous)	± 10%
Voltage cyclic variation deviation	5%
Voltage ripple (a.c. r.m.s. over steady d.c. voltage)	10%

2.2.3 *(1/7/2017)*

Where harmonic filters are fitted onboard, e.g. in electric propulsion plant systems, the total harmonic distortion (THD) of electrical distribution systems is not to exceed 8%. This limit may be exceeded where all installed equipment and systems have been designed for a higher specified limit and this relaxation on limits is to be documented (harmonic distortion calculation report) and made available onboard as a reference for the surveyor in charge for survey.

Note 1: installation where harmonic filters are installed for single application frequency drives such as pump motors, are exclude from the application of this requirement.

Table 8 : Voltage variations for battery systems *(1/7/2006)*

Systems	Variations
Components connected to the battery during charging **(1)**	+30%, -25%
Components not connected to the battery during charging	+20%, -25%
(1) Different voltage variations as determined by the charging/discharging characteristics, including ripple voltage from the charging device, may be considered.	

3 Electromagnetic susceptibility

3.1 Electromagnetic compatibility and disturbance levels

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 Chapter 3.

Note 1: See also IEC Publication 60533 - “Electromagnetic Compatibility of Electrical and Electronic Installations in Ships and of Mobile and Fixed Offshore Units”.

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 *(1/7/2006)*

The insulation classes given in Tab 9 may be used.

Table 9 : 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 Sec 9, [1.3].

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 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 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.

5.2.3 For cable entries see [4.3.1].

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 (e.g. oil tankers, liquefied gas carriers, chemical tankers, etc.), 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)
- oil-immersed apparatus (see Note 1): Ex(o)

Note 1: Only when required by the application.

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.

6.2 Protection against combustible dust hazard

6.2.1 Electrical appliances intended for use in areas where a combustible dust hazard may be present are to be arranged with enclosures having a degree of protection and maximum surface temperature suitable for the dust to which they may be exposed.

Note 1: Where the characteristics of the dust are unknown, the appliances are to have a degree of protection IP6X. For most dusts a maximum surface temperature of 200°C is considered adequate.

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
- two-wire with one pole earthed

b) on a.c. installations:
- three-phase three-wire with neutral insulated
- three-phase three-wire with neutral directly earthed or earthed through an impedance
- three-phase four-wire with neutral directly earthed or earthed through an impedance
- single-phase two-wire insulated
- single-phase two-wire with one phase earthed.

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 hull return system of distribution is not to be used for power, heating or lighting in any ship of 1600 tons gross tonnage and upwards.

1.1.4 The requirement of [1.1.3] 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.

1.1.5 For the supply systems of ships carrying liquid developing combustible gases or vapours, see Pt E, Ch 7, Sec 5, Pt E, Ch 8, Sec 10 or Pt E, Ch 9, Sec 10.

1.1.6 For the supply systems in HV Installations, see Sec 13.

1.2 Maximum voltages

1.2.1 The maximum voltages for both alternating current and direct current low-voltage systems of supply for the ship’s services are given in Tab 1.

Table 1 : Maximum voltages for various ship services

Use		Maximum voltage, in 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 appliances which are not hand-held during operation (e.g. refrigerated containers) 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 starting/stopping 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.

1.2.2 Voltages exceeding those shown will be specially considered in the case of specific systems.

1.2.3 For high voltage systems see Sec 13.

2 Sources of electrical power

2.1 General

2.1.1 *Electrical installations are to be such that:*

a) All electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions and for the preservation of the cargo *will be assured without recourse to the emergency source of electrical power.*

b) Electrical services essential for safety will be assured under various emergency conditions.

c) When a.c. generators are involved, attention is to be given to the starting of squirrel-cage motors connected to the system, particularly with regard to the effect of the magnitude and duration of the transient voltage change produced due to the maximum starting current and the power factor. The voltage drop due to such starting current is not to cause any motor already operating to stall or have any adverse effect on other equipment in use.

2.2 Main source of electrical power

2.2.1 *A main source of electrical power is to be provided, of sufficient capability to supply all electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions* and for the preservation of the cargo *without recourse to the emergency source of electrical power.*

2.2.2 For ships propelled by electrical power and having two or more constant voltage propulsion generating sets which constitute the source of electrical energy for the ship's auxiliary services, see Sec 14.

2.2.3 *(1/7/2019)*

The main source of electrical power is to consist of at least two generating sets.

The capacity of these generating sets is to be such that in the event of any one generating set being stopped it will still be possible to supply those services necessary to provide:

a) normal operational conditions of propulsion and safety (see [2.2.4])

b) minimum comfortable conditions of habitability (see Sec 1, [3.4.2])

c) preservation of the cargo.

Such capacity is, in addition, to be sufficient to start the largest motor without causing any other motor to stop or having any adverse effect on other equipment in operation.

Note 1: for ships having navigation notation "sheltered area" or "special navigation" having an area of operation at not more than 6 miles from the shore (see Sec 1, [1.1.3]) and not subject to the SOLAS convention, the Society may accept that:

- the main source of electrical power consists of one generator (which may have the ship's propulsion machinery as prime mover), and one accumulator battery, provided that the capacity of the accumulator battery is sufficient to supply, without being recharged, all essential services for not less than 1.2 times the expected duration of the longest voyage, but not less than:
  - 5 hours, or
  - 30 minutes for ships having navigation notation "sheltered area",
- the main switchboard is supplied by only one cable by main generator and accumulator battery provided that main generator and accumulator battery are individually protected against short-circuit and overload.

2.2.4 Those services necessary to provide normal operational conditions of propulsion and safety include primary and secondary essential services.

For the purpose of calculating the capacity necessary for such services, it is essential to consider which of them can be expected to be in use simultaneously.

For a duplicated service, one being supplied electrically and the other non-electrically (e.g. driven by the main engine), the electrical capacity is not included in the above calculation.

2.2.5 The services in [2.2.4] do not include:

- thrusters not forming part of the main propulsion
- cargo handling gear
- cargo pumps
- refrigerators for air conditioning.

2.2.6 *Further to the provisions above, the generating sets shall be such as to ensure that with any one generator or its primary source of power out of operation, the remaining generating sets shall be capable of providing the electrical services necessary to start the main propulsion plant from a "dead ship" condition.*

2.2.7 *The emergency source of electrical power may be used for the purpose of starting from a "dead ship" condition if its capability either alone or combined with that of any other source of electrical power is sufficient to provide at the same time those services required to be supplied in accordance with the provisions of* [3.7.3] (items a, b, c, d) or Pt E, Ch 11, Sec 5 *for passenger ships.*

2.2.8 *The arrangement of the ship's main source of electrical power shall be such that essential services can be maintained regardless of the speed and direction of rotation of the main propulsion machinery or shafting.*

2.2.9 Generators driven by the propulsion plant (shaft generators) which are intended to operate at constant speed (e.g. a system where vessel speed and direction are controlled by varying propeller pitch) may be accepted as forming part of the main source of electrical power if, in all sailing and manoeuvring conditions including the propeller being stopped, the capacity of these generators is sufficient to provide the electrical power to comply with [2.2.3] and all further requirements, especially those of [2.2.6]. They are to be not less effective and reliable than the independent generating sets.

2.2.10 *(1/7/2022)*

Generators and generator systems, having the ship's propulsion machinery as their prime mover but not forming part of the ship's main source of electrical power (see Note 1) may be used whilst the ship is at sea to supply electrical services required for normal operational and habitable conditions, provided that:

a) there are sufficient and adequately rated additional generators fitted, which constitute the main source of electrical power required by [2.2.1], meeting the provisions of [2.2.8]

b) arrangements are fitted to automatically start one or more of the generators constituting the main source of electrical power required by [2.2.1], in compliance with [3.4.5] and also in the event of frequency variations exceeding ± 10% of the limits specified below

c) within the declared operating range of the generators and/or generator systems, the specified limits for the voltage variations in IEC 60092-301/AMD2 and the frequency variations in Sec 2, Tab 6 can be met

d) the short-circuit current of the generator and/or generator system is sufficient to trip the generator/generator system circuit-breaker taking into account the selectivity of the protective devices for the distribution system

e) where considered appropriate, load shedding arrangements are fitted to meet the requirements of [3.4.6], [3.4.7] and [3.4.8]

f) on ships having remote control of the propulsion machinery from the navigating bridge, means are provided or procedures are in place so as to ensure that supplies to essential services are maintained during manoeuvring conditions in order to avoid a blackout situation (see Note 2).

Note 1: Such generator systems are those whose operation does not meet the requirements of IEC 60092-201, paragraph 8.1.1.

Note 2: A 'blackout situation' means that the main and auxiliary machinery installations, including the main power supply, are out of operation but the services for bringing them into operation (e.g. compressed air, starting current from batteries etc.) are available.

2.2.11 *(1/7/2006)*

Where transformers, converters or similar appliances *constitute an essential part of the electrical supply system, the system is to be so arranged as to ensure the same continuity of supply as stated in this sub-article [2.2].*

This may be achieved by arranging at least two three-phase or three single-phase transformers supplied, protected and installed as indicated in Fig 1, so that with any one transformer not in operation, the remaining transformer(s) is (are) sufficient to ensure the supply to the services stated in [2.2.3].

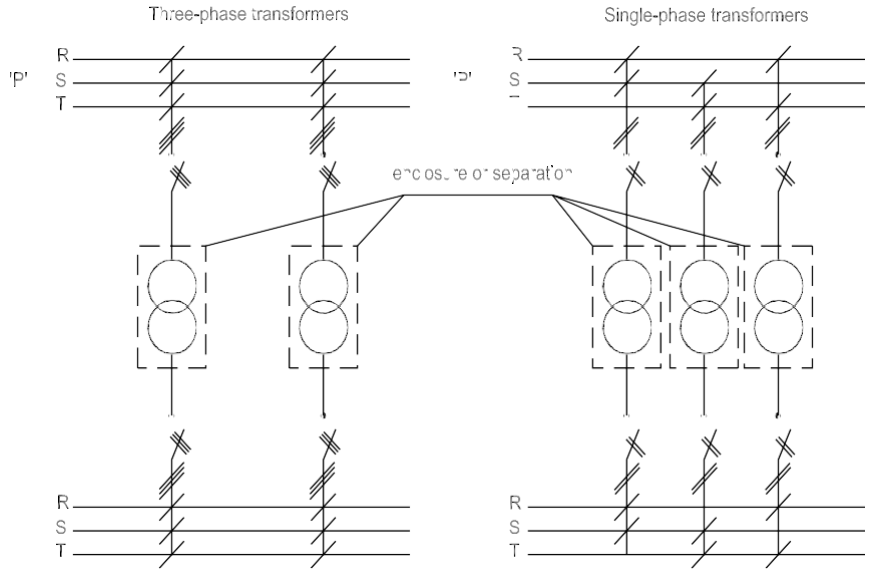
Each transformer required is to be located as a separate unit with separate enclosure or equivalent, and is to be served by separate circuits on the primary and secondary sides. Each of the primary circuits is to be provided with switchgears and protection devices in each phase. Each of the secondary circuits is to be provided with a multiple isolating switch.

Suitable interlocks or a warning label are to be provided in order to prevent maintenance or repair of one single-phase transformer unless both switchgears are opened on their primary and secondary sides.

2.2.12 For ships intended for operation with periodically unattended machinery spaces, see Part F, Chapter 3.

2.2.13 For starting arrangements for main generating sets, see Ch 1, Sec 2, [5.1].

Figure 1



2.3 Emergency source of electrical power

2.3.1 *A self-contained emergency source of electrical power shall be provided.*

2.3.2 *Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used, exceptionally, and for short periods, to supply non-emergency circuits.*

Exceptionally is understood to mean conditions, while the vessel is at sea, such as:

a) blackout situation

b) dead ship situation

c) routine use for testing

d) short-term parallel operation with the main source of electrical power for the purpose of load transfer.

Unless otherwise instructed by the Society, the emergency generator may be used during lay time in port for the supply of the ship mains, provided the requirements of [2.4] are complied with.

2.3.3 *The electrical power available shall be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously.*

2.3.4 *The emergency source of electrical power shall be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the services stated in* [3.7.3] *for the period specified, if they depend upon an electrical source for their operation.*

2.3.5 *The transitional source of emergency electrical power, where required, is to be of sufficient capacity to supply at least the services stated in* [3.7.7] *for half an hour, if they depend upon an electrical source for their operation.*

2.3.6 *An indicator shall be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power referred to in* [2.3.13] *and* [2.3.14] *are being discharged.*

2.3.7 If the services which are to be supplied by the transitional source receive power from an accumulator battery by means of semiconductor convertors, means are to be provided for supplying such services also in the event of failure of the convertor (e.g. providing a bypass feeder or a duplication of convertor).

2.3.8 *(1/7/2002)*

Where electrical power is necessary to restore propulsion, the capacity of the emergency source shall be sufficient to restore propulsion to the ship in conjunction to other machinery as appropriate, from a dead ship condition within 30 min. after blackout.

For the purpose of this requirement only, the dead ship condition and blackout are both understood to mean a condition under which the main propulsion plant, boilers and auxiliaries are not in operation and in restoring the propulsion, no stored energy for starting the propulsion plant, the main source of electrical power and other essential auxiliaries is to be assumed available. It is assumed that means are available to start the emergency generator at all times.

The emergency generator and other means needed to restore the propulsion are to have a capacity such that the necessary propulsion starting energy is available within 30 minutes of blackout/dead ship condition as defined above. Emergency generator stored starting energy is not to be directly used for starting the propulsion plant, the main source of electrical power and/or other essential auxiliaries (emergency generator excluded).

For steam ships, the 30 minute time limit given in SOLAS Convention can be interpreted as time from blackout/dead ship condition defined above to light-off the first boiler.

For passenger ships not engaged in international voyages and cargo ships of less than 500 gross tonnage or of 500 gross tonnage and upwards not engaged in international voyages, the 30 minute time limit does not apply.

2.3.9 *Provision shall be made for the periodic testing of the complete emergency system and shall include the testing of automatic starting arrangements,* where provided.

2.3.10 For starting arrangements for emergency generating sets, see Ch 1, Sec 2, [5.1].

2.3.11 *The emergency source of electrical power may be either a generator or an accumulator battery which shall comply with the requirements of* [2.3.12] *or* [2.3.13]*, respectively.*

2.3.12 *Where the emergency source of electrical power is a generator, it shall be:*

a) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed cup test) of not less than 43°C;

b) started automatically upon failure of the main source of electrical power supply to the emergency switchboard *unless a transitional source of emergency electrical power in accordance with (c) below is provided; where the emergency generator is automatically started, it shall be automatically connected to the emergency switchboard; those services referred to in* [3.7.7] *shall then be connected automatically to the emergency generator; and*

c) provided with a transitional source of emergency electrical power as specified in [2.3.14] *unless an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 s.*

2.3.13 *Where the emergency source of electrical power is an accumulator battery it shall be capable of:*

a) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage;

b) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and

c) immediately supplying at least those services specified in [3.7.7].

2.3.14 *The transitional source of emergency electrical power where required by* [2.3.12] (item c) *shall consist of an accumulator battery which shall operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage and be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the services in* [3.7.7] *if they depend upon an electrical source for their operation.*

2.3.15 For the emergency source of electrical power in passenger ships, see Pt E, Ch 11, Sec 5.

2.3.16 *(1/1/2022)*

When the emergency generator room ventilation system is fitted with closable ventilation louvers and ventilator closing appliances, the following requirements apply:

a) ventilation louvers and closing appliances may either be hand-operated or power-operated (hydraulic / pneumatic / electric) and are to be operable under a fire condition;

b) hand-operated ventilation louvers and closing appliances are to be kept open during normal operation of the vessel. Corresponding instruction plates are to be provided at the location where hand-operation is provided;

c) power-operated ventilation louvers and closing appliances are to be of a fail-to-open type. Closed power-operated ventilation louvers and closing appliances are acceptable during normal operation of the vessel;

d) power-operated ventilation louvers and closing appliances are to open automatically whenever the emergency generator is starting / in operation;

e) it is to be possible to close ventilation openings by a manual operation from a clearly marked safe position outside the space, where the closing operation can be easily confirmed. The louver status (open / closed) shall be indicated at this position. Such closing shall not be possible from any other remote position.

2.4 Use of emergency generator in port

2.4.1 To prevent the generator or its prime mover from becoming overloaded when used in port, arrangements are to be provided to shed sufficient non-emergency loads to ensure its continued safe operation.

2.4.2 The prime mover is to be arranged with fuel oil filters and lubrication oil filters, monitoring equipment and protection devices as requested for the prime mover for main power generation and for unattended operation.

2.4.3 The fuel oil supply tank to the prime mover is to be provided with a low level alarm, arranged at a level ensuring sufficient fuel oil capacity for the emergency services for the period of time as required in [3.7].

2.4.4 The prime mover is to be designed and built for continuous operation and should be subjected to a planned maintenance scheme ensuring that it is always available and capable of fulfilling its role in the event of an emergency at sea.

2.4.5 Fire detectors are to be installed in the location where the emergency generator set and emergency switchboard are installed.

2.4.6 Means are to be provided to readily change over to emergency operation.

2.4.7 Control, monitoring and supply circuits for the purpose of the use of the emergency generator in port are to be so arranged and protected that any electrical fault will not influence the operation of the main and emergency services.

When necessary for safe operation, the emergency switchboard is to be fitted with switches to isolate the circuits.

2.4.8 Instructions are to be provided on board to ensure that, even when the vessel is underway, all control devices (e.g. valves, switches) are in a correct position for the independent emergency operation of the emergency generator set and emergency switchboard.

These instructions are also to contain information on the required fuel oil tank level, position of harbour/sea mode switch, if fitted, ventilation openings, etc.

3 Distribution

3.1 Earthed distribution systems

3.1.1 System earthing is to be effected by means independent of any earthing arrangements of the non-current-carrying parts.

3.1.2 Means of disconnection are to be fitted in the neutral earthing connection of each generator so that the generator may be disconnected for maintenance or insulation resistance measurements.

3.1.3 Generator neutrals may be connected in common, provided that the third harmonic content of the voltage wave form of each generator does not exceed 5%.

3.1.4 Where a switchboard is split into sections operated independently or where there are separate switchboards, neutral earthing is to be provided for each section or for each switchboard. Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

3.1.5 Where for final sub-circuits it is necessary to locally connect a pole (or phase) of the sub-circuits to earth after the protective devices (e.g. in automation systems or to avoid electromagnetic disturbances), provision (e.g. d.c./d.c. convertors or transformers) is to be made such that current unbalances do not occur in the individual poles or phases.

3.1.6 For high voltage systems see Sec 13.

3.2 Insulated distribution systems

3.2.1 *Every insulated distribution system, whether primary or secondary* (see Note 1)*, for power, heating or lighting, 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.*

Note 1: A primary system is one supplied directly by generators. Secondary systems are those supplied by transformers or convertors.

3.2.2 For high voltage systems see Sec 13.

3.3 Distribution systems with hull return

3.3.1 *Where the hull return system is used,* if permitted*, all final sub-circuits, i.e. all circuits fitted after the last protective device, shall be two-wire.*

The hull return is to be achieved by connecting to the hull one of the busbars of the distribution board from which the final sub-circuits originate.

3.4 General requirements for distribution systems

3.4.1 The distribution system is to be such that the failure of any single circuit will not endanger or impair primary essential services and will not render secondary essential services inoperative for longer periods.

3.4.2 No common switchgear (e.g. contactors for emergency stop) is to be used between the switchboard's busbars and two primary non duplicated essential services.

3.4.3 *Where the main source of electrical power is necessary for propulsion and steering of the ship, the system shall be so arranged that the electrical supply to equipment necessary for propulsion and steering and to ensure safety of the ship will be maintained or immediately restored in the case of loss of any one of the generators in service.*

3.4.4 *(1/1/2001)*

Where the electrical power is normally supplied by more than one generator set simultaneously in parallel operation, provision of protection, including automatic disconnection of sufficient non-essential services and if necessary secondary essential services and those provided for habitability, are to be made to ensure that, in case of loss of any of these generating sets, the remaining ones are kept in operation to permit propulsion and steering and to ensure safety.

3.4.5 *(1/1/2001)*

Where the electrical power is normally supplied by one generator, provision are to be made, upon loss of power, for automatic starting and connecting to the main switchboard of stand-by generator(s)of sufficient capacity with automatic restarting of the essential auxiliaries, in sequential operation if required. Starting and connection to the main switchboard of one generator is to be as rapid as possible, preferably within 30 seconds after loss ofpower.

Where prime movers with longer starting time are used, this starting and connection time may be exceeded upon approval from the Society.

3.4.6 *(1/1/2001)*
Load shedding or other equivalent arrangements are to be provided to protect the generators against sustained overload.

3.4.7 *(1/1/2001)*
The load shedding is to be automatic.

3.4.8 *(1/1/2001)*
The non-essential services, service for habitable conditions may be shed and, where necessary, additionally, the secondary essential services, sufficient to ensure the connected generator set or generator sets are not overloaded.

3.5 Harmonic distortion for ship electrical distribution system including harmonic filters

3.5.1 Monitoring of harmonic distortion levels for ships including harmonic filters *(1/1/2020)*
For ships where harmonic filters are installed on main busbars of electrical distribution system facilities to continuously monitor the levels of harmonic distortion experienced on the main busbar, as well as alerting the crew should the level of harmonic distortion exceed the acceptable limits, are to be fitted.

Where the engine room is provided with automation systems, the reading should be logged electronically, otherwise the reading is to be recorded in the engine log book for inspection by the surveyor.

3.5.2 Protection arrangements for harmonic filters *(1/1/2020)*
The harmonic filters should be arranged as three phase units with individual protection of each phase.

The activation of the protection arrangement in a single phase is to result in automatic disconnection of the complete filter.

Additionally, a current unbalance detection system, independent of the overcurrent protection, alerting the crew in case of current unbalance, is to be provided.

Arrangements are to be provided to alert the crew in the event of activation of the protection of a harmonic filter circuit.

Consideration is to be given to additional protection for the individual capacitor element as e.g. relief valve or overpressure disconnector in order to protect against damage from rupturing; this consideration should take into account the type of capacitors used.

3.5.3 Mitigation of the effects of harmonic filter failure on a ship's operation *(1/1/2020)*
The system integrator of the distribution system is to show, by calculation, the effect of a failure of a harmonic filter on the level of harmonic distortion experienced.

The system integrator of the distribution system is to provide the ship Owner with guidance documenting permitted modes of operation of the electrical distribution system while maintaining harmonic distortion levels within acceptable limits during normal operation as well as following the failure of any combination of harmonic filters.

The calculation results and validity of the guidance provided are to be verified by the surveyor during sea trials.

Note 1: harmonic filters installed for single application frequency drives, such as pump motors, may be excluded from requirements of [3.5].

3.6 Main distribution of electrical power

3.6.1 Where the main source of electrical power is necessary for propulsion of the ship, the main busbar is to be divided into at least two parts which are normally to be connected by circuit breakers or other approved means such as circuit breakers without tripping mechanisms or disconnecting links or switches by means of which busbars can be split safely and easily.

The connection of generating sets and associated auxiliaries and other duplicated equipment is to be equally divided between the parts as far as practicable, so that in the event of damage to one section of the switchboard the remaining parts are still supplied.

3.6.2 *(1/1/2021)*
Two or more units serving the same consumer (e.g. main and standby lubricating oil pumps) are to be supplied by individual separate circuits without the use of common feeders, protective devices or control circuits.

This requirement is satisfied when such units are supplied by separate cables from the main switchboard or from two independent distribution boards.

3.6.3 *A main electric lighting system which shall provide illumination throughout those parts of the ship normally accessible to and used by (passengers or) crew shall be supplied from the main source of electrical power.*

3.7 Emergency distribution of electrical power

3.7.1 *The emergency switchboard shall be supplied during normal operation from the main switchboard by an interconnector feeder which shall be adequately protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power.*

Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short-circuit.

3.7.2 *In order to ensure ready availability of the emergency source of electrical power, arrangements shall be made where necessary to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that power shall be available to the emergency circuits.*

3.7.3 *(1/1/2023)*

The emergency source of electrical power shall be capable of supplying simultaneously at least the following services for the periods specified hereafter, if they depend upon an electrical source for their operation:

a) for a period of 3 hours, emergency lighting at every muster and embarkation station and over the sides;

b) for a period of 18 hours, emergency lighting:

1) in all service and accommodation alleyways, stairways and exits, personnel lift cars and personnel lift trunks;

2) in the machinery spaces and main generating stations including their control positions;

3) in all control stations, machinery control rooms, and at each main and emergency switchboard;

4) at all stowage positions for firemen's outfits;

5) at the steering gear;

6) at the fire pump referred to in (e) below, at the sprinkler pump, if any, at the emergency bilge pump, if any, and at the starting positions of their motors; and

7) in all cargo pump-rooms of tanker

c) for a period of 18 hours:

1) the navigation lights and other lights required by the International Regulations for Preventing Collisions at Sea in force;

2) on ships constructed on or after 1 February 1995 the VHF radio installation required by Regulation IV/7.1.1 and IV/7.1.2 of SOLAS Consolidated Edition 1992, and, if applicable:

- *the MF radio installation required by Regulations IV/9.1.1, IV/9.1.2, IV/10.1.2 and IV/10.1.3;*
- *the ship earth station required by Regulation IV/10.1.1; and*
- *the MF/HF radio installation required by Regulations IV/10.2.1, IV/10.2.2 and IV/11.1;*

d) for a period of 18 hours:

1) all internal communication equipment as required in an emergency [3.7.4]*;*

2) the shipborne navigational equipment as required by Regulation V/19; where such provision is unreasonable or impracticable the Society may waive this requirement for ships of less than 5 000 tons gross tonnage;

3) the fire detection and fire alarm systems (see Sec 1, [1.1.2]); and

4) intermittent operation of the daylight signalling lamp, the ship's whistle, the manually operated call points and all internal signals (see [3.7.5]) *that are required in an emergency;*

unless such services have an independent supply for the period of 18 hours from an accumulator battery suitably located for use in an emergency;

e) for a period of 18 hours: one of the fire pumps, when required, if dependent upon the emergency generator for its source of power (see Sec 1, [1.1.2]);

f) for the period of time required in Ch 1, Sec 11, [2]*, the steering gear where it is required to be so supplied.*

Note 1: for ships having navigation notation "sheltered area" or "special navigation" in an area at not more than 6 miles from the shore (see Sec 1, [1.1.3]) and not subject to the SOLAS convention, the Society may accept that the emergency source of electrical power is capable of supplying, for a period of not less than 2 times the expected duration of the longest voyage, but not less than:

- *3 hours, or*
- *30 minutes for ships having navigation notation "sheltered area",*

only the following services:

- *emergency lighting;*
- *navigation lights;*
- *radio installation;*
- *internal communication equipment and general alarm system;*
- *fire detection and alarm system;*
- *the steering gear pump (where it is required to be so supplied);*
- *fire pump (when required, if dependent upon the emergency source of electrical power for its source of power);*
- *power to the control, indication and alarm circuits of watertight and fire doors (where provided).*

3.7.4 *(1/1/2026)*

Internal communication equipment required in an emergency generally includes:

a) the means of communication between the navigating bridge and the steering gear compartment

b) the means of communication between the navigating bridge and the position in the machinery space or control room from which the engines are normally controlled

c) the means of communication between the bridge and the radio telegraph or radio telephone stations, where separately arranged outside the bridge.

d) the general emergency alarm system (as required in [3.15])

e) the public address system (as required in [3.16]).

3.7.5 *(1/7/2007)*

Internal signals required in an emergency generally include:

a) general alarm (see Sec 1, [1.1.2])

b) watertight door indication.

3.7.6 In a ship engaged regularly in voyages of short duration, i.e. voyages where the route is no greater than 20 nautical miles offshore or where the vessel has a class notation "Coastal Navigation", the Society may, if satisfied that an adequate standard of safety would be attained, accept a lesser period than the 18-hour period specified in [3.7.3] (item b to item e) but not less than 12 hours.

Note 1: In ships for which SOLAS is not applicable, a reduced period of time may be accepted.

Note 2: For passenger ships see Pt E, Ch 11, Sec 5.

3.7.7 *The transitional source of emergency electrical power, where required, shall supply for half an hour at least the following services if they depend upon an electrical source for their operation:*

a) the lighting required by [3.7.3](item a, b, c1)*; for this transitional phase, the required emergency electric lighting, in respect of the machinery space and the accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps; and*

b) all services required by [3.7.3] (item d1, d3, d4) *unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.*

3.8 Shore supply

3.8.1 Where arrangements are made for supplying the electrical installation from a source on shore or elsewhere, a suitable connection box is to be installed on the ship in a convenient location to receive the flexible cable from the external source.

3.8.2 *(1/7/2006)*

Permanently fixed cables of adequate rating are to be provided for connecting the box to the main switchboard or emergency switchboard.

3.8.3 Where necessary for systems with earthed neutrals, the box is to be provided with an earthed terminal for connection between the shore's and ship's neutrals or for connection of a protective conductor.

3.8.4 *(1/7/2009)*

The connection box is to contain a circuit-breaker or a switch-disconnector and fuses.

The shore connection is to be protected against short-circuit and overload; however, the overload protection may be omitted in the connection box if provided on the main or emergency switchboard.

3.8.5 Means are to be provided for checking the phase sequence of the incoming supply in relation to the ship's system.

3.8.6 *(1/7/2009)*
The cable connection to the box is to be provided with at least one switch-disconnector on the main or emergency switchboard.

3.8.7 *(1/7/2009)*
The shore connection is to be provided with an indicator at the main or emergency switchboard in order to show when the cable is energised.

3.8.8 At the connection box a notice is to be provided giving full information on the nominal voltage and frequency of the installation.

3.8.9 *(1/7/2009)*
The switch-disconnector on the main or emergency switchboard is to be interlocked with the generator circuit-breakers in order to prevent its closure when any generator is supplying the main or emergency switchboard unless special provisions to the satisfaction of the Society are taken to permit safe transfer of electrical load.

3.8.10 Adequate means are to be provided to equalise the potential between the hull and the shore when the electrical installation of the ship is supplied from shore.

3.8.11 *(1/7/2013)*
Where high voltage shore connections are provided, the requirements of Pt F, Ch 13, Sec 15 are to be complied with.

3.9 Supply of motors

3.9.1 A separate final sub-circuit is to be provided for every motor required for an essential service (and for every motor rated at 1 kW or more).

3.9.2 Each motor is to be provided with controlgear ensuring its satisfactory starting.

Depending on the capacity of the generating plant or the cable network, it may be necessary to limit the starting current to an acceptable value.

Direct on line starters are accepted if the voltage drop does not exceed 15% of the network voltage.

3.9.3 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.

3.9.4 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.

3.10 Specific requirements for special power services

3.10.1 For the supply and characteristics of the distribution of the following services see the requirements listed:

- Steering gear: Ch 1, Sec 11, [2]
- Fire-extinguishing and detecting systems: Ch 4, Sec 1, [6]
- Permanently installed submergible bilge pump: Ch 1, Sec 10, [6.7.7]
- Ventilation fans: Chapter 4
- Fuel pumps: Ch 1, Sec 10
- Pumps discharging overboard above the lightest water line and in way of the area of lifeboat and liferaft launching: Ch 1, Sec 10, [5.2.4].

3.10.2 All power circuits terminating in a bunker or cargo space are to be provided with a multiple-pole switch outside the space for disconnecting such circuits.

3.11 Power supply to heaters

3.11.1 Each heater rated more than 16A is to be connected to a separate final circuit.

3.12 Power supply to lighting installations

3.12.1 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.

3.13 Special lighting services

3.13.1 In spaces such as:

- main and large machinery spaces
- large galleys
- passageways
- stairways leading to boat-decks
- public spaces

there is to be more than one final sub-circuit for lighting such that failure of any one circuit does not reduce the lighting to an insufficient level.

3.13.2 Where the emergency installation is required, one of the circuits in [3.13.1] may be supplied from the emergency source of power.

3.13.3 All lighting circuits terminating in a bunker or cargo space are to be provided with a multiple-pole switch outside the space for disconnecting such circuits.

3.14 Navigation lights

3.14.1 *(1/7/2003)*

Navigation lights are to be connected separately to a distribution board specially reserved for this purpose.

Signalling lights may be connected to the navigation light distribution board, or to a separate distribution board.

3.14.2 *(1/7/2003)*

The navigation light distribution board is to be supplied from two alternative circuits, one from the main source of power and one from the emergency source of power; see also [3.7].

The transfer of supply is to be practicable from the bridge, for example by means of a switch.

3.14.3 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 [3.14.1].

3.14.4 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.

3.14.5 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.

3.15 General emergency alarm system

3.15.1 *(1/7/2007)*

For the application of this item [3.15], see Sec 1, [1.1.2].

3.15.2 *(1/7/2002)*
An electrically operated bell or klaxon or other equivalent warning system installed in addition to the ship's whistle or siren, for sounding the general emergency alarm signal, is to comply with the requirements of this sub-article.

For passenger ships not engaged in international voyages and cargo ships of less than 500 gross tonnage or of 500 gross tonnage and upwards not engaged in international voyages, the system is to be capable of operation from the navigating bridge, it is to be continuously supplied from an emergency source of electrical power and it is to comply with [3.15.3], [3.15.4], [3.15.9], [3.15.11] and [3.15.13].

3.15.3 The general emergency alarm system is to be supplemented by either a public address system complying with the requirements in [3.16] or other suitable means of communication.

3.15.4 Entertainment sound system is to be automatically turned off when the general alarm system is activated.

3.15.5 The system is to be continuously powered and is to have an automatic change-over to a standby power supply in case of loss of normal power supply.

An alarm is to be given in the event of failure of the normal power supply.

3.15.6 The system is to be powered by means of two circuits, one from the ship's main supply and the other from the emergency source of electrical power required by [2.3] and [3.7].

3.15.7 The system is to be capable of operation from the navigation bridge and, except for the ship’s whistle, also from other strategic points.

Note 1: Other strategic points are taken to mean those locations, other than the navigation bridge, from where emergency situations are intended to be controlled and the general alarm system can be activated. A fire control station or a cargo control station should normally be regarded as strategic points.

3.15.8 The alarm is to continue to function after it has been triggered until it is manually turned off or is temporarily interrupted by a message on the public address system.

3.15.9 The alarm system is to be audible throughout all the accommodation and normal crew working spaces.

3.15.10 The minimum sound pressure level for the emergency alarm tone in interior and exterior spaces is to be 80 dB (A) and at least 10 dB (A) above ambient noise levels occurring during normal equipment operation with the ship underway in moderate weather.

3.15.11 In cabins without a loudspeaker installation, an electronic alarm transducer, e.g. a buzzer or similar, is to be installed.

3.15.12 The sound pressure level at the sleeping position in cabins and in cabin bathrooms is to be at least 75 dB (A) and at least 10 dB (A) above ambient noise levels.

3.15.13 For cables used for the general emergency alarm system, see [9.6].

3.16 Public address system

3.16.1 *(1/7/2007)*
For the application of this item [3.16], see Sec 1, [1.1.2].

3.16.2 *(1/7/2002)*
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.

3.16.3 *(1/7/2002)*
In spaces such as under deck passageways, bosun’s locker, hospital and pump rooms, the public address system is/may not be required.

For passenger ships not engaged in international voyages and cargo ships of less than 500 gross tonnage or of 500 gross tonnage and upwards not engaged in international voyages, item [3.16.9] does not apply.

3.16.4 Where the public address system is used to supplement the general emergency alarm system as per [3.15.3], it is to be continuously powered from the emergency source of electrical power required by [3.7].

3.16.5 The system is to allow for the broadcast of messages from the navigation bridge and from other places on board the ship as deemed necessary.

3.16.6 The system is to be protected against unauthorised use.

3.16.7 The system is to be installed with regard to acoustically marginal conditions and not require any action from the addressee.

3.16.8 Where an individual loudspeaker has a device for local silencing, an override arrangement from the control station(s), including the navigating bridge, is to be in place.

3.16.9 With the ship underway in normal conditions, the minimum sound pressure level for broadcasting emergency announcements is to be:

a) in interior spaces, 75 dB (A) and at least 20 dB (A) above the speech interference level

b) in exterior spaces, 80 dB (A) and at least 15 dB (A) above the speech interference level.

With respect to cabin/state rooms, the sound pressure level is to be attained as required inside such spaces during sea trials.

3.16.10 *(1/7/2013)*

For cables used for the public address system, see [9.6].

3.17 Combined general emergency alarm - public address system

3.17.1 *(1/7/2007)*

For the application of this item [3.17], see Sec 1, [1.1.2].

3.17.2 Where the public address system is the only means for sounding the general emergency alarm signal and the fire alarm, in addition to the requirements of [3.15] and [3.16], the following are to be satisfied:

- the system automatically overrides any other 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.

3.18 Control and indication circuits

3.18.1 For the supply of automation systems, comprising control, alarm and safety system, see the requirements of Chapter 3.

3.18.2 Control and indicating circuits relative to primary essential services are to be branched off from the main circuit in which the relevant equipment is installed. Equivalent arrangements may be accepted by the Society.

3.18.3 Control and indicating circuits relative to secondary essential services and to non-essential services may be supplied by distribution systems reserved for the purpose to the satisfaction of the Society.

3.19 Power supply to the speed control systems of main propulsion engines

3.19.1 Electrically operated speed control systems of main engines are to be fed from the main source of electrical power.

3.19.2 *(1/1/2021)*

Where more than one main propulsion engine is foreseen, each speed control system is to be provided with an individual supply by means of separate wiring from the main switchboard or from two independent distribution boards.

Where the main busbars are divided into two sections, the governors are, as far as practicable, to be supplied equally from the two sections.

3.19.3 In the case of propulsion engines which do not depend for their operation on electrical power, i.e. pumps driven from the main engine, the speed control systems are to be fed both from the main source of electrical power and from an accumulator battery for at least 15 minutes or from a similar supply source.

Such battery may also be used for other services such as automation systems, where foreseen.

3.20 Power supply to the speed control systems of generator sets

3.20.1 Each electrically operated control and/or speed control system of generator sets is to be provided with a separate supply from the main source of electric power and from an accumulator battery for at least 15 minutes or from a similar supply source.

3.20.2 The wiring supplying the main source of electrical power is to be from the main switchboard or from independent section boards.

Where the main busbars are divided into two sections, the governors are, as far as practicable, to be supplied from the sections to which the relevant generators are connected.

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.

4.1.2 Equipment supplied at nominal voltages in excess of 500 V and accessible to non-authorised personnel (e.g. equipment not located in machinery spaces or in locked compartments under the responsibility of the ship's officers) is to have a degree of protection against touching live parts of at least IP4X.

4.1.3 In addition to the requirements of this sub-article, equipment installed in spaces with an explosion hazard is also subject to the provisions of Sec 2, [6].

4.1.4 The enclosures of electrical equipment for the monitoring and control of watertight doors which are situated below the bulkhead deck are to provide suitable protection against the ingress of water.

In particular, the minimum required degree of protection is to be:

- IPX7 for electric motors, associated circuits and control components
- IPX8 for door position indicators and associated circuit components
- IPX6 for door movement warning signals.

Note 1: The water pressure testing of the enclosures protected to IPX8 is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 hours.

Table 2 : Minimum required degrees of protection *(1/1/2026)*

Condition in location	Example of location	Switchboard Control gear Motor starters	Generators	Motors	Transformers	Luminaires	Heating appliances	Cooking appliances	Socket outiets	Accessories (e.g. switches, connection boxes)
Danger of touching live parts only	Dry accommodation spaces Dry control rooms	I P 20	X **(1)**	I P 20	I P 20	I P 20	I P20	I P 20	I P 20	I P 20

Condition in location	Example of location	Switchboard Control gear Motor starters	Generators	Motors	Transformers	Luminaires	Heating appliances	Cooking appliances	Socket outiets	Accessories (e.g. switches, connection boxes)
Danger of dripping liquid and/for moderate mechanical damage	Control rooms, wheel-house, radio room	I P 22	X	I P 22	I P 22	I P 22	I P22	I P 22	I P 22	I P 22
	Engine and boiler rooms above floor	I P 22	I P 22	I P 22	I P 22	I P 22	I P22	I P 22	I P 44	I P 44
	Steering gear rooms	I P 22	I P 22	I P 22	I P 22	I P 22	I P22	X	I P 44	I P 44
	Emergency machinery rooms	I P 22	I P 22	I P 22	I P 22	I P 22	I P22	X	I P 44	I P 44
	General storerooms	I P 22	X	I P 22	I P 22	I P 22	I P22	X	I P 22	I P 44
	Pantries	I P 22	X	I P 22	I P 22	I P 22	I P22	I P 22	I P 44	I P 44
	Provision rooms	I P 22	X	I P 22	I P 22	I P 22	I P22	X	I P 44	I P 44
	Ventilation ducts	X	X	I P 22	X	X	X	X	X	X
Increased danger of liquid and/for mechanical damage	Bathrooms and/or showers	X	X	X	X	I P 34	I P44	X	I P 55	I P 55
	Engine and boiler rooms below floor	X	X	I P 44	X	I P 34	I P44	X	X	I P 55
	Closed fuel oil separator rooms	I P 44	X	I P 44	I P 44	I P 34	I P44	X	X	I P 55
	Closed lubricating oil separator rooms	I P 44	X	I P 44	I P 44	I P 34	I P44	X	X	I P 55
Increased danger of liquid and mechanical damage	Ballast pump rooms	I P 44	X	I P 44 **(2)**	I P 44 **(2)**	I P 34	I P44	X	I P 55	I P 55
	Refrigerated rooms	X	X	I P 44	X	I P 34	I P44	X	I P 55	I P 55
	Galleys and laundries	I P 44	X	I P 44	I P 44	I P 34	I P44	I P 44	I P 44	I P 44
	Public bathrooms and shower	X	X	I P 44	I P 44	I P 34	I P44	X	I P 44	I P 44
Danger of liquid spraying. Presence of cargo dust. Serious mechanical damage. Aggressive fumes	Shaft or pipe tunnels in double bottom	I P 55	X	I P 55	I P 55	I P 55	I P55	X	I P 56	I P 56
	Holds for general cargo	X	X	I P 55	X	I P 55	I P55	X	I P 56	I P 56
	Ventilation trunks	X	X	I P 55	X	X	X	X	X	X
Danger of liquid in massive quantities	Open decks	I P 56	X	I P 56	X	I P 55	I P56	X	I P 56	I P 56

Condition in location	Example of location	Switchboard Control gear Motor starters	Generators	Motors	Transformers	Luminaires	Heating appliances	Cooking appliances	Socket outiets	Accessories (e.g. switches, connection boxes)
Danger of submersion	Spaces in which equipment, required to remain operational, may be subject to submersion (e.g. spaces below the bulkhead deck) **(3)**	X	X	IP X8 **(4)**	X	X	X	X	X	IP X8 **(4)**

(1) The symbol "X" denotes equipment which it is not advised to install.

(2) Electric motors and starting transformers for lateral thrust propellers located in spaces similar to ballast pump rooms may have degree of protection IP22.

(3) For watertight doors see also [4.1.4]; and for solenoid valves and remote indication devices (limit switches) installed on remotely controlled bilge valves see also Ch 1, Sec 10, [2.7.3].

(4) Conditions of pressure and time to be specified.

Table 3 : Required Environmental Categories *(1/7/2017)*

Location within main area				
Main Areas on Board	General	Inside cubicles, desks, etc.	On machinery such as internal combustion engines, compressors	Masts
Machinery Spaces/Steering Gear	EC21	EC3a1	EC3b3	X **(1)**
Control Room, Accommodation	EC21 EC11C	EC3a1	X	X
Bridge	EC21 EC11C	EC3a1	X	X
Pump Room, Holds, Rooms with no Heating	EC41	X	X	X
Exposed Decks	EC41S	X	X	EC42S

(1) The symbol "X" denotes locations which are generally not applicable.

4.1.5 *(1/7/2005)*

For electrical and electronic equipment installed in engine rooms protected by fixed water-based local application fire-fighting systems, see Ch 4, Sec 1, [7].

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 Environmental categories of the equipment

6.1 Environmental categories

6.1.1 The environmental categories of the electrical equipment, in relation to the place of installation, are generally to be those specified in Tab 3.

6.1.2 For ships operating outside the tropical belt, the maximum ambient air temperature may be assumed as equal to + 40 °C instead of + 45 °C, so that the first characteristic numeral changes from 1 to 3.

7 Electrical protection

7.1 General requirements for overcurrent protection

7.1.1 Electrical installations are to be protected against accidental overcurrents including 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 service in the event of a fault, through coordinated and discriminative action of the protective devices
- elimination of the effects of faults to reduce damage to the system and the hazard of fire as far as possible.

Note 1: An overcurrent is a current exceeding the nominal current.

Note 2: 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.

7.1.2 Devices provided for overcurrent protection are to be chosen according to the requirements, especially with regard to overload and short-circuit.

Note 1: Overload is an operating condition in an electrically undamaged circuit which causes an overcurrent.

7.1.3 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.

7.2 Short-circuit currents

7.2.1 In calculating the maximum prospective short-circuit current, the source of current is to include the maximum number of generators which can be simultaneously connected (as far as permitted by any interlocking arrangements), and the maximum number of motors which are normally simultaneously connected in the system.

The maximum number of generators or transformers is to be evaluated without taking into consideration short-term parallel operation (e.g. for load transfer) provided that suitable interlock is foreseen.

7.2.2 Short-circuit current calculations are to be performed in accordance with a method recognised by the Society, such as that given in IEC Publication 61363-1.

7.2.3 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:

  $I_{ac} = 10\ I_{TG} + 3{,}5\ I_{TM}$

  $I_{pk} = 2{,}4\ I_{ac}$
- for direct current systems supplied by batteries:

  $I_p = K\ C_{10} + 6\ I_{TM}$

where:

I_p : Maximum short-circuit current

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 = 8
- 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.

7.3 Selection of equipment

7.3.1 *(1/7/2013)*

Circuit-breakers are to be suitable for isolation.

Circuit-breakers of withdrawable type are required where they are not suitable for isolation.

7.3.2 Equipment is to be chosen on the basis of its rated current and its making/breaking capacity.

7.3.3 *(1/7/2013)*

In the selection of circuit-breakers with intentional short-time delay for short-circuit release (e.g. generator circuit-breakers), 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 (I_{cw}).

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 (I_{cs}).

Note 1: For the purpose of these Rules, circuit breakers are distinguished according to the utilization categories A and B in compliance with IEC publication 60947-2 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 and therefore without a short-time withstand current rating (Icw).
- 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. Such circuit-breakers have a short-time withstand current rating (Icw).

7.3.4 For duplicated essential services and non-essential services, circuit-breakers may be selected according to their ultimate short-circuit breaking capacity (I_{cu}).

7.3.5 *(1/7/2013)*

Circuit breakers used in insulated systems are to comply with Annex H of IEC Publication 60947-2.

7.3.6 For switches, the making/breaking capacity is to be in accordance with utilisation category AC-22 A or DC-22 A (in compliance with IEC Publication 60947-3).

7.3.7 For fuse-switch disconnectors or switch-disconnector fuse units, the making/breaking capacity is to be in accordance with utilisation categories AC-23 A or DC-23 A (in compliance with IEC Publication 60947-3).

7.4 Protection against short-circuit

7.4.1 Protection against short-circuit currents is to be provided by circuit- breakers or fuses.

7.4.2 The rated short-circuit breaking capacity of every protective device is to be not less than the maximum prospective value of the short-circuit current at the point of installation at the instant of contact separation.

7.4.3 The rated short-circuit making capacity of every mechanical switching device intended to be capable of being closed on short-circuit is to be not less than the maximum value of the short-circuit current at the point of installation. On alternating current this maximum value corresponds to the peak value allowing for maximum asymmetry.

7.4.4 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.

7.4.5 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 generator side by a fuse or by a circuit-breaker having at least the necessary short-circuit rating and not being the generator circuit-breaker.

7.4.6 The same fuse or circuit-breaker may back up more than one circuit-breaker where the circuits concerned do not involve essential services.

7.4.7 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.

7.4.8 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.

7.4.9 When determining the performance requirements for the above-mentioned back-up protection arrangement, it is permissible to take into account the impedance of the various circuit elements of the arrangement, such as the impedance of a cable connection when the backed-up circuit-breaker is located away from the back-up breaker or fuse.

7.5 Continuity of supply and continuity of service

7.5.1 The protection of circuits is to be such that a fault in one service does not cause the loss of any essential services.

7.5.2 The protection of the emergency circuit is to be such that a failure in one circuit does not cause a loss of other emergency services.

Note 1: The continuity of supply for the primary essential services and the continuity of service for the secondary essential services are to be ensured.

The continuity of supply is the condition for which during and after a fault in a circuit, the supply to the healthy circuits (see circuit 3 in Fig 2) is permanently ensured.

The continuity of service is the condition for which after a fault in a circuit has been cleared, the supply to the healthy circuits (see circuit 3 in Fig 2) is re-established.

7.6 Protection against overload

7.6.1 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.

7.6.2 The use of fuses up to 320 A for overload protection is permitted.

7.7 Localisation of overcurrent protection

7.7.1 Short-circuit protection is to be provided for every non-earthed conductor.

7.7.2 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.

7.7.3 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.

7.7.4 Electrical protection is to be located as close as possible to the origin of the protected circuit.

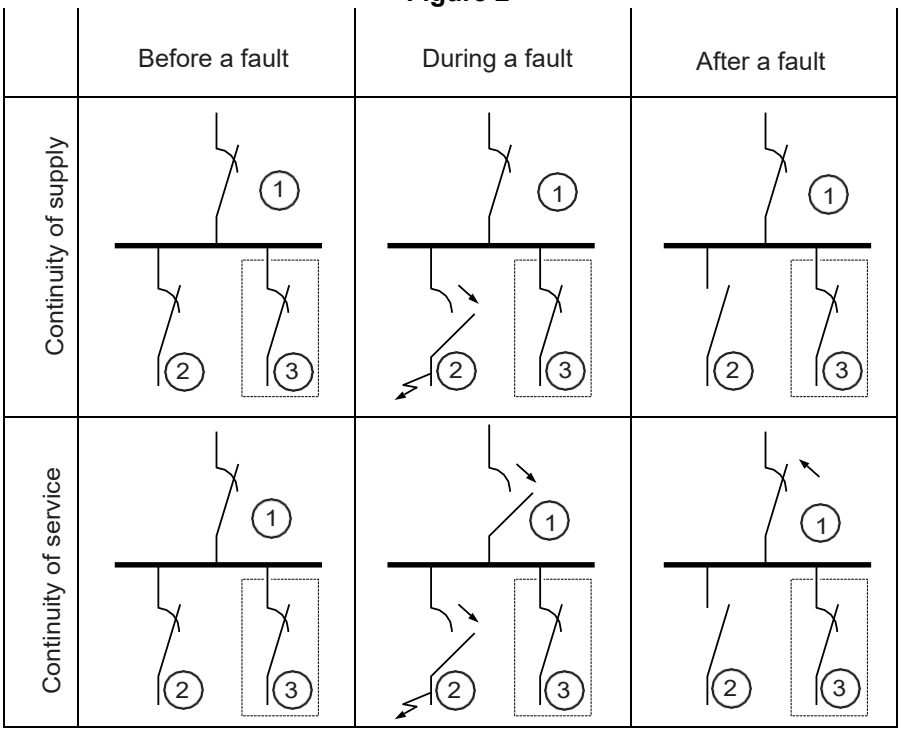
7.8 Protection of generators

7.8.1 Generators are to be protected against short-circuits and overloads by multipole circuit-breakers.

For generators not arranged to operate in parallel with a rated output equal to or less than 50 kVA, a multipole switch with a fuse in each insulated phase on the generator side may be accepted.

7.8.2 When multipole switch and fuses are used, the fuse rating is to be maximum 110% of the generator rated current.

Figure 2



7.8.3 Where a circuit-breaker is used:

a) the overload protection is to trip the generator circuit-breaker at an overload between 10% and 50%; for an overload of 50% of the rated current of the generator the time delay is not to exceed 2 minutes; however, the figure of 50% or the time delay of 2 minutes may be exceeded if the construction of the generator permits this

b) the setting of the short-circuit protection is to instantaneously trip the generator circuit-breaker at an overcurrent less than the steady short-circuit current of the generator. Short time delays (e.g. from 0,5 s to 1 s) may be introduced for discrimination requirements in "instantaneous" tripping devices.

7.8.4 For emergency generators the overload protection may, instead of disconnecting the generator automatically, give a visual and audible alarm in a permanently attended space.

7.8.5 After disconnection of a generator due to overload, the circuit-breaker is to be ready for immediate reclosure.

7.8.6 Generator circuit-breakers are to be provided with a reclosing inhibitor which prevents their automatic reclosure after tripping due to a short-circuit.

7.8.7 Generators having a capacity of 1500 kVA or above are to be equipped with a suitable protective device or system which, in the event of a short-circuit in the generator or in the supply cable between the generator and its circuit-breaker, will de-excite the generator and open the circuit-breaker (e.g. by means of differential protection).

7.8.8 *Where the main source of electrical power is necessary for the propulsion of the ship, load shedding or other equivalent arrangements are to be provided to protect the generators against sustained overload.*

7.8.9 Arrangements are to be made to disconnect or reduce automatically the excess load when the generators are overloaded in such a way as to prevent a sustained loss of speed and/or voltage (see Sec 2, Tab 6). The operation of such device is to activate a visual and audible alarm. A time delay of 5-20 s is considered acceptable.

7.8.10 When an overload is detected the load shedding system is to disconnect automatically, after an appropriate time delay, the circuits supplying the non-essential services and, if necessary, the secondary essential services in a second stage.

7.8.11 Alternating current generators arranged to operate in parallel are to be provided with reverse-power protection. The protection is to be selected in accordance with the characteristics of the prime mover.

The following values are recommended:

- 2-6% of the rated power for turbogenerators
- 8-15% of the rated power for diesel generators.

The reverse-power protection may be replaced by other devices ensuring adequate protection of the prime movers.

7.8.12 Generators are to be provided with an undervoltage protection which trips the breaker if the voltage falls to 70% - 35% of the rated voltage.

For generators arranged for parallel operation, measures are to be taken to prevent the generator breaker from closing if the generator is not generating and to prevent the generator remaining connected to the busbars if voltage collapses.

The operation of the undervoltage release is to be instantaneous when preventing closure of the breaker, but it is to be delayed for selectivity purposes when tripping the breaker.

7.9 Protection of circuits

7.9.1 *Each separate circuit shall be protected against short-circuit and against overload, unless otherwise specified in these Rules or where the Society may exceptionally otherwise permit.*

7.9.2 Each circuit is to be protected by a multipole circuit-breaker or switch and fuses against overloads and short-circuits.

7.9.3 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.

7.9.4 The protective devices of the circuits supplying motors are to allow excess current to pass during transient starting of motors.

7.9.5 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.

7.9.6 Steering gear circuits are to be provided with short-circuit protection only (see Ch 1, Sec 11, [2]).

7.10 Protection of motors

7.10.1 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 [7.9.5]).

7.10.2 For motors intended for essential services, the overload protection may be replaced by an overload alarm (for steering gear motors see Ch 1, Sec 11, [2]).

7.10.3 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.

7.10.4 For continuous duty motors the protective gear is to have a time delay characteristic which ensures reliable thermal protection against overload.

7.10.5 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.

7.10.6 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.

7.10.7 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.

7.10.8 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.

7.10.9 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.

7.10.10 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.

7.11 Protection of storage batteries

7.11.1 Batteries are to be protected against overload and 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.

7.11.2 Emergency batteries supplying essential services are to have short-circuit protection only.

7.12 Protection of shore power connection

7.12.1 Permanently fixed cables connecting the shore connection box to the main switchboard are to be protected by fuses or circuit-breakers (see [3.8.4]).

7.13 Protection of measuring instruments, pilot lamps and control circuits

7.13.1 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.

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.

7.13.2 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.

7.13.3 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.

7.13.4 Circuits whose failure could endanger operation, such as steering gear control feeder circuits, are to be protected only against short-circuit.

7.13.5 The protection is to be adequate for the minimum cross-section of the protected circuits.

7.14 Protection of transformers

7.14.1 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.

7.14.2 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.

7.14.3 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.

8 System components

8.1 General

8.1.1 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.

8.1.2 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.

9 Electrical cables

9.1 General

9.1.1 *All electrical cables and wiring external to equipment shall be at least of a flame-retardant type,* in accordance with IEC Publication 60332-1.

9.1.2 In addition to the provisions of [9.1.1], when cables are laid in bundles, cable types are to be chosen in compliance with IEC Publication 60332-3 Category A, or other means (see Sec 12) are to be provided such as not to impair their original flame-retarding properties.

9.1.3 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 [9.1.1] and [9.1.2].

9.1.4 *(1/1/2007)*
Cables which are required to have fire-resisting characteristics are to comply with the requirements stipulated in [9.6].

9.2 Choice of insulation

9.2.1 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.

9.2.2 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 4. Special consideration will be given to other insulating materials.

9.2.3 PVC insulated cables are not to be used either in refrigerated spaces, or on decks exposed to the weather of ships classed for unrestricted service.

9.2.4 Mineral insulated cables will be considered on a case by case basis.

9.3 Choice of protective covering

9.3.1 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.

9.3.2 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 Sec 9, [1.5].

9.3.3 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.

9.3.4 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).

9.3.5 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.

9.4 Cables in refrigerated spaces

9.4.1 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.

9.5 Cables in areas with a risk of explosion

9.5.1 For cables in areas with a risk of explosion, see [10].

9.6 Electrical services required to be operable under fire conditions and fire-resistant cables

9.6.1 *(1/1/2007)*

Electrical services required to be operable under fire conditions are as follows:

- Control and power systems to power-operated fire doors and status indication for all fire doors
- Control and power systems to power-operated watertight doors and their status indication
- Emergency fire pump
- Emergency lighting
- Fire and general alarms
- Fire detection systems
- Fire-extinguishing systems and fire-extinguishing media release alarms
- Low location lighting
- Public address systems
- Remote emergency stop/shutdown arrangements for systems which may support the propagation of fire and/or explosion.

9.6.2 *(1/1/2022)*

Where cables for services specified in [9.6.1] including their power supplies pass through high fire risk areas (see Note 1), and in addition for passenger ships, main vertical fire zones, other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the service in any other area or zone. This may be achieved by either of the following measures:

a) Cables being of a fire-resistant type complying with IEC 60331-1 for cables of greater than 20 mm overall diameter, otherwise IEC 60331-21 or IEC 60331-2 for cables with an overall diameter not exceeding 20 mm, are installed and run continuous to keep the fire integrity within the high fire risk area (see Fig 3).

b) At least two loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

Systems that are, fail safe or duplicated with cable runs as widely separated as is practicable may be exempted.

Note 1:

a) For the purpose of application of this item [9.6], the definition of "high fire risk areas" is the following:

(1) Machinery spaces as defined by Chapter 4Regulation 3.30 of SOLAS Chapter II-2, as amended by IMO resolutions up to MSC.421(98) (hereinafter the same), except spaces having little or no fire risk as defined by paragraph (10) of Regulation 9.2.2.3.2.2 of SOLAS Chapter II-2 (including the interpretations for tables 9.3, 9.4, 9.5, 9.6, 9.7 and 9.8 given in MSC/Circ.1120 as amended by MSC.1/Circ.1436 and MSC.1/Circ.1510)

(2) Spaces containing fuel treatment equipment and other highly flammable substances

(3) Galley and Pantries containing cooking appliances

(4) Laundry containing drying equipment

(5) Spaces as defined by paragraphs (8), (12), and (14) of Reg. 9.2.2.3.2.2 of SOLAS Chapter II-2 for ships carrying more than 36 passengers

b) Fire-resistant type cables are to be easily distinguishable.

c) For special cables, requirements in the following standards may be used:

(1) IEC60331-23: Procedures and requirements - Electric data cables

(2) IEC60331-25: Procedures and requirements - Optical fibre cables.

9.6.3 *(1/1/2016)*

The electrical cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source(s) of power and prime mover(s).

They are to be of a fire resistant type, in accordance with [9.6.2] a), where they pass through other high fire risk areas.

9.7 Cables for submerged bilge pumps

9.7.1 Cables and their connections to such pumps are to be capable of operating under a head of water equal to their distance below the bulkhead deck. The cable is to be impervious-sheathed and armoured, is to be installed in continuous lengths from above the bulkhead to the motor terminals and is to enter the air bell from the bottom.

9.8 Internal wiring of switchboards and other enclosures for equipment

9.8.1 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.

9.9 Current carrying capacity of cables

9.9.1 The current carrying capacity for continuous service of cables given in Tab 5 to Tab 9 is based on the maximum permissible service temperature of the conductor also indicated therein and on an ambient temperature of 45°C.

9.9.2 The current carrying capacity cited in [9.9.1] is applicable, with rough approximation, to all types of protective covering (e.g. both armoured and non-armoured cables).

9.9.3 Values other than those shown in Tab 5 to Tab 9 may be accepted provided they are determined on the basis of calculation methods or experimental values approved by the Society.

9.9.4 When the actual ambient temperature obviously differs from 45°C, the correction factors shown in Tab 10 may be applied to the current carrying capacity in Tab 5 to Tab 9.

9.9.5 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.

Figure 3 *(1/1/2007)*

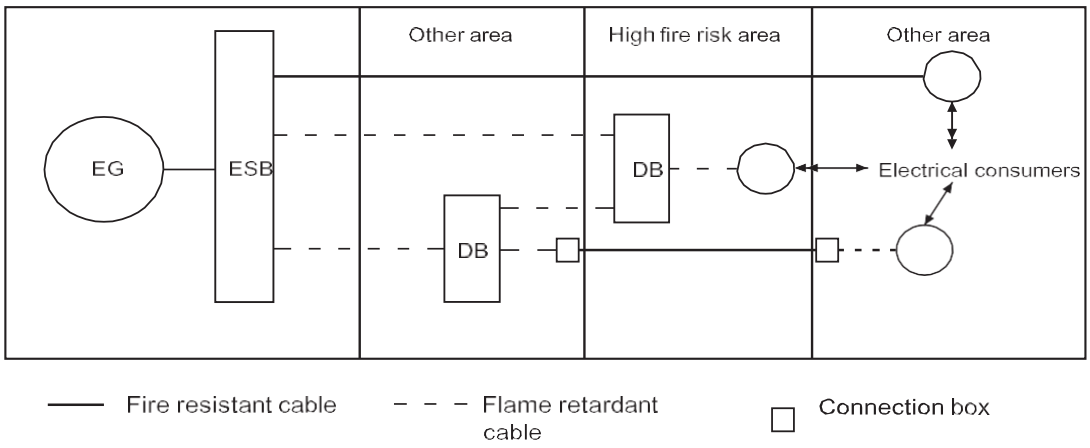


Table 4 : Maximum rated conductor temperature *(1/7/2024)*

Type of insulating compound	Abbreviated designation	Maximum rated conductor temperature, in °C	
		Normal operation	Short-circuit
a) Thermoplastic:			
- based upon polyvinyl chloride or copolymer of vinyl chloride and vinyl acetate	PVC	70	150
b) 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 (2)
- 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 (2)
- based upon cross-linked polyolefin material for halogen free cable **(1)**	HF 90	90	250
(1) Used on sheathed cable only			
(2) This temperature is applicable only to power cables and not appropriate for tinned copper conductors			

Table 5 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 60°C (ambient temperature 45°C) *(1/7/2024)*

Nominal section mm^2	Number of conductors		
	1	2	3 or 4
1,5	10	9	7
2,5	17	14	12
4	23	20	16
6	29	25	20
10	40	34	28
16	54	46	38
25	71	60	50
35	88	75	62
50	110	94	77
70	135	115	95
95	164	139	115
120	189	161	132
150	218	185	153
185	248	211	174
240	292	248	204
300	336	286	235
400	d.c.:390 a.c.:380	d.c.:332 a.c.:323	d.c.:273 a.c.:266
500	d.c.:450 a.c.:430	d.c.:383 a.c.:366	d.c.:315 a.c.:301
600	d.c.:520 a.c.:470	d.c.:442 a.c.:400	d.c.:364 a.c.:329

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) *(1/7/2024)*

Nominal section mm^2	Number of conductors		
	1	2	3 or 4
1,5	15	13	11
2,5	21	18	15
4	29	25	20
6	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	d.c.:500 a.c.:490	d.c.:425 a.c.:417	d.c.:350 a.c.:343
500	d.c.:580 a.c.:550	d.c.:493 a.c.:468	d.c.:406 a.c.:385
600	d.c.:670 a.c.:610	d.c.:570 a.c.:519	d.c.:467 a.c.:427

Table 7 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 85°C (ambient temperature 45°C) *(1/7/2024)*

Nominal section mm^2	Number of conductors		
	1	2	3 or 4
1,5	21	18	15
2,5	28	24	20
4	38	32	27
6	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

Nominal section mm²	Number of conductors		
	1	2	3 or 4
400	d.c.:650 a.c.:630	d.c.:553 a.c.:536	d.c.:455 a.c.:441
500	d.c.:740 a.c.:680	d.c.:629 a.c.:578	d.c.:518 a.c.:476
600	d.c.:840 a.c.:740	d.c.:714 a.c.:629	d.c.:588 a.c.:518

Table 8 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 90°C (ambient temperature 45°C) *(1/7/2024)*

Nominal section mm²	Number of conductors		
	1	2	3 or 4
1,5	23	20	16
2,5	40	26	21
4	51	34	28
6	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	d.c.:690 a.c.:670	d.c.:587 a.c.:570	d.c.:483 a.c.:469
500	d.c.:780 a.c.:720	d.c.:663 a.c.:612	d.c.:546 a.c.:504
600	d.c.:890 a.c.:780	d.c.:757 a.c.:663	d.c.:623 a.c.:546

Table 9 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 95°C (ambient temperature 45°C) *(1/7/2024)*

Nominal section mm²	Number of conductors		
	1	2	3 or 4
1,5	26	22	18
2,5	32	27	22
4	43	37	30
6	55	47	39
10	76	65	53
16	102	87	71
25	135	115	95
35	166	141	116

Nominal section mm^2	Number of conductors		
	1	2	3 or 4
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	d.c.:760 a.c.:725	d.c.:646 a.c.:616	d.c.:532 a.c.:508
500	d.c.:875 a.c.:810	d.c.:744 a.c.:689	d.c.:612 a.c.:567
600	d.c.:1010 a.c.:900	d.c.:859 a.c.:765	d.c.:707 a.c.:630

9.9.6 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 5 to Tab 9 may be increased by applying the corresponding correction factors given in Tab 11.

In no case is a period shorter than 1/2-hour to be used, whatever the effective period of operation.

9.9.7 For supply cables to single services for intermittent loads (e.g. cargo winches or machinery space cranes), the current carrying capacity obtained from Tab 5 to Tab 9 may be increased by applying the correction factors given in Tab 12.

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.

9.10 Minimum nominal cross-sectional area of conductors

9.10.1 In general the minimum allowable conductor cross-sectional areas are those given in Tab 13.

9.10.2 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 mm^2. In such case the cross-sectional area of the neutral conductor is to be equal to that of the phase.

9.10.3 For the nominal cross-sectional area of:

- earthing conductors, see Sec 12, [2.3]
- earthing connections for distribution systems, see Sec 12, [2.5].

9.11 Choice of cables

9.11.1 The rated voltage of any cable is to be not lower than the nominal voltage of the circuit for which it is used.

9.11.2 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.

9.11.3 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.

9.11.4 When the conductors are carrying the maximum nominal service current, the voltage drop from the main or emergency 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 increased to 10%.

For the circuits of navigation lights, the voltage drop is not to exceed 5% of the rated voltage under normal conditions.

Table 10 : Correction factors for various ambient air temperatures (Reference ambient temperature of 45°C) *(1/7/2024)*

Maximum rated conductor temperature, in °C	Correction factors for 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	-	-	-	-	-	-	-
65	1,22	1,12	1,00	0,87	0,71	-	-	-	-	-	-
70	1,18	1,10	1,00	0,89	0,77	0,63	-	-	-	-	-
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	-	-
90	1,10	1,05	1,00	0,94	0,88	0,82	0,74	0,67	0,58	0,47	-
95	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

Table 11 : Correction factors for short-time loads

½ -hour service		1-hour service		
Sum of nominal cross-sectional areas of all conductors in the cable, in mm^2		Sum of nominal cross-sectional areas of all conductors in the cable, in mm^2		Correlation factor
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 12 : Correction factors for intermittent service

Sun of nominal cross selectionel areas of all conductors in the cable, in mm^2		Correction factor
Cables with metallic sheath and armoured cables	Cables without metallic sheath and non-amoured cables	
	$S \leq 5$	1,10
	$5 < S \leq 8$	1,15
	$8 < S \leq 16$	1,20
$S \leq 4$	$16 < S \leq 825$	1,25
$4 < S \leq 7$	$25 < S \leq 42$	1,30
$7 < S \leq 17$	$42 < S \leq 72$	1,35
$17 < S \leq 42$	$72 < S \leq 140$	1,40
$42 < S \leq 110$	$140 < S$	1,45
$110 < S$	-	1,50

10 Electrical installations in hazardous areas

10.1 Electrical equipment

10.1.1 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.

10.1.2 Where electrical equipment of a safe type is permitted in hazardous areas it is to be selected with due consideration to the following:

a) risk of explosive dust concentration; see Sec 2, [6.2]:
   - degree of protection of the enclosure
   - maximum surface temperature

b) risk of explosive gas atmosphere; see Sec 2, [6.1]:
   - explosion group
   - temperature class.

10.1.3 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.

10.1.4 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.

Table 13 : Minimum nominal cross-sectional areas

Service	Nominal cross-sectional area	
	external wiring mm^2	internal wiring mm^2
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 ship or crew calls	0,2	0,1
Bus and data cables	0,2	0,1

10.1.5 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.

10.1.6 *(1/1/2022)*
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 (electrical equipment having an enclosure of at least IP55).

10.1.7 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.

10.2 Electrical cables

10.2.1 Electrical cables are not to be installed in hazardous areas except as specifically permitted or when associated with intrinsically safe circuits.

10.2.2 *(1/7/2003)*
All cables installed in Zone 0, Zone 1 and weather exposed areas classified Zone 2 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).

10.2.3 All cables installed in non-weather exposed Zone 2 areas are to be provided with at least a non-metallic external impervious sheath.

10.2.4 Cables of intrinsically safe circuits are to have a metallic shielding with at least a non-metallic external impervious sheath.

10.2.5 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.

10.3 Electrical installations in battery rooms

10.3.1 *(1/7/2003)*
Only intrinsically safe apparatus and certified safe type lighting fittings may be installed in compartments assigned solely to large vented storage batteries; see Sec 11, [6.2.1].

The associated switches are to be installed outside such spaces.

Electric ventilator motors are to be outside ventilation ducts and, if within 3 m of the exhaust end of the duct, they are to be of an explosion-proof safe type. The impeller of the fan is to be of the non-sparking type.

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.

Electrical equipment for use in battery rooms is to have minimum explosion group IIC and temperature class T1.

10.3.2 Standard marine electrical equipment may be installed in compartments assigned solely to valve-regulated sealed storage batteries.

10.3.3 *(1/7/2004)*
Where vented (see Note 1) type batteries replace valve-regulated sealed (see Note 2) types, the requirements of Sec 11 are to be complied with.

Note 1: A vented battery is one in which the cells have a cover provided with an opening through which products of electrolysis and evaporation are allowed to escape freely from the cells to atmosphere.

Note 2: A valve-regulated battery is one in which cells are closed but have an arrangement (valve) which allows the escape of gas if the internal pressure exceeds a predetermined value.

10.4 Electrical equipment allowed in paint stores and in enclosed spaces leading to paint stores

10.4.1 General *(1/1/2022)*

Electrical equipment is to be installed in paint stores and in ventilation ducts serving such spaces only when it is essential for operational services

Certified safe type equipment of the following type is acceptable:

a) intrinsically safe Exi

b) flameproof Exd

c) pressurised Exp

d) increased safety Exe

e) special protection Exs

Cables (through-runs or terminating cables) of armoured type or installed in metallic conduits are to be used.

10.4.2 Minimum Requirements *(1/1/2022)*

The minimum requirements for certified safe type equipment are as follows:

- explosion group II B
- temperature class T3.

Note 1: The paint stores and inlet and exhaust ventilation ducts under [10.4.1] are classified as Zone 1 and areas on open deck under [10.4.3] b) as Zone 2, as defined in IEC 60092-502 (Electrical Installation in ships-part 502: Tankers-special features).

Note 2: A watertight door may be considered as being gas-tight.

10.4.3 Special requirements *(1/1/2022)*

a) Switches, protective devices and motor control gear of electrical equipment installed in a paint store are to interrupt all poles or phases and are preferably to be located in a non-hazardous space.

b) In areas on open deck within 1m of inlet and exhaust ventilation openings or within 3 m of exhaust mechanical ventilation outlets, the following electrical equipment may be installed:
   - electrical equipment with the type of protection as permitted in paint stores;
   - equipment of protection class Exn;
   - appliances which do not generate arcs in service and whose surface does not reach unacceptably high temperature;
   - appliances with simplified pressurised enclosures or vapour-proof enclosures (electrical equipment having an enclosure of at least IP55) whose surface does not reach unacceptably high temperature; or
   - cables as specified in [10.4.1].

c) The enclosed spaces giving access to the paint store may be considered as non-hazardous, provided that:
   - the door to the paint store is a gas-tight door with self-closing devices without holding back arrangements;
   - the paint store is provided with an acceptable, independent, natural ventilation system ventilated from a safe area; and
   - warning notices are fitted adjacent to the paint store entrance stating that the store contains flammable liquids.

10.5 Electrical installations in stores for welding gas (acetylene) bottles

10.5.1 The following equipment may be installed in stores for welding gas bottles provided that it is of a safe type appropriate for Zone 1 area installation:

- lighting fittings
- ventilator motors where provided.

10.5.2 Electrical cables other than those pertaining to the equipment arranged in stores for welding gas bottles are not permitted.

10.5.3 Electrical equipment for use in stores for welding gas bottles is to have minimum explosion group IIC and temperature class T2.

10.6 Special ships

10.6.1 For installations in hazardous areas in:

- oil tankers, chemical tankers and liquefied gas carriers, see Pt E, Ch 7, Sec 5, Pt E, Ch 8, Sec 10 or Pt E, Ch 9, Sec 10
- ships arranged with spaces for the carriage of vehicles, see Pt E, Ch 1, Sec 4 or Pt E, Ch 12, Sec 4.

11 Recording of the Type, Location and Maintenance Cycle of Batteries

11.1 Battery schedule

11.1.1 *(1/7/2004)*

Where batteries are fitted for use for essential and emergency services, a schedule of such batteries is to be compiled and maintained. The schedule, required in Sec 1, Tab 1, is to include at least the following information regarding the battery(ies):

- type and Manufacturer's type designation
- voltage and ampere-hour rating
- location
- equipment and/or system(s) served
- maintenance/replacement cycle dates
- date(s) of last maintenance and/or replacement
- for replacement batteries in storage, the date of manufacture and shelf life.

Note 1: Shelf life is the duration of storage under specified conditions at the end of which a battery retains the ability to give a specified performance.

SECTION 4 ROTATING MACHINES

1 Constructional and operational requirements for generators and motors

1.1 Mechanical construction

1.1.1 *(1/7/2001)*

Insulating materials, insulated windings and construction of electrical machines are to conform to the relevant requirements of Sec 2, [4] and Sec 2, [5].

1.1.2 Shafts are to be made of material complying with the provisions of Pt D, Ch 2, Sec 3 or, where rolled products are allowed in place of forgings, with those of Pt D, Ch 2, Sec 1.

1.1.3 Where welded parts are foreseen on shafts and rotors, the provisions of Part D, 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 For surface-cooled machines with an external fan installed on the open deck, adequate protection of the fan against icing is to be provided.

1.1.7 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.

1.1.8 *(1/7/2013)*

Motors cooled with a water jacket can be accepted for both propulsion and auxiliary services, however the use of water jacket cooled electric motors for propulsion is limited to installations with motor redundancy.

In motors cooled with a water jacket, internal water leakage sensors are to be provided.

The water jacket is to be pressure tested at not less than 1,5 times the working pressure after final machining.

1.1.9 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 Sec 2, [4.2] and 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 1, Sec 2, [4.7].

2.1.2 When 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 constituted by a battery installation in accordance with the requirements for electrical starting systems of auxiliary machinery (see Ch 1, Sec 2).

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 of the prime movers are to be such that, within the limits of 20% and 100% total load, the load on any generating set will not normally differ from its proportionate share of the total load by more than 15% of the rated power in kW of the largest machine or 25% of the rated power in kW of the individual machine in question, whichever is the lesser.

2.2.5 For a.c. generating sets intended to operate in parallel, means are to be provided to regulate the governor so as to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.

2.2.6 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.

3 Testing of rotating machines

3.1 General

3.1.1 *(1/1/2002)*

All machines are to be tested by the Manufacturer

3.1.2 *(1/1/2002)*

Manufacturer’s test records are to be provided for machines for essential services, for other machines they are to be available upon request.

3.1.3 *(1/1/2002)*

All tests are to be carried out according to IEC 60092-301.

3.1.4 *(1/1/2002)*

All a.c. generators having rated power of 100 kVA and above, all d.c. generators having rated power of 100 kW and above, and all a.c./d.c. motors having rated power of 100 kW and above, intended for essential services are to be surveyed by the Society during testing and, if appropriate, during manufacturing.

Note 1: An Alternative Certification 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 *(1/1/2002)*

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 *(1/1/2002)*

Shaft material for other machines is to be in accordance with recognised international or national standards (See [1.1.2]).

3.3 Tests

3.3.1 *(1/7/2002)*

Type tests are to be carried out on a prototype machine or on the first of a batch of machines, and routine tests carried out on subsequent machines in accordance with Tab 1.

Note 1: Test requirements may differ for shaft generators, special purpose machines and machines of novel construction.

Table 1 : Tests to be carried out on electrical rotating machines *(1/1/2002)*

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 tests on prototype machine or tests on at least the first of a batch of machines.
(2) The report on routinely tested machines is to contain the Manufacturer's serial number of the machine which has been type tested and the test result.
(3) Only functional test of voltage regulator system.
(4) Only applicable for machine of essential services rated above 100kW/kVA.
(5) Verification of steady short circuit condition applies to synchronous generators only.
(6) Not applicable for squirrel cage motors.

Table 2 : Minimum insulation resistance *(1/1/2002)*

Rated voltage U_n, in V	Minimum test voltage, in V	Minimum insulation resistance, in MΩ
$U_n = 250$	$2\ U_n$	1
$250 < U_n \leq 1000$	500	1
$1000 < U_n \leq 7200$	1000	$U_n/1000 + 1$
$7200 < U_n \leq 15000$	5000	$U_n/1000 + 1$

4 Description of the test

4.1 Examination of the technical documentation, as appropriate, and visual inspection

4.1.1 Examination of the technical documentation *(1/1/2002)*

Technical documentation of machines rated at 100kW (kVA) and over is to be available for examination by the Surveyor.

4.1.2 Visual inspection *(1/1/2002)*

A visual examination of the machine is to be made to ensure, as far as is practicable, that it complies with the technical documentation.

4.2 Insulation resistance measurement

4.2.1 *(1/1/2002)*

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 2. The insulation resistance is to be measured close to the operating temperature, or an appropriate method of calculation is to be used.

4.3 Winding resistance measurement

4.3.1 *(1/1/2002)*

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 voltage regulation system

4.4.1 *(1/1/2017)*

The alternating current generator, together with its voltage regulation system, at all loads from no load running to full load, is to be able to keep the rated voltage at the rated power factor under steady conditions within ± 2.5%. These limits may be increased to ± 3.5% for emergency sets.

4.4.2 *(1/1/2002)*

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 *(1/1/2002)*

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. For emergency sets, these values may be increased to plus or minus 4% in not more than 5 s.

4.4.4 *(1/1/2017)*

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. Subject to Classification Society's approval, such voltage regulation during transient conditions may be calculated values based on the previous type test records, and need not to be tested during factory testing of a generator.

4.5 Rated load test and temperature rise measurements

4.5.1 *(1/7/2022)*

The temperature rises are to be measured at the rated output, voltage and frequency and for the duty for which the machine is rated and marked in accordance with the testing methods specified in IEC 60034-1, or by means of a combination of other tests.

The limits of temperature rise are those specified in IEC 60034-1 adjusted as necessary for the ambient reference temperatures specified in Sec 2.

4.6 Overload/overcurrent tests

4.6.1 *(1/1/2002)*

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 60034-1. The overload test can be replaced at a routine test by an overcurrent 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).

4.6.2 *(1/1/2002)*

In the case of machines for special uses (e.g. for windlasses), overload values other than the above may be considered.

4.7 Verification of steady short-circuit conditions

4.7.1 *(1/1/2017)*

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.

In order to provide sufficient information to the party responsible for determining the discrimination settings in the distribution system where the generator is going to be used, the generator manufacturer shall provide documentation showing the transient behaviour of the short circuit current upon a sudden short-circuit occurring when excited, and running at nominal speed. The influence of the automatic voltage regulator shall be taken into account, and the setting parameters for the voltage regulator shall be noted together with the decrement curve. Such a decrement curve shall be available when the setting of the distribution system's short-circuit protection is calculated. The decrement curve need not be based on physical testing. The manufacturers simulation model for the generator and the voltage regulator may be used where this has been validated through the previous type test on the same model.

4.8 Overspeed test

4.8.1 *(1/1/2002)*

Machines are to withstand the overspeed test as specified in IEC 60034-1. This test is not applicable for squirrel cage motors.

4.9 Dielectric strength test

4.9.1 *(1/1/2002)*

New and completed rotating machines are to withstand a dielectric test as specified in IEC 60034-1.

4.9.2 *(1/1/2002)*

For high voltage machines an impulse test is to be carried out on the coils according to Sec 13.

4.9.3 *(1/1/2002)*

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 60034-1.

4.9.4 *(1/1/2002)*

Completely rewound windings of used machines are to be tested with the full test voltage applied in the case of new machines.

4.9.5 *(1/1/2002)*

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.

4.9.6 *(1/1/2002)*
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.

4.9.7 *(1/1/2002)*
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 performed, 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.

4.10 No load test

4.10.1 *(1/1/2002)*
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.

4.11 Verification of degree of protection

4.11.1 *(1/1/2002)*
As specified in IEC 60034-5.

4.12 Verification of bearings

4.12.1 *(1/1/2002)*
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.

5 Requirements for AC Generating sets

5.1 General

5.1.1 *(1/7/2020)*
This Section provides requirements for AC Generating sets (i.e. Reciprocating Internal Combustion enginesa), b), alternatorsc) and couplings) in addition to those stated Ch 1, Sec 2; Ch 1, Sec 16; Ch 1, App 1 and Sec 4.

a) Reciprocating Internal Combustion engines are to comply with the requirements in Ch 1, Sec 2; Ch 1, Sec 16 and Ch 1, App 1.

b) The Reciprocating Internal Combustion engine speed governor and overspeed protective device are to comply with the requirements of Ch 1, Sec 2, [4.7.3] to [4.7.7].

c) Alternators are to comply with the requirements in Sec 4.

5.1.2 *(1/7/2020)*
The requirements are applicable to AC generating sets driven by reciprocating internal combustion engines irrespective of their types (i.e. diesel engine, dual fuel engine, gasfuel engine), except for those sets consisting of a propulsion engine which also drives power take off (PTO) generator(s).

5.2 Generating sets - requirements

5.2.1 *(1/7/2020)*
The generating set shall show torsional vibration levels which are compatible with the allowable limits for the alternator, shafts, coupling and damper.

5.2.2 *(1/7/2020)*
The coupling selection for the generating set shall take into account the stresses and torques imposed on it by the torsional vibration of the system. Where flexible couplings are adopted, the provisions of Ch 1, Sec 7, [2.5.4] b) and

Ch 1, Sec 9, [3.6.3] are to be complied with. The torsional vibration calculations are to be submitted to the Society for approval when the engine power is 110 kW or above.

5.2.3 *(1/7/2020)*
The rated power shall be appropriate for the actual use of the generator set.

5.2.4 *(1/7/2020)*
The entity responsible of assembling the generating set shall install a rating plate marked with at least the following information:

(i) the generating set manufacturer’s name or mark;

(ii) the set serial number;

(iii) the set date of manufacture (month/year);

(iv) the rated power (both in kW and KVA) with one of the prefixes COP, PRP (or, only for emergency Generating sets, LTP) as defined in ISO 8528-1:2018;

(v) the rated power factor;

(vi) the set rated frequency (Hz);

(vii) the set rated voltage (V Sec 4);

(viii) the set rated current (A);

(ix) the mass (kg).

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 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 Short-circuit conditions and parallel operation

1.3.1 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 Sec 3, [9.11.4]).

1.3.2 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.

1.3.3 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 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.

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 Sec 4, [4.9].

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.

Table 1 : Temperature rise limits for transformers

No.	Part of machine	Temperature rise by class of insulation, in °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				

1.5.5 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 f_n/f_p 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 apply.

2.1.5 *(1/7/2004)*

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.

Note 1: An Alternative Certification Scheme may be agreed by the Society with the Manufacturer whereby the attendance of the Surveyor will not be required as indicated above.

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 *(1/7/2009)*

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	High voltage test	X	X
4	Temperature rise measurement	X	
5	Induced voltage test	X	X
6	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 Sec 8).

1.1.2 The monitoring and control circuits are generally to comply with the requirements of 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 and 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 Sec 2, [2.2]).

1.2.4 An alarm is to be provided for tripping of protective devices against overvoltages and overcurrents in electric propulsion convertors and for convertors for the emergency source of power.

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
$U \leq 60$	600
$60 < U \leq 90$	900
$90 < U$	$2U + 1000$ (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 *(1/1/2017)*
All the convertors are to be subjected to the tests stated in [2.2].

2.1.2 *(1/1/2017)*
For convertors intended for essential services the manufacturer is to provide 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; for other convertors the test report is to be made available upon request.

Note 1: An Alternative Certification Scheme may be agreed by the Society with the Manufacturer whereby the attendance of the Surveyor will not be required as indicated above.

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 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

No.	Tests	Type test **(1)**	Routine test **(2)**
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, CHARGERS, UNINTERRUPTIBLE POWER SYSTEMS AND FUEL CELLS

1 Constructional requirements for batteries

1.1 General

1.1.1 The requirements of this Article apply to permanently installed storage batteries (not to portable batteries).

1.1.2 *(1/1/2019)*

Storage batteries may be of the lead-acid or nickel-alkaline type, due consideration being given to the suitability for any specific application.

The use of batteries other than Lead-acid or alkaline batteries is allowed subject to the compliance of the battery system and its installation to the requirements given in App 2.

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 40° from the vertical.

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 minimise 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 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 *(1/7/2004)*

The tests of battery chargers of 50 kVA and over intended for essential services are to be attended by a Surveyor of the Society.

Note 1: An Alternative Certification Scheme may be agreed by the Society with the Manufacturer whereby the attendance of the Surveyor will not be required as indicated above.

3 Uninterruptible power system (UPS) units

3.1 Application

3.1.1 *(1/7/2025)*

These requirements apply to UPS units, for the following cases:

a) when providing an alternative power supply as an accumulator battery in terms of being an independent power supply for the emergency services defined in Pt E, Ch 11, Sec 5, [2.2.3] c) or Sec 3, [3.7.3] d)

b) when providing an alternative power supply or transitional power supply to any other emergency services as defined in Pt E, Ch 11, Sec 5, [2] and Sec 3, [3.7]

c) where required, constituting a means of continuous and uninterruptible power supply to essential services as defined in Sec 1, [3.2] to [3.4].

d) when providing power supply in accordance with conditions specified and mandated by FSS Code Chapter 9, 2.2.2 to 2.2.4.

3.1.2 *(1/7/2025)*

These requirements may be referenced to UPS units for other cases than in [3.1.1], and the application of requirements is at the discretion of the Society.

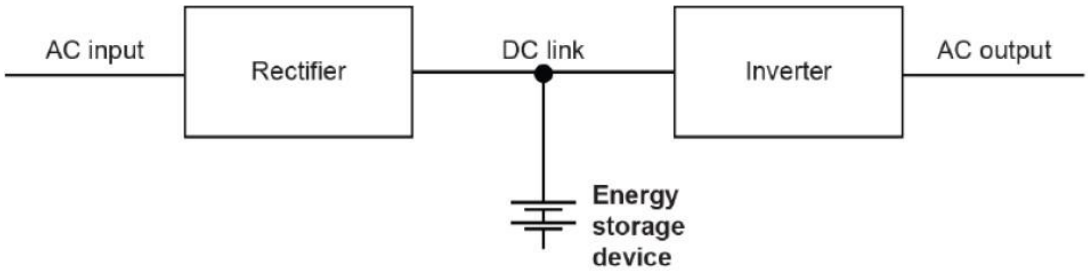
3.2 Definitions

3.2.1 *(1/7/2025)*

Uninterruptible Power System (UPS) - combination of convertors, switches and energy storage devices (such as batteries), constituting a power system for maintaining continuity of load power in case of AC input power failure (IEC 62040-3).

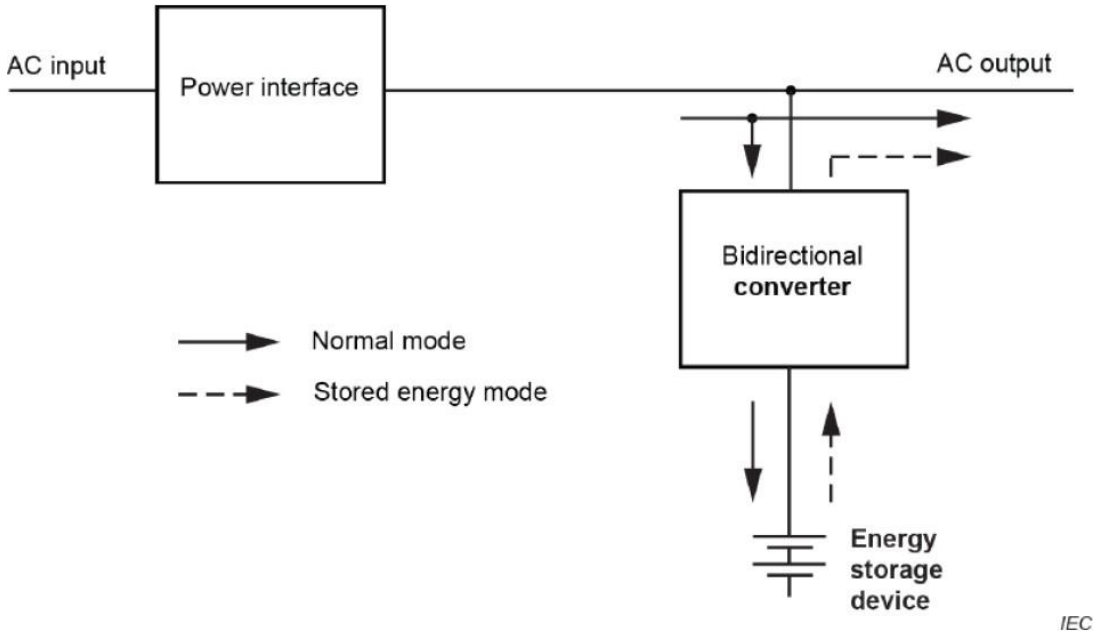
Double Conversion topology - a UPS topology comprises an AC to DC converter, generally a rectifier, and a DC to AC converter, generally an inverter. When the AC input power is out of UPS pre-set tolerances, the UPS enters stored energy mode (refer to Annex B to IEC 62040-3).

Figure 1 *(1/7/2025)*



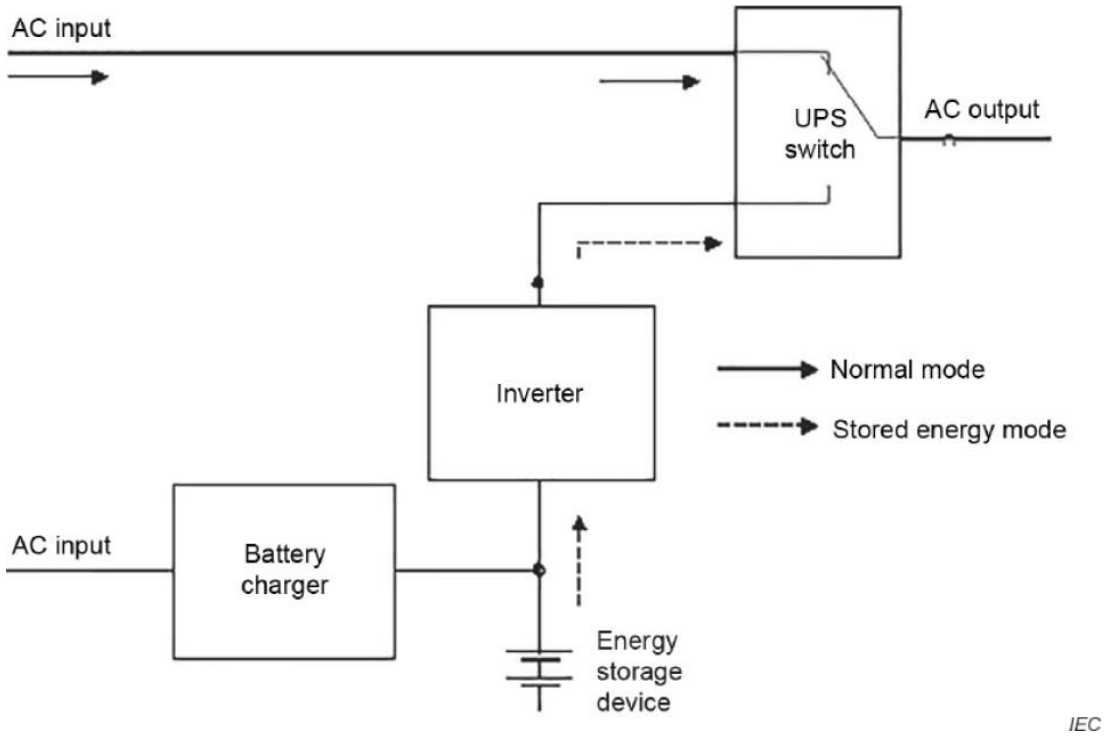
Line interactive topology - a UPS topology comprises bidirectional AC to DC power conversion, generally through a bidirectional converter and an AC power interface. When AC input power voltage or frequency is out of UPS pre-set tolerances, the UPS runs in stored energy mode (refer to Annex B to IEC 62040-3).

Figure 2 *(1/7/2025)*



Standby topology - a UPS topology comprises a battery charger, a DC to AC converter, generally a unidirectional inverter and a UPS switch. When the AC input power is out of UPS pre-set tolerances, the UPS operates in stored energy mode (refer to Annex B to IEC 62040-3).

Figure 3 *(1/7/2025)*



Energy storage device - system consisting of a single or multiple devices designed to provide power to the UPS inverter/converter (IEC 62040-3).

AC input power failure - variation in the AC input power which could cause the UPS to operate in stored energy mode (IEC 62040-3).

Bidirectional converter - converter which has the functions of both a rectifier and an inverter, and which can reverse the flow of power from AC to DC and vice-versa (IEC 62040-3).

3.3 Design and construction

3.3.1 *(1/7/2025)*

UPS units are to be constructed in accordance with IEC 62040-1 + AMD1 + AMD2, IEC 62040-2, IEC 62040-3, IEC 62040-4 and/or IEC 62040-5-3, as applicable, or an acceptable and relevant national or international standard.

3.3.2 *(1/7/2006)*

The operation of the UPS is not to depend upon external services.

3.3.3 *(1/7/2025)*

The configuration and topology of UPS unit employed is to be appropriate to the power supply requirements of the connected load equipment.

3.3.4 *(1/7/2025)*

When external bypass is provided, bypass transfer switch is to be arranged to protect the load against power disturbances or interruption arising from inrush or fault current (refer to Annex C to IEC 62040-3).

3.3.5 *(1/7/2025)*

The UPS unit is to be monitored and audible and visual alarm is to be given in a continuously manned station(s) for:

- power supply failure (voltage and frequency) to the connected load,
- earth fault,
- operation of a battery protective device,
- when the battery is being discharged,
- when the bypass is in operation in case an external bypass is provided, and
- any other fault and abnormal conditions of the UPS unit, as applicable.

3.4 Location

3.4.1 *(1/7/2025)*

The UPS unit for emergency services in paragraphs [3.1.1] and [3.1.2] is to be suitably located for use in an emergency.

3.4.2 *(1/7/2025)*

UPS units using valve regulated sealed batteries may be located in compartments with normal electrical equipment, provided the ventilation arrangements are in accordance with the requirements of IEC 62040-1 + AMD1 + AMD2, IEC 62040-2, IEC 62040-3, IEC 62040-4 and/or IEC 62040-5-3, as applicable, or an acceptable and relevant national or international standard.

3.5 Performance

3.5.1 *(1/7/2022)*

The output power is to be maintained for the duration required for the connected emergency services as stated in SOLAS II-1/42 or SOLAS II-1/43.

3.5.2 *(1/7/2006)*

No additional circuits are to be connected to the UPS unit without verification that the latter has adequate capacity. The UPS battery capacity is, at all times, to be capable of supplying the designated loads for the time specified in the regulations.

3.5.3 *(1/7/2006)*

On restoration of the input power, the rating of the charge unit is to be sufficient to recharge the batteries while maintaining the output supply to the load equipment.

3.6 Testing and survey

3.6.1 *(1/7/2025)*

UPS units of 50 kVA and over are to be surveyed by the Society during manufacturing and testing, in accordance with [3.6.2].

3.6.2 *(1/7/2025)*

Appropriate testing is to be carried out to demonstrate that the UPS unit is suitable for its intended environment. This is expected to include, as a minimum, the following tests:

- Functionality, including operation of alarms in [3.3.5];
- Temperature rise;
- Ventilation rate;
- Battery capacity.

3.6.3 *(1/7/2006)*

Where the supply is to be maintained without a break following a power input failure, this is to be verified after installation by means of a practical test.

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.

4 Fuel cells

4.1 General

4.1.1 *(1/1/2023)*
The requirements of this Article apply to fuel cells installed on board.

4.1.2 *(1/1/2023)*
The use of fuel cells is allowed subject to the compliance of the fuel cell power installation to the requirements given in App 3.

SECTION 8 SWITCHGEAR AND CONTROLGEAR ASSEMBLIES

1 Constructional requirements for main and emergency switchboards

1.1 Construction

1.1.1 *(1/1/2021)*

Construction is to be in accordance with IEC Publication 60092-302-2.

1.1.2 *(1/1/2021)*

Switchboard manufactured and tested to standards other than those specified in [1.1.1] will be accepted provided they are in accordance with an acceptable international or national standard of an equivalent or higher safety level.

1.1.3 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.

1.1.4 Insulating material for panels and other elements of the switchboard is at least to be moisture-resistant and flame-retardant.

1.1.5 Switchboards are to be of dead front type, with enclosure protection according to Sec 3, Tab 2.

1.1.6 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.

1.1.7 Where the aggregate capacity of generators connected to the main busbars exceeds 100 kVA, a separate cubicle for each generator is to be arranged with flame-retardant partitions between the different cubicles. Similar partitions are to be provided between the generator cubicles and outgoing circuits.

1.1.8 Instruments, handles or push-buttons for switchgear 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 earthings, is reduced as far as practicable.

1.1.9 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.

1.1.10 All parts of the switchboard are to be readily accessible for maintenance, repair or replacement. In particular, fuses are to be able to be safely inserted and withdrawn from their fuse-bases.

1.1.11 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.

1.1.12 Means of isolation of the circuit-breakers of generators and other important parts of the installation are to be provided so as to permit safe maintenance while the main busbars are alive.

1.1.13 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.

1.1.14 All measuring instruments and all monitoring and control devices are to be clearly identified with indelible labels of durable, flame-retardant material.

1.1.15 The rating of each circuit, together with the rating of the fuse or the appropriate setting of the overload protective device (circuit-breaker, thermal relay etc.) for each circuit is to be permanently indicated at the location of the fuse or protective device.

1.2 Busbars and bare conductors

1.2.1 Busbars are to be of copper or of copper-surrounded aluminium alloy if suitable for use in the marine environment and if precautions are taken to avoid galvanic corrosion.

1.2.2 All connections are to be so made as to inhibit corrosion.

1.2.3 Busbars are to be dimensioned in accordance with IEC Publication 60092-302-2.

The mean temperature rise of busbars is not to exceed 45°C under rated current condition with an ambient air temperature of 45°C (see Sec 2, [1.2.5]) and is not to have any harmful effect on adjacent components. Higher values of temperature rise may be accepted to the satisfaction of the Society.

1.2.4 The cross-section of neutral connection on an a.c. three-phase, four-wire system is to be at least 50% of the cross-section for the corresponding phases.

1.2.5 Bare main busbars, excluding the conductors between the main busbars 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.

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

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.

1.2.6 Reduced values as specified in IEC Publication 60092-302-2 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)
- overvoltage category III (distribution circuit level)
- inhomogenous 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.

1.2.7 Busbars 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.

1.2.8 Busbars 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 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 busbars to protective devices are to be as short as possible. They are to be laid and secured in such a way to minimise 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 Non-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.

1.4 Switchgear and controlgear, protective devices

1.4.1 *(1/7/2013)*
Switchgear and controlgear are to comply with IEC 60947 series adjusted as necessary for the ambient air reference temperature specified in Sec 2, Tab 1 and to be type tested or type approved when required in accordance with Sec 15.

1.4.2 The characteristics of switchgear, controlgear and protective devices for the various consumers are to be in compliance with Sec 3, [7].

1.4.3 *(1/7/2015)*
For high voltage switchgear and controlgear see Sec 13, [7].

1.4.4 *(1/7/2014)*
For materials and construction, see Sec 2, [4] and Sec 2, [5].

1.4.5 *(1/7/2014)*
Power-driven circuit-breakers are to be equipped with an additional separate drive operated by hand.

1.4.6 *(1/7/2014)*
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.

1.4.7 *(1/7/2014)*
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.

1.4.8 *(1/7/2014)*
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.

1.4.9 *(1/7/2014)*
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.

1.4.10 *(1/7/2014)*
Short-circuit releases for generators are to be equipped with reclosing inhibitors and are to be delayed for selective tripping.

1.4.11 *(1/7/2014)*
Overload releases or relays are to operate reliably at any voltage variation of the supply voltage in the protected circuit.

1.4.12 *(1/7/2014)*
Undervoltage relays or releases are to cause the circuit-breaker to open if the voltage drops to 70%-35% of the rated voltage.

1.4.13 *(1/7/2014)*
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.

1.4.14 *(1/7/2014)*
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.

1.4.15 *(1/7/2014)*
Single-phase failure devices in three-phase circuits are to operate without a time lag.

1.4.16 *(1/7/2014)*
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.

1.5 Fuses

1.5.1 *(1/7/2015)*
Low voltage fuses are to comply with IEC Publication 60269 series and are to be type tested or type approved when required in accordance with Sec 15, [2.1.1].

1.5.2 *(1/7/2014)*
For high voltage fuses see Sec 13, [7].

1.6 Auxiliary circuits

1.6.1 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.

1.6.2 Auxiliary circuits of essential systems are to be independent of other auxiliary circuits.

1.6.3 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.

1.6.4 Auxiliary circuits are to be branched off from the main circuit in which the relevant switchgear is used.

1.6.5 The supply of auxiliary circuits by specifically arranged control distribution systems will be specially considered by the Society.

1.6.6 Means are to be provided for isolating the auxiliary circuits as well when the main circuit is isolated (e.g. for maintenance purposes).

1.6.7 For the protection of auxiliary circuits see Sec 3, [7.13].

1.7 Instruments

1.7.1 The upper limit of the scale of every voltmeter is to be not less than 120% of the rated voltage of the circuit in which it is installed.

1.7.2 The upper limit of the scale of every ammeter is to be not less than 130% of the normal rating of the circuit in which it is installed.

1.7.3 The upper limit of the scale of every wattmeter is to be not less than 120% of the rated voltage of the circuit in which it is installed.

1.7.4 Wattmeters for use with a.c. generators which may be operated in parallel are to be capable of indicating 15% reverse power.

1.7.5 For wattmeters using one current circuit only, the measurement of the current of all generators is to be made in the same phase.

1.7.6 The rated value of the measure read, at full load, is to be clearly indicated on the scales of instruments.

1.7.7 Frequency meters are to have a scale at least $\pm$ 5% of the nominal frequency.

1.7.8 The secondary windings of instrument transformers are to be earthed.

1.7.9 Each a.c. generator not operated in parallel is to be provided with:

- 1 voltmeter
- 1 frequency meter
- 1 ammeter in each phase or 1 ammeter with a selector switch to enable the current in each phase to be read
- 1 three-phase wattmeter in the case of generators rated more than 50 kVA.

1.7.10 Each a.c. generator operated in parallel is to be provided with:

- 1 three-phase wattmeter
- 1 ammeter in each phase or 1 ammeter with a selector switch to enable the current in each phase to be read.

1.7.11 For paralleling purposes the following are to be provided:

- 2 voltmeters
- 2 frequency meters
- 1 synchroscope and synchronising indicating lamps or equivalent means.

A switch is to be provided to enable one voltmeter and one frequency meter to be connected to each generator before the latter is connected to the busbars.

The other voltmeter and frequency meter are to be permanently connected to the busbars.

1.7.12 Each secondary distribution system is to be provided with one voltmeter.

1.7.13 Switchboards are to be fitted with means for monitoring the insulation level of insulated distribution systems as stipulated in Sec 3, [3.2.1].

1.7.14 The main switchboard is to be fitted with a voltmeter or signal lamp indicating that the cable between the shore-connection box and the main switchboard is energised (see Sec 3, [3.8.7]).

1.7.15 For each d.c. power source (e.g. convertors, rectifiers and batteries), one voltmeter and one ammeter are to be provided, except for d.c. power sources for starting devices (e.g. starting motor for emergency generator).

2 Constructional requirements for distribution boards

2.1 Construction

2.1.1 *(1/1/2021)*

Distribution boards are to be constructed, insofar as applicable, as specified for main and emergency switchboards.

2.1.2 All parts which require operation in normal use are to be placed on the front.

2.1.3 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.

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 *(1/1/2021)*

The test procedures are as specified in IEC Publication 60092-302-2.

3.1.5 *(1/1/2021)*

The following switchgear and controlgear assemblies are to be surveyed by the Society during testing:

a) main and emergency switchboards;

b) low voltage distribution boards, starters and motor control centers having busbars rated current of 100A and above;

c) steering gear starter;

d) high voltage assemblies.

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, etc. 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 U_i V	Test voltage c.a (r.m.s.) V
$U_i \leq 60$	1000
$60 < U_i \leq 300$	2000
$300 < U_i \leq 660$	2500
$660 < U_i \leq 800$	3000
$800 < U_i \leq 1000$	3500

Table 3 : Test voltage for auxiliary circuits

Rated insulation voltage U_i V	Test voltage c.a (r.m.s.) V
$U_i \leq 12$	250
$12 < U_i \leq 60$	500
$U_i > 60$	2 U_i + 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 MΩ.

SECTION 9 CABLES

1 Constructional requirements

1.1 Construction

1.1.1 *(1/7/2022)*
Cables manufactured in accordance with the relevant recommendations of IEC 60092-350, 60092-360, 60092-352, 60092-353, 60092-354, 60092-370 and 60092-376 are acceptable to the Society provided that they are tested as specified in this Chapter.

1.1.2 Mineral-insulated cables are to be constructed according to IEC Publication 60702.

1.1.3 Optical fibre cables are to be constructed in accordance with IEC Publication 60794.

1.1.4 Flexible cables constructed according to national standards will be specially considered by the Society.

1.1.5 *(1/7/2017)*
Cables manufactured and tested to standards other than those specified in [1.1.1] will be accepted provided they are in accordance with an acceptable and relevant international or national standard of an equivalent or higher safety level.

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.

1.2 Conductors

1.2.1 Conductors are to be of annealed electrolytic copper with a resistivity not exceeding 17,241 Ω 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 Sec 3, [9.10].

1.3 Insulating materials

1.3.1 The materials used for insulation are to comply with IEC Publication 60092-360 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.., 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 Sec 3, [9.3]).

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 60092-360 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.

1.6.3 *(1/7/2003)*

Fire-resisting cables are to be clearly labelled with the indication of the standard according to which this characteristic has been verified.

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.

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 *(29/8/2003)*

Power cables for electrical propulsion systems, other than internal wiring in switchboards, are to be type approved and tested for acceptance in the presence of the Surveyor. Acceptance tests are to include at least:

a) a high voltage test

b) insulation resistance measurement.

2.2.6 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 Lighting fittings

1.1 Applicable requirements

1.1.1 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.

1.2 Construction

1.2.1 The temperature of terminals for connection of supplying cables is not to exceed the maximum conductor temperature permitted for the cable (see Sec 3, [9.9]).

Where necessary, luminaires are to be fitted with terminal boxes which are thermally insulated from the light source.

1.2.2 Wires used for internal connections are to be of a temperature class which corresponds to the maximum temperature within the luminaire.

1.2.3 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.

1.2.4 The temperature rise of surface parts which can easily be touched in service is not to exceed 15°C.

1.2.5 High-power lights with higher surface temperatures than those in [1.2.2] and [1.2.3] are to be adequately protected against accidental contact.

2 Accessories

2.1 Applicable requirements

2.1.1 Accessories are to be constructed in accordance with the relevant IEC Publications, and in particular with Publication 60092-306.

2.2 Construction

2.2.1 Enclosures of accessories are to be of metal having characteristics suitable for the intended use on board, or of flame-retardant insulating material.

2.2.2 Terminals are to be suitable for the connection of stranded conductors, except in the case of rigid conductors for mineral-insulated cables.

3 Plug-and-socket connections

3.1 Applicable requirements

3.1.1 *(1/1/2022)*

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 switchgear: IEC Publications, e.g. 60130 and 60603
- for refrigerated containers: ISO 1496-2
- for high voltage shore connections: IEC Publications 62613-1 (see Pt F, Ch 13, Sec 15).

4 Heating and cooking appliances

4.1 Applicable requirements

4.1.1 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.

4.2 General

4.2.1 Heating elements are to be enclosed and protected with metal or refractory material.

4.2.2 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.

4.2.3 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.

4.3 Space heaters

4.3.1 The casing or enclosure of heaters is to be so designed that clothing or other flammable material cannot be placed on them.

4.3.2 The temperature of the external surface of space heaters is not to exceed 60°C.

4.3.3 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.

4.4 Cooking appliances

4.4.1 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.

4.5 Fuel oil and lube oil heaters

4.5.1 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.

4.5.2 Each oil heater is to be provided with a thermostat maintaining the oil temperature at the correct level.

4.5.3 In addition to the thermostat in [4.5.2], 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.

4.6 Water heaters

4.6.1 Water heaters are to be provided with a thermostat and safety temperature limiter.

5 Cable trays/protective casings made of plastics materials

5.1 General requirement

5.1.1 *(1/7/2023)*

Cable trays/protective casings (see Note 1) made of plastic (see Note 2) materials are to be type tested or type approved (See Note 3).

Note 1: "Protective casing" means a closed cover in the form of a pipe or other closed ducts of non-circular shape.

Note 2: "Plastics" means both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and fibre reinforced plastics - FRP.

Note 3: “Cable trays/protective casings made of plastic materials” are to be type tested or type approved in accordance with the latest published version of IACS REC 73.

5.2 Installation Requirements

5.2.1 *(1/7/2003)*

Cable trays/protective casings made of plastics materials 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 an injury to personnel and/or an obstruction to any escape route.

Note 1: When plastic cable trays/protective casings are used on open deck, they are additionally to be protected against UV light.

5.2.2 *(1/7/2003)*

The load on the cable trays/protective casings is to be within the Safe Working Load (SWL). The support spacing is to be not greater than the Manufacturer's recommendation or in excess of the spacing at the SWL test. In general it is not to exceed 2 metres.

The selection and spacing of cable tray/protective casing supports are to take into account:

- dimensions of cable trays/protective casings;
- mechanical and physical properties of their material;
- mass of cable trays/protective casings;
- loads due to weight of cables, external forces, thrust forces and vibrations;
- maximum accelerations to which the system may be subjected;
- combination of loads.

5.2.3 *(1/7/2003)*

The sum of the cables' total cross-sectional area, based on the cables' external diameter, is not to exceed 40% of the protective casing's internal cross-sectional area. This does not apply to a single cable in a protective casing.

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 Sec 3, Tab 2, Sec 3, Tab 3 and 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 Sec 3, [10].

2 Main electrical system

2.1 Location in relation to the emergency system

2.1.1 The arrangement of the emergency electrical system is to be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated converting equipment, if any, the emergency switchboard and the emergency lighting switchboard will not render inoperative the main electric lighting system and the other primary essential services.

2.2 Main switchboard

2.2.1 *The main switchboard shall be so placed relative to one main generating station 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.*

2.2.2 *An environmental enclosure for the main switchboard, such as may be provided by a machinery control room situated within the main boundaries of the space, is not to be considered as separating switchboards from generators.*

2.2.3 The main generating station is to be situated within the machinery space, i.e. within the extreme main transverse watertight bulkheads.

2.2.4 Any bulkhead between the extreme main transverse watertight bulkheads is not regarded as separating the equipment in the main generating station provided that there is access between the spaces.

2.2.5 The main switchboard is to be located as close as practicable to the main generating station, within the same machinery space and the same vertical and horizontal A60 fire boundaries.

2.2.6 *(1/1/2021)*
Where essential services for steering and propulsion are supplied from distribution boards, these and any transformers, convertors and similar appliances constituting an essential part of the electrical supply system are also to satisfy the above provisions.

2.2.7 A non-required subdivision bulkhead, with sufficient access, located between the switchboard and generators, or between two or more generators, is not to be considered as separating the equipment.

3 Emergency electrical system

3.1 Spaces for the emergency source

3.1.1 *The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard shall be located above the uppermost continuous deck and shall be readily accessible from the open deck.*
They shall not be located forward of the collision bulkhead.

3.1.2 *The spaces containing the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency electrical power and the emergency switchboard are not to be contiguous to the boundaries of machinery spaces of Category A or those spaces containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard.*

Where this is not practicable, the contiguous boundaries are to be Class A60.

3.2 Location in relation to the main electrical system

3.2.1 *The location of the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency power, the emergency switchboard and the emergency lighting switchboard in relation to the main source of electrical power, associated transforming equipment, if any, and the main switchboard shall be such as to ensure to the satisfaction of the Society that a fire or other casualty in the space containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard or in any machinery space of Category A will not interfere with the supply, control and distribution of emergency electrical power.*

3.2.2 The arrangement of the main electrical system is to be such that a fire or other casualty in spaces containing the main source of electrical power, associated converting equipment, if any, the main switchboard and the main lighting switchboard will not render inoperative the emergency electric lighting system and the other emergency services other than those located within the spaces where the fire or casualty has occurred.

3.3 Emergency switchboard

3.3.1 *The emergency switchboard shall be installed as near as is practicable to the emergency source of electrical power.*

3.3.2 *Where the emergency source of electrical power is a generator, the emergency switchboard shall be located in the same space unless the operation of the emergency switchboard would thereby be impaired.*

3.4 Emergency battery

3.4.1 *No accumulator battery fitted in accordance with the provisions of* Sec 3, [2.3] *shall be installed in the same space as the emergency switchboard.*

3.4.2 *(1/1/2021)*

For ships not subject to SOLAS, accumulator batteries fitted in accordance with the provisions of Sec 3, [2.3] may be accepted in the same space as the emergency switchboard, provided that they are not vented type batteries connected to a charging device of power greater than 2 kW.

4 Distribution boards

4.1 Distribution boards for cargo spaces and similar spaces

4.1.1 Distribution boards containing multipole switches for the control of power and lighting circuits in bunkers and cargo spaces are to be situated outside such spaces.

4.2 Distribution board for navigation lights

4.2.1 The distribution board for navigation lights is to be placed in an accessible position on the bridge.

5 Cable runs

5.1 General

5.1.1 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.

5.1.2 Cable runs are to be selected so as to avoid action from condensed moisture and from dripping of liquids.

5.1.3 Connection and draw boxes are to be accessible.

5.1.4 Cables are generally not to be installed across expansion joints.

Where this is unavoidable, however, a loop of cable of length proportional to the expansion of the joint is to be provided (see Sec 12, [7.2.2]).

5.2 Location of cables in relation to the risk of fire and overheating

5.2.1 *(1/1/2026)*

Cables and wiring serving essential or emergency 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.

The relevant interpretation in IACS UI SC11 applies.

5.2.2 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 (e.g. cables connecting fire pumps to the emergency switchboard), the cable is to be of a fire-resistant type or adequately protected against direct exposure to fire.

5.2.3 *(1/1/2021)*

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
- the cables in that area are of the fire-resisting type.

Note 1: Main cable runs are for example:

- cable runs from generators and propulsion motors to main and emergency switchboards
- cable runs directly above or below main and emergency switchboards, centralised motor starter panels, distribution 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.

5.2.4 Cables and wiring serving essential or emergency 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.

5.2.5 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.

5.3 Location of cables in relation to electromagnetic interference

5.3.1 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 3, Sec 7).

5.4 Services with a duplicate feeder

5.4.1 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.

5.5 Emergency circuits

5.5.1 Cables supplying emergency circuits are not to run through spaces containing the main source of electrical power, associated transforming equipment, if any, the main switchboard and the main lighting switchboard, except for cables supplying emergency equipment located within such spaces (see [3.2.2]).

5.6 Electrical distribution in passenger ships

5.6.1 For the electrical distribution in passenger ships, see Pt E, Ch 11, Sec 5, [1.3].

6 Storage batteries

6.1 General

6.1.1 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.

6.1.2 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.

6.1.3 Starter batteries are to be located as close as practicable to the engine or engines served.

6.1.4 *Accumulator batteries shall not be located in sleeping quarters except where hermetically sealed to the satisfaction of the Society.*

6.1.5 Lead-acid batteries and alkaline batteries are not to be installed in the same compartment (room, locker, box), unless of valve-regulated sealed type.

6.2 Large vented batteries

6.2.1 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.

Where this is not possible, they may be arranged in a suitable locker on deck.

6.2.2 Rooms assigned to large batteries are to be provided with mechanical exhaust ventilation.

Natural ventilation may be employed for boxes located on open deck.

6.2.3 The provisions of [6.2.1] and [6.2.2] also apply to several batteries connected to charging devices of total power exceeding 2 kW calculated for each one as stated in [6.2.1].

6.3 Moderate vented batteries

6.3.1 Batteries connected to a charging device of power between 0,2 kW and 2 kW calculated as stated in [6.2.1] (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.

6.3.2 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.

6.3.3 The provisions of [6.3.1] and [6.3.2] 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 [6.2.1].

6.4 Small vented batteries

6.4.1 Batteries connected to a charging device of power less than 0,2 kW calculated as stated in [6.2.1] (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.

6.4.2 Boxes for small batteries may be ventilated only by means of openings near the top to permit escape of gas.

6.5 Ventilation

6.5.1 The ventilation of battery compartments is to be independent of ventilation systems for other spaces.

6.5.2 The quantity of air expelled (by natural or forced ventilation) for compartments containing vented type batteries is to be at least equal to:

$$Q = 110 \cdot I \cdot n$$

where:

Q : Quantity of air expelled, in litres per hour

I : Maximum current delivered by the charging equipment during gas formation, but not less than one quarter of the maximum obtainable charging current in amperes

n : Number of cells in series.

6.5.3 The quantity of air expelled (by natural or forced ventilation) for compartments containing valve-regulated sealed batteries is to be at least 25% of that given in [6.5.2].

6.5.4 Ducts are to be made of a corrosion-resisting material or their interior surfaces are to be painted with corrosion-resistant paint.

6.5.5 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).

Air inlet may be from the open air or from another space (for example from machinery spaces).

6.5.6 Exhaust ducts of natural ventilation systems:

a) are to be run directly from the top of the compartment to the open air above (they may terminate in the open or in well-ventilated spaces)

b) are to terminate not less than 90 cm above the top of the battery compartment

c) are to have no part more than 45° from the vertical

d) are not to contain appliances (for example for barring flames) which may impede the free passage of air or gas mixtures.

Where natural ventilation is impracticable or insufficient, mechanical exhaust ventilation is to be provided.

6.5.7 In mechanical exhaust ventilation systems:

a) electric motors are to be outside the exhaust ducts and battery compartment and are to be of safe type if installed within 3 m from the exhaust of the ventilation duct

b) 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

c) steel or aluminium impellers are not to be used

d) the system is to be interlocked with the charging device so that the battery cannot be charged without ventilation (trickle charge may be maintained)

e) a temperature sensor is to be located in the battery compartment to monitor the correct behaviour of the battery in cases where the battery element is sensitive to temperature.

6.5.8 For natural ventilation systems for deck 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 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 ship'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]).

2 Earthing of non-current carrying parts

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 direct current or 50 V, 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 ship'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

<table>
<tr><th colspan="2">Type of earthing connection</th><th>Cross-sectional area of associated current carrying conductor</th><th>Minimum cross-sectional area of copper earthing connection</th></tr>
<tr><td>1</td><td>Earth-continuity conductor in flexible cable or flexible cord</td><td>any</td><td>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="4">2</td><td rowspan="4">Earth-continuity conductor incorporated in fixed cable</td><td rowspan="4">any</td><td>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 : Earthing connection mm^2</td></tr>
<tr><td>1 ÷ 2,5 : 1</td></tr>
<tr><td>4 ÷ 6 : 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>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>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>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.

2.4 Connection to the ship's structure

2.4.1 Every connection of an earth-continuity conductor or earthing lead to the ship's 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.

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 In a distribution system with hull return, the system earthing connection is to have at least the same cross-sectional area as the feeder lines.

2.5.4 The earthing connection is to be in an accessible position where it may readily be inspected and disconnected for insulation testing.

2.6 Aluminium superstructures

2.6.1 When aluminium superstructures are insulated from the steel hull to prevent electrolytic corrosion, they are to be secured to the hull by means of a separate bonding connection.

2.6.2 The connections are to be adequately close together and are to have a resistance less than 0.1 Ω.

2.6.3 The connections are to be located where they may readily be inspected.

3 Rotating machines

3.1 Preferred direction of installation

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 Sec 2, Tab 4.

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 from the top and at least one side to permit replacement and periodical maintenance.

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 emergency battery fron 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.

5.2.2 Interior surfaces of metal shelves for battery cells, whether or not grouped in crates or trays, are to be protected by a lining of electrolyte-resistant material, watertight and carried up to at least 75 mm on all sides. In particular, linings

are to have a minimum thickness of 1,5 mm, if of lead sheet for lead-acid batteries, and of 0,8 mm, if of steel for alkaline batteries.

Alternatively, the floor of the room or locker is to be lined as specified above to a height of at least 150 mm.

5.2.3 Battery boxes are to be lined in accordance with [5.2.2] to a height of at least 75 mm.

6 Switchgear and controlgear 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.

6.1.2 An unobstructed space is to be left in front of the switchboard wide enough to allow access for operation; such width is generally about 1 metre.

When withdrawable equipment is contained in the switchboard, the width of the space is to be not less than 0,5 m when the equipment is fully withdrawn.

Reduced widths may be considered for small ships.

6.1.3 Where necessary, an unobstructed space is to be provided at the rear of the switchboard ample to permit maintenance; in general, the width of this passage is to be not less than 0,6 m, except that this may be reduced to 0,5 m in way of stiffeners and frames, and the height sufficient for the operation foreseen.

6.1.4 Where the switchboard is open at the rear, the rear space in [6.1.3] is to form a locked space provided at each end with an access door. The required IP protection for the corresponding location is to be fulfilled.

6.1.5 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.

6.1.6 When the voltage exceeds the safety voltage, non-conducting mats or gratings are to be provided at the front and rear of the switchboard as necessary.

6.1.7 Piping and conduits are not to be installed directly above or in the vicinity of switchboards and controlgear assemblies.

Where this is unavoidable, pipes and conduits are to have welded joints only or to be provided with protection against spray from steam or pressurised liquids or dripping.

6.2 Emergency switchboard

6.2.1 For the installation of the emergency switchboard, the same requirements apply as given in [6.1] for the installation of the main switchboard.

6.3 Distribution boards

6.3.1 *(1/1/2021)*

For the installation of 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 and emergency 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
- at the boundaries of the spaces in cargo areas.

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.

7.2 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.

7.2.2 Where the installation of cables across expansion joints is unavoidable, the minimum internal radius of the loop at the end of the travel of the expansion joint is to be not less than 12 times the external diameter of the cable.

Figure 1 : Totally enclosed trunks

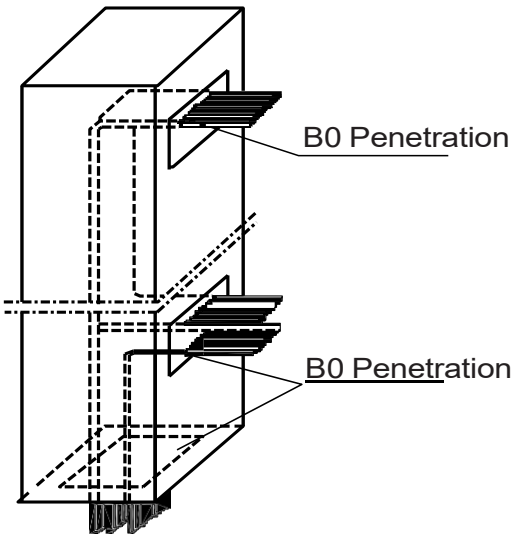


Table 2 : Bending radii

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

Figure 2 : Non-totally enclosed trunks, vertical

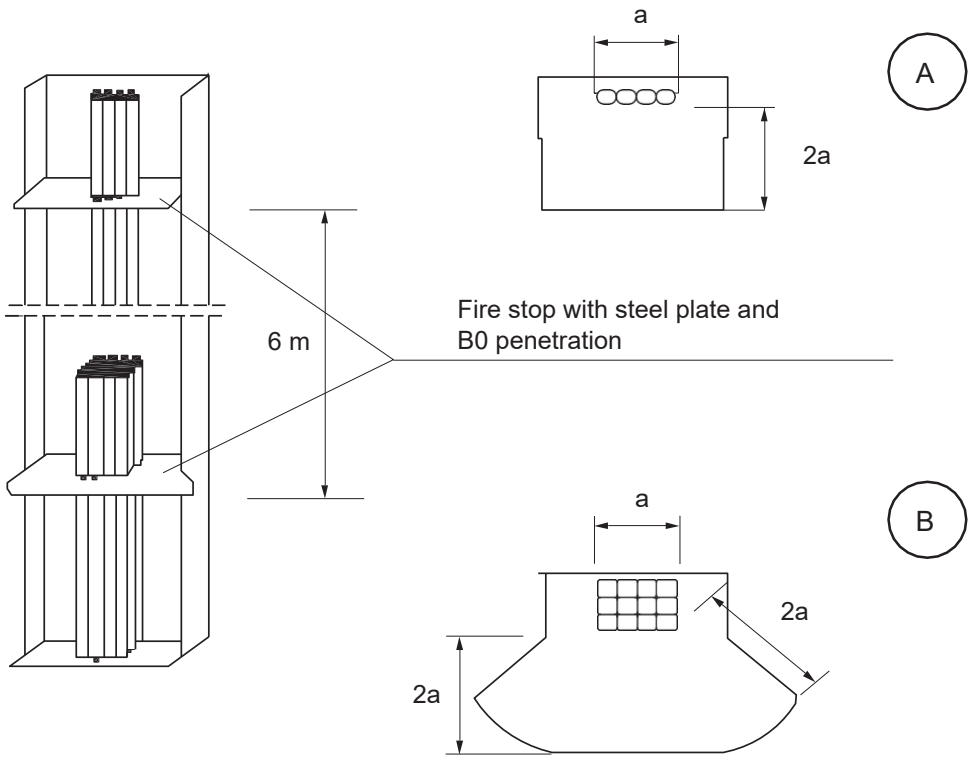


Figure 3 : Non-totally enclosed trunks, horizontal

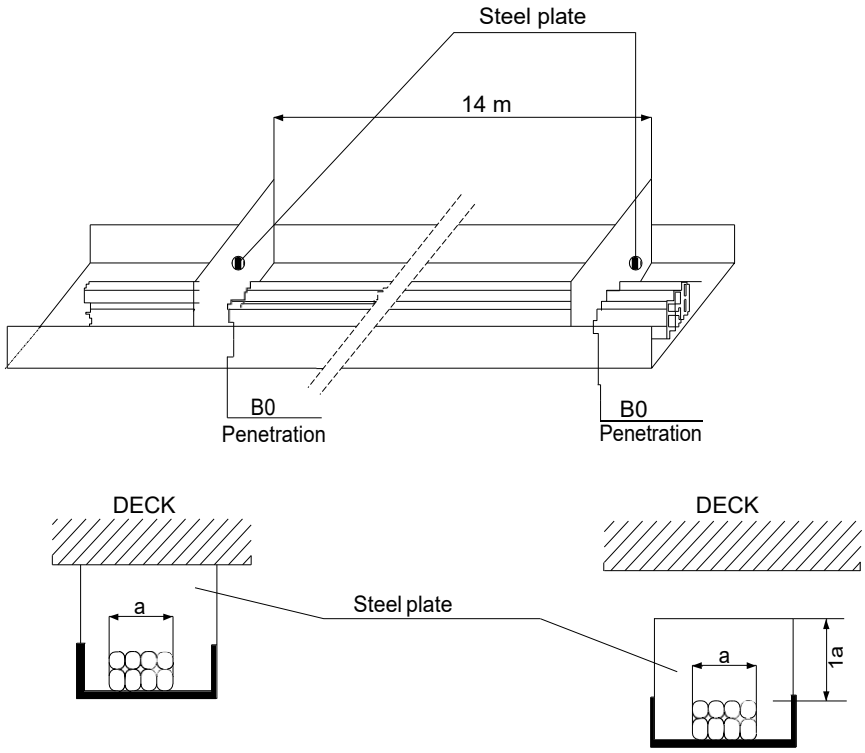
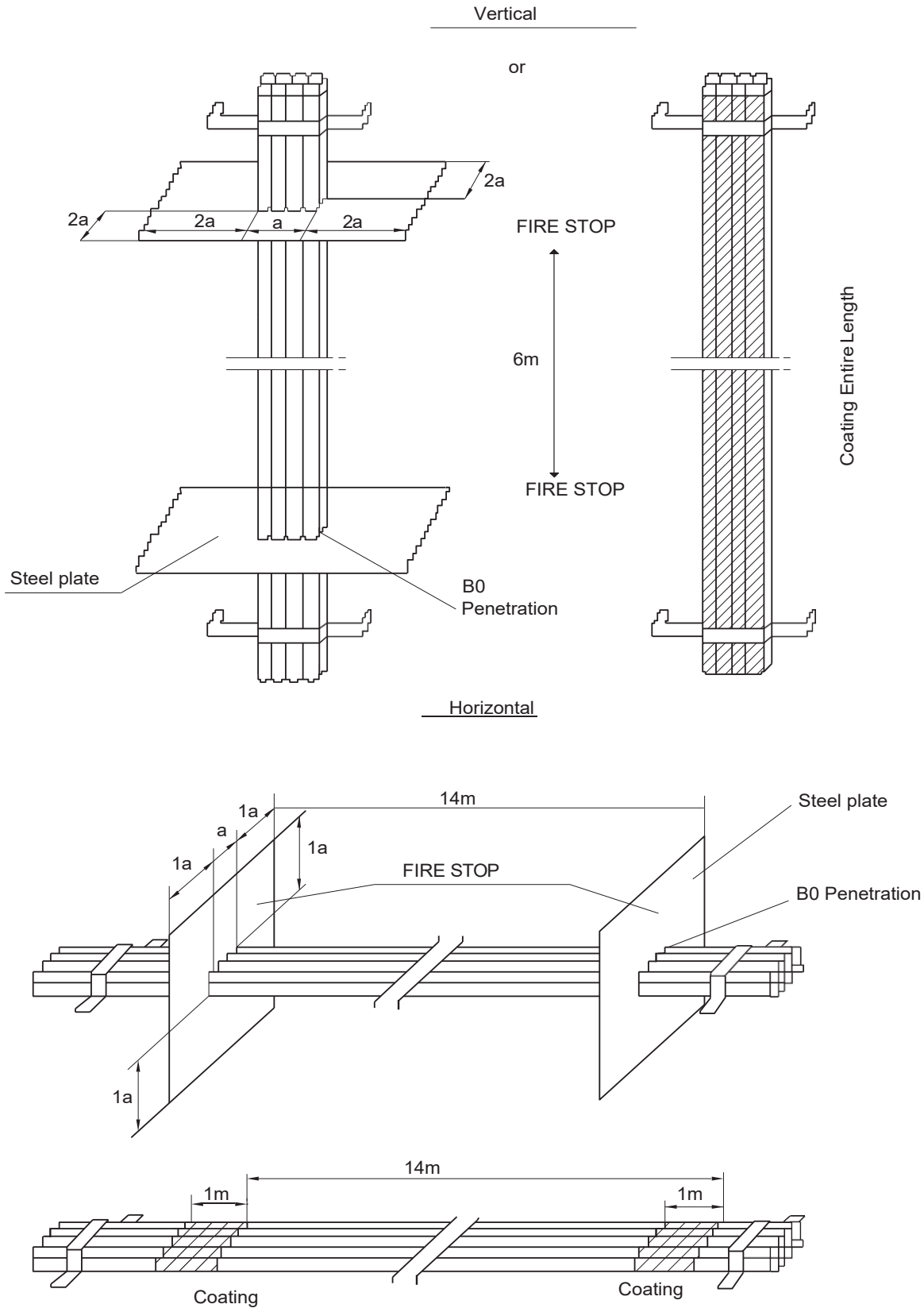


Figure 4 : Open cables runs



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.

For mineral-insulated cables with copper sheath, fixing devices in contact with the sheath are to be of copper alloy.

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, cargo spaces, etc., cables are to be protected by metal casing, trunkings or conduits, even when armoured, if the ship'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 [7.5.3].

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 Cables passing through decks and continuing vertically are to be protected against mechanical damage to a suitable height above the deck.

7.5.4 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.

7.5.5 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 ship, different load conditions and temperature variations, appropriate expansion joints are to be provided.

This may apply in particular in the case of cable runs on the weather deck.

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.

7.9.3 Cables not having a moisture-resistant insulation (e.g. mineral-insulated) are to have their ends effectively sealed against ingress of moisture.

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.

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 ship.

7.11.2 Metal coverings are generally to be earthed at both ends of the cable, except for [7.11.3] 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 3, Sec 7), 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 Sec 3, [9.4].

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 Sec 3, [10.2].

7.15.2 For penetration of bulkheads or decks separating areas with a risk of explosion, see [7.5.4].

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 in the vicinity of radio equipment

7.16.1 All cables between antennas and transmitters are to be routed separately of any other cable.

7.16.2 Where it is necessary to use single-core cables, the arrangement of conductors is to be such as to avoid complete or partial loops.

7.17 Cables for submerged bilge pumps

7.17.1 See Sec 3, [9.7].

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 Sec 3, [9.9]), 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 HIGH VOLTAGE INSTALLATIONS

1 General

1.1 Field of application

1.1.1 *(1/1/2002)*

The following requirements apply to a.c. three-phase systems with nominal voltage exceeding 1kV, the nominal voltage being the voltage between phases.

If not otherwise stated herein, construction and installation applicable to low voltage equipment generally apply to high voltage equipment.

1.2 Nominal system voltage

1.2.1 *(1/1/2002)*

The nominal system voltage is not to exceed 15 kV.

Note 1: Where necessary for special application, higher voltages may be accepted by the Society.

1.3 High-voltage, low-voltage segregation

1.3.1 *(1/1/2002)*

Equipment with voltage above about 1 kV is not to be installed in the same enclosure as low voltage equipment, unless segregation or other suitable measures are taken to ensure that access to low voltage equipment is obtained without danger.

2 System Design

2.1 Distribution

2.1.1 **Network configuration for continuity of ship services** *(1/1/2002)*

It is to be possible to split the main switchboard into at least two independent sections, by means of at least one circuit breaker or other suitable disconnecting devices, each supplied by at least one generator. If two separate switchboards are provided and interconnected with cables, a circuit breaker is to be provided at each end of the cable.

Services which are duplicated are to be divided between the sections.

2.1.2 **Earthed neutral systems** *(1/1/2002)*

In the event of an earth fault, the current is not to be greater than full load current of the largest generator on the switchboard or relevant switchboard section and not less than three times the minimum current required to operate any device against earth fault.

It is to be assured that at least one source neutral to ground connection is available whenever the system is in the energised mode. Electrical equipment in directly earthed neutral or other neutral earthed systems is to withstand the current due to a single phase fault against earth for the time necessary to trip the protection device.

2.1.3 **Neutral disconnection** *(1/1/2002)*

Means of disconnection are to be fitted in the neutral earthing connection of each generator so that the generator may be disconnected for maintenance and for insulation resistance measurement.

2.1.4 **Hull connection of earthing impedance** *(1/1/2002)*

All earthing impedances are to be connected to the hull. The connection to the hull is to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.

2.1.5 **Divided systems** *(1/1/2002)*

In systems with neutral earthed, connection of the neutral to the hull is to be provided for each section.

2.2 Degrees of protection

2.2.1 General *(1/1/2002)*

Each part of the electrical installation is to be provided with a degree of protection appropriate to the location, as a minimum the requirements of IEC 60092-201.

2.2.2 Rotating machines *(1/1/2002)*

The degree of protection of enclosures of rotating electrical machines is to be at least IP 23.

The degree of protection of terminals is to be at least IP44.

For motors installed in spaces accessible to unqualified personnel, a degree of protection against approaching or contact with live or moving parts of at least IP4X is required.

2.2.3 Transformers *(1/1/2002)*

The degree of protection of enclosures of transformers is to be at least IP23.

For transformers installed in spaces accessible to unqualified personnel a degree of protection of at least IP4X is required.

For transformers not contained in enclosures, see [8.1].

2.2.4 Switchgear, controlgear assemblies and convertors *(1/1/2002)*

The degree of protection of metal enclosed switchgear, controlgear assemblies and static convertors is to be at least IP32. For switchgear, control gear assemblies and static convertors installed in spaces accessible to unqualified personnel, a degree of protection of at least IP4X is required.

2.3 Insulation

2.3.1 *(1/1/2002)*

In general, for non Type Tested equipment phase-to-phase air clearances and phase-to- earth air clearances between non-insulated parts are to be not less than those specified in Tab 1.

Intermediate values may be accepted for nominal voltages provided that the next highest air clearance is observed.

In the case of smaller distances, an appropriate voltage impulse test is to be applied.

Table 1 : Minimum clearances *(1/7/2004)*

Rated voltage, in kV	Minimum clearance, in mm
3 - 3,3	55
6 - 6,6	90
10 - 11	120
15	160

2.3.2 *(1/7/2016)*

Creepage distances between live parts and between live parts and earthed metal parts are to be in accordance with IEC 60092-503 for the nominal voltage of the system, the nature of the insulation material and the transient overvoltage developed by switch and fault conditions.

2.4 Protection

2.4.1 Faults on the generator side of the circuit breaker *(1/1/2002)*

Protective devices are to be provided against phase-to-phase faults in the cables connecting the generators to the main switchboard and against interwinding faults within the generators. The protective devices are to trip the generator circuit breaker and to automatically de-excite the generator.

In distribution systems with a neutral earthed, phase to earth faults are also to be treated as above.

2.4.2 Faults to earth *(1/7/2016)*

Any earth fault in the system is to be indicated by means of a visual and audible alarm.

In low impedance or direct earthed systems provision is to be made to automatically disconnect the faulty circuits. In high impedance earthed systems, where outgoing feeders will not be isolated in case of an earth fault, the insulation of the equipment is to be designed for the phase to phase voltage (see Note 1).

A system is defined effectively earthed (low impedance) when earthing factor is lower than 0,8. A system is defined non-effectively earthed (high impedance) when earthing factor is higher than 0,8.

Note 1: Earthing factor is defined as the ratio between the phase to earth voltage of the health phase and the phase to phase voltage. This factor may vary between 1/√3and 1.

2.4.3 Power transformers *(1/1/2002)*

Power transformers are to be provided with overload and short circuit protection.

When transformers are connected in parallel, tripping of the protective devices on the primary side is to automatically trip the switch connected on the secondary side.

2.4.4 Voltage transformers for control and instrumentation *(1/1/2002)*

Voltage transformers are to be provided with overload and short circuit protection on the secondary side.

2.4.5 Fuses *(1/1/2002)*

Fuses are not to be used for overload protection.

2.4.6 Low voltage systems *(1/1/2002)*

Lower voltage systems supplied through transformers from high voltage systems are to be protected against overvoltages. This may be achieved by:

a) direct earthing of the lower voltage system

b) appropriate neutral voltage limiters

c) earthed screen between the primary and secondary windings of transformers.

2.4.7 Arc Detection System *(1/7/2017)*

In order to limit the consequences of an internal arc to the high voltage main switchboard, measures may be adopted for a rapid fault-clearance times initiated by an Arc Detection System by means of detectors, e.g. sensitive to light, pressure or heat.

Where the Arc Detection System is fitted, the following requirements are to be complied with:

a) Arc Detection Systems for each section of the main switchboard are to be independent

b) The total disconnection of one section of the main switchboard, as a consequence of an arc fault, is permitted only when it is demonstrated that an arc fault located in any compartments of the switchboard (e.g. cable compartments, circuit breaker compartment, etc.) may jeopardise the operation of the entire switchboard

c) The arrangement of the power supplies are to be in such a way that a failure inside the Arc Detection System will not cause the loss of generators and/or essential services.

d) A failure analysis is to be carried out using appropriate means (e.g. FMEA) to demonstrate that, for single failures, system will fail to safety and that system in operation will not be lost or degraded beyond acceptable performance criteria. Faults are to be simulated as realistically as possible to demonstrate appropriate system fault detection and system response.

e) The Arc Detection System, including relevant arc detectors, is to be type tested or type approved according to the tests listed in Ch 3, Sec 8, Tab 1.

3 Rotating machinery

3.1 Stator windings of generators

3.1.1 *(1/1/2002)*

Generator stator windings are to have all phase ends brought out for the installation of the differential protection.

3.2 Temperature detectors

3.2.1 *(1/1/2002)*

Rotating machinery is to be provided with temperature detectors in its stator windings to actuate a visual and audible alarm in a normally attended position whenever the temperature exceeds the permissible limit.

If embedded temperature detectors are used, means are to be provided to protect the circuit against overvoltage.

3.3 Tests

3.3.1 *(1/1/2002)*

In addition to the tests normally required for rotating machinery, a high frequency high voltage test in accordance with IEC 60034-15 is to be carried out on the individual coils in order to demonstrate a satisfactory withstand level of the inter-turn insulation to steep fronted switching surges.

4 Power Transformers

4.1 General

4.1.1 *(1/7/2022)*

Dry type transformers are to comply with IEC 60076-11.

Liquid cooled transformers are to comply with the applicable Parts of the IEC 60076 Series.

Oil immersed transformers are to be provided with the following alarms and protection:

- liquid level (Low) - alarm
- liquid temperature (High) - alarm
- liquid level (Low) - trip or load reduction
- liquid temperature (High) - trip or load reduction
- gas pressure relay (High) - trip

5 Cables

5.1 General

5.1.1 *(1/1/2002)*

Cables are to be constructed in accordance with IEC 60092-353 and 60092-354 or other equivalent Standard.

6 Fuses

6.1 General

6.1.1 *(1/7/2015)*

Fuses are to be constructed in accordance with IEC 60282-1 or other equivalent Standard.

7 Switchgear and controlgear assemblies

7.1 General

7.1.1 *(1/1/2002)*

Switchgear and controlgear assemblies are to be constructed according to IEC 62271-200 and the following additional requirements.

7.2 Construction

7.2.1 **Mechanical construction** *(1/1/2002)*

Switchgear is to be of metal - enclosed type in accordance with IEC 62271-200 or of the insulation - enclosed type in accordance with IEC 62271-201.

7.2.2 **Locking facilities** *(1/1/2002)*

Withdrawable circuit breakers and switches are to be provided with mechanical locking facilities in both service and disconnected positions. For maintenance purposes, key locking of withdrawable circuit breakers and switches and fixed disconnectors is to be possible.

Withdrawable circuit breakers are to be located in the service position so that there is no relative motion between fixed and moving portions.

7.2.3 Shutters *(1/7/2016)*

The fixed contacts of withdrawable circuit breakers and switches are to be so arranged that in the withdrawable position the live contacts are automatically covered.

Shutters are to be clearly marked for incoming and outgoing circuits; this is to be achieved with the use of colours or labels.

7.2.4 Earthing and short-circuiting *(1/7/2016)*

For maintenance purposes an adequate number of earthing and short-circuiting devices is to be provided to enable circuits to be worked upon with safety.

7.2.5 Internal Arc Classification (IAC) *(1/7/2016)*

Switchgear and controlgear assemblies are to be internal arc classified (IAC) in accordance with IEC 62271-200.

Where switchgear and controlgear are accessible by authorized personnel only, Accessibility Type A is sufficient. Where switchgear and controlgear are accessible by non-authorised personnel, accessibility Type B is required.

Installation and location of the switchgear and controlgear is to correspond with its internal arc classification and classified sides (F, L and R).

7.3 Auxiliary systems

7.3.1 Source of supply *(1/1/2002)*

If electrical energy and/or physical energy is required for the operation of circuit breakers and switches, a store supply of such energy is to be provided for at least two operations of all the components.

However, the tripping due to overload or short-circuit, and under-voltage is to be independent of any stored electrical energy sources. This does not preclude shunt tripping provided that alarms are activated upon lack of continuity in the release circuits and power supply failures.

7.3.2 Number of supply sources *(1/7/2004)*

When external supply is necessary for auxiliary circuits, at least two external sources of supply are to be provided and so arranged that a failure or loss of one source will not cause the loss of more than one generator set and/or set of essential services.

Where necessary, one source of supply is to be from the emergency source of electrical power for the start up from dead ship condition.

7.4 High voltage test

7.4.1 *(1/1/2002)*

A power-frequency voltage test is to be carried out on any switchgear and controlgear assemblies. The test procedure and voltages are to be according to IEC 62271-200.

8 Installation

8.1 Electrical equipment

8.1.1 *(1/7/2016)*

Where equipment is not contained in an enclosure but a room forms the enclosure of the equipment, the access doors are to be so interlocked that they cannot be opened until the supply is isolated and the equipment earthed down.

At the entrance to spaces where high-voltage electrical equipment is installed, a suitable marking is to be placed indicating danger of high-voltage. As regards high-voltage electrical equipment installed outside the aforementioned spaces, similar marking is to be provided.

An adequate, unobstructed working space is to be left in the vicinity of high voltage equipment for preventing potential severe injuries to personnel performing maintenance activities. In addition, the clearance between the switchboard and the ceiling/deckhead above is to meet the requirements of the Internal Arc Classification (see [7.2.5]).

8.2 Cables

8.2.1 Runs of cables *(1/1/2002)*

In accommodation spaces, high voltage cables are to be run in enclosed cable transit systems.

8.2.2 Segregation *(1/1/2002)*

High voltage cables are to be segregated from cables operating at different voltage ratings; in particular, they are not to be run in the same cable bunch, in the same ducts or pipes, or in the same box.

Where high voltage cables of different voltage ratings are installed on the same cable tray, the air clearance between cables is not to be less than the minimum air clearance for the higher voltage side in [2.3.1]. However, high voltage cables are not to be installed on the same cable tray for cables operating at the nominal system voltage of 1 kV and less.

8.2.3 Installation arrangements *(1/7/2016)*

High voltage cables are generally to be installed on carrier plating cable tray when they are provided with a continuous metallic sheath or armour which is effectively bonded to earth; otherwise they are to be installed for their entire length in metallic castings effectively bonded to earth.

8.2.4 Terminations *(1/1/2002)*

Terminations in all conductors of high voltage cables are, as far as practicable, to be effectively covered with suitable insulating material. In terminal boxes, if conductors are not insulated, phases are to be separated from earth and from each other by substantial barriers of suitable insulating materials.

High voltage cables of the radial field type, i.e. having a conductive layer to control the electric field within the insulation, are to have terminations which provide electric stress control.

Terminations are to be of a type compatible with the insulation and jacket material of the cable and are to be provided with means to ground all metallic shielding components (i.e. tapes, wires etc).

8.2.5 Marking *(1/1/2002)*

High voltage cables are to be readily identifiable by suitable marking.

8.2.6 Test after installation *(1/7/2019)*

Before a new high voltage cable installation, or an addition to an existing installation, is put into service a voltage withstand test is to be satisfactorily carried out on each completed cable and its accessories.

The test is to be carried out after an insulation resistance test in accordance with Sec 15, [3.1.1].

For cables with rated voltage (U0/U) above 1,8/3 kV (Um=3,6 kV) an a.c. voltage withstand test is to be carried out upon advice from high voltage cable manufacturer. For this purpose, one of the following test methods are to be used:

a) test for 5 min with the phase-to-phase voltage of the system applied between the conductor and the metallic screen/sheath;

b) test for 24 h with the normal operating voltage of the system.

Alternatively, a d.c. voltage equal to 4 Uo is to be applied for 15 minutes.

For cables with rated voltage (U0/U) up to 1.8/3 kV (Um=3.6 kV) a d.c. voltage equal to 4 Uo is to be applied for 15 minutes.

After completion of the test the conductors are to be connected to earth for a sufficient period in order to remove any trapped electric charge.

An insulation resistance test in accordance with Sec 15, [3.1.1] is then repeated.

SECTION 14 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 are to comply with the requirements of Ch 1, Sec 2.

1.1.3 For the torsional vibration characteristics of the electric propulsion plant, the provisions of Ch 1, Sec 9 apply.

1.1.4 Cooling and lubricating oil systems are to comply with the requirements of Ch 1, Sec 10.

1.1.5 Monitoring and control systems are to comply with the requirements of Chapter 3.

1.1.6 Installations assigned an additional notation for automation are to comply with the requirements of Part F.

1.2 Operating conditions

1.2.1 The normal torque available on the electric propulsion motors for manoeuvring is to be such as to enable the vessel to be stopped or reversed when sailing at its maximum service speed.

1.2.2 Adequate torque margin is to be provided for three-phase synchronous motors to avoid the motor pulling out of synchronism during rough weather and when turning.

1.2.3 When an electric generating plant has a continuous rating greater than the electric propulsion motor rating, means are to be provided to limit the continuous input to the motor. This value is not to exceed the continuous full load torque for which motor and shafts are designed.

1.2.4 The plant as a whole is to have sufficient overload capacity to provide the torque, power and reactive 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.

1.2.5 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 may be supplied from generating sets, dedicated to the propulsion system, or from a central power generation plant, which supplies the ship's services and electric propulsion.

The minimum configuration of an electric propulsion plant consists of one prime mover, one generator and one electric motor. When the electrical production used for propulsion is independent of the shipboard production, the diesel engines driving the electric generators are to be considered as main engines.

2.1.2 For plants having only one propulsion motor controlled via a static convertor, a standby convertor which it is easy to switch over to is to be provided. Double stator windings with one convertor for each winding are considered as an alternative solution.

2.1.3 In electric propulsion plants having two or more constant voltage propulsion generating sets, the electrical power for the ship's auxiliary services may be derived from this source. Additional ship's generators for auxiliary services need not be fitted provided that effective propulsion and the services mentioned in Sec 3, [2.2.3] are maintained with any one generating set out of service.

Where transformers are used to supply the ship's auxiliary services, see Sec 5.

2.1.4 Plants having two or more propulsion generators, 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.

2.1.5 *(1/1/2026)*
For single essential propulsion components and their reliability, refer to Ch 1, Sec 1, [2.1.2].

2.2 Power supply

2.2.1 Where the plant is intended exclusively for electric propulsion, voltage variations and maximum voltage are to be maintained within the limits required in Sec 2.

2.2.2 In special conditions (e.g. during crash-stop manoeuvres), frequency variations may exceed the limits stipulated in Sec 2 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 Sec 2.

2.3 Auxiliary machinery

2.3.1 Propeller/thruster auxiliary plants are to be supplied directly from the main switchboard or from the main distribution board or from a distribution board reserved for such circuits, at the auxiliary rated voltage.

2.3.2 When the installation has one or more lubrication systems, devices are to be provided to ensure the monitoring of the lubricating oil return temperature.

2.3.3 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 the case of propulsion plants supplied by generators in parallel, suitable controls are to ensure that, if one or more generators are disconnected, those remaining are not overloaded by the propulsion motors.

2.4.6 In three-phase systems, phase-balance protective devices are to be provided for the motor circuit which de-excite the generators and motors or disconnect the circuit concerned.

2.5 Excitation of electric propulsion motor

2.5.1 Each propulsion motor is to have its own exciter.

2.5.2 For plants where only one generator or only one motor is foreseen, each machine is to be provided with a standby static electronic exciter, which it is easy to switch over to.

2.5.3 In the case of multi-propeller propulsion ships, one standby static electronic exciter which it is easy to switch over to is to be provided.

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.

3 Construction of rotating machines and semiconductor convertors

3.1 Ventilation

3.1.1 Where electrical machines are fitted with an integrated fan and are to be operated at speeds below the rated speed with full load torque, full load current, full load excitation or the like, the design temperature rise is not to be exceeded.

3.1.2 Where electrical machines or convertors are force-ventilated, at least two fans, or other suitable arrangements, 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 500 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.

3.4 Semiconductor convertors

3.4.1 The following limiting repetitive peak voltages U_{RM} are to be used as a base for each semiconductor valve:

- when connected to a supply specifically for propeller drives:

  $U_{RM} = 1,5\ U_P$

- when connected to a common main supply:

  $U_{RM} = 1,8\ U_P$

  where

  U_P : is the peak value of the rated voltage at the input of the semiconductor convertor.

3.4.2 For semiconductor convertor elements connected in series, the values in [3.4.1] are to be increased by 10%. Equal voltage distribution is to be ensured.

3.4.3 For parallel-connected convertor elements, an equal current distribution is to be ensured.

3.4.4 Means are to be provided, where necessary, to limit the effects of the rate of harmonics to the system and to other semiconductor convertors. Suitable filters are to be installed to keep the current and voltage within the limits given in Sec 2.

4 Control and monitoring

4.1 General

4.1.1 The control and monitoring systems, including programmable electronic systems, are to be type approved, according to Ch 3, Sec 8.

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 generated power (i.e. blackout) or loss of propulsion.

4.2.4 The loss of power plant control systems is not to cause variations in the available power; i.e. starting or stopping of generating sets is not to occur as a result.

4.2.5 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 operation.

4.2.6 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 or pitch control of the propeller
- shutdown or slow down when necessary.

4.2.7 Where the electric propulsion system is supplied by the main switchboard together with the ship's services, load shedding of the non-essential services and /or power limitation of the electric propulsion is to be provided. An alarm is to be triggered in the event of power limitation or load shedding.

4.2.8 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 Chapter 3 of the Rules, instruments indicating consumed power and power available for propulsion are to be provided at each propulsion remote control position.

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:

- 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
- a voltmeter for the measurement of the voltage between phases of each motor supplied through a semiconductor frequency convertor.

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 An ammeter is to be provided on the supply circuit for each propulsion semiconductor bridge.

4.4 Alarm system

4.4.1 An alarm system is to be provided, in accordance with the requirements of Chapter 3. 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.

4.4.2 Where an alarm system is provided for other essential equipment or installations, the alarms in [4.4.1] may be connected to such system.

4.4.3 *(1/7/2004)*

Critical alarms for propulsion may be grouped, but are to be indicated to the bridge separately from other alarms.

4.4.4 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 generators and 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 Power is to be automatically reduced in the following cases:

- low lubricating oil pressure of bearings of propulsion generators and motors
- high winding temperature of propulsion generators and motors
- fan failure in machines and convertors provided with forced ventilation, or failure of cooling system
- lack of coolant in machines and semiconductor convertors
- load limitation of generators or inadequate available 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.

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 3, Sec 7.

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 sliprings 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 Sec 4.

6.1.2 For rotating machines, such as synchronous generators and synchronous electric motors, of a power of more than 3 MW, 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 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.

7 Specific requirements for PODs

7.1 General

7.1.1 The requirements for the structural part of a POD are specified in Pt B, Ch 10, Sec 1, [11].

7.1.2 When used as steering manoeuvring system, the POD is to comply with the requirements of Ch 1, Sec 11.

7.2 Rotating commutators

7.2.1 As far as the electrical installation is concerned, the electric motor is supplied by a rotating commutator which rotates with the POD. The fixed part of the power transmission is connected to the ship supply, which uses the same components as a conventional propulsion system. Sliding contacts with a suitable support are used between the fixed and rotating parts.

7.2.2 *(1/7/2003)*
Type tests are to be carried out, unless the manufacturer can produce evidence based on previous experience indicating the satisfactory performance of such equipment on board ships.

7.2.3 A test program is to be submitted to the Society for approval. It is to be to demonstrated that the power transmission and transmission of low level signals are not affected by the environmental and operational conditions prevailing on board. To this end, the following checks and tests are to be considered:

- check of the protection index (I.P.), in accordance with the location of the rotating commutator
- check of the clearances and creepage distances
- check of insulation material (according to the test procedure described in IEC Publication 60112)
- endurance test:

After the contact pressure and rated current are set, the commutator is subjected to a rotation test. The number of rotations is evaluated taking into consideration the ship operation and speed rotation control system. The possibility of turning the POD 180° to proceed astern and 360° to return to the original position is to be considered. The commutator may be submitted to cycles comprising full or partial rotation in relation to the use of the POD as steering gear. The voltage drops and current are to be recorded.

An overload test is to be carried out in accordance with Sec 4 (minimum 150%, 15 seconds)

- check of the behaviour of the sliprings when subjected to the vibration defined in Ch 3, Sec 8
- check of the behaviour of the sliprings, after damp heat test, as defined in Chapter 3, and possible corrosion of the moving parts and contacts

After the damp heat test, are to be carried out the hereunder listed tests.

- Insulation measurement resistance test. The minimum resistance is to be in accordance with Sec 4, Tab 3.
- Dielectric strength test as defined in Sec 4.

7.3 Electric motors

7.3.1 The thermal losses are dissipated by the liquid cooling of the bulb and by the internal ventilation of the POD. The justification for the evaluation of the heating balance between the sea water and air cooling is to be submitted to the Society.

Note 1: The calculation method used for the evaluation of the cooling system (mainly based on computer programs) is to be documented. The calculation method is to be justified based on the experience of the designer of the system. The results of scale model tests or other methods may be taken into consideration.

7.3.2 Means to adjust the air cooler characteristics are to be provided on board, in order to obtain an acceptable temperature rise of the windings. Such means are to be set following the dock and sea trials.

7.4 Instrumentation and associated devices

7.4.1 Means are to be provided to transmit the low level signals connected to the sensors located in the POD.

7.5 Additional tests

7.5.1 Tests of electric propulsion motors are to be carried out in accordance with Sec 4, and other tests in accordance with Ch 1, Sec 16.

7.5.2 Tests are to be performed to check the validation of the temperature rise calculation.

SECTION 15 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 [3], [4] and [5] 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.

2 Type approved components

2.1 Type approval and case by case approval

2.1.1 *(1/7/2023)*

The following components are to be type tested or type approved according to the requirements in the present Chapter 2 and, excluding cables, transformers, rotating machines and converters (but not the relevant electronic control equipment), according to the tests listed in Ch 3, Sec 8, Tab 1, as far as applicable, or in accordance with [2.1.2]:

- electrical cables (internal wiring of equipment excluded)
- transformers
- rotating machines
- electrical convertors
- circuit-breakers, contactors, fuses and fuse-combination units used in power and lighting distribution systems, motor and transformer circuits, overcurrent protective devices
- sensors, alarm panels, electronic protective devices, automatic and remote control equipment, actuators, safety devices for installations intended for essential services (steering, controllable pitch propellers, propulsion machinery, etc.), electronic speed regulators for main or auxiliary engines, electronic devices for alarm, safety and control of electrical convertors for primary essential services and emergency services as defined in Sec 3, [3.7.3]
- programmable electronic systems intended for functions which are subject to classification requirements
- cable trays/protective casings made of plastic materials.

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 *(1/1/2021)*
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, emergency switchboard, distribution 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 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 satisfactory operation of the emergency source of power and of the transitional source of power, when required, is to be tested. In particular, the automatic starting and the automatic connection to the emergency switchboard, in case of failure of the main source of electrical power, are to be tested.

5.2 Switchgear

5.2.1 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.

5.2.2 Short-circuit tests may also be required at the discretion of the Society in order to verify the selectivity characteristics of the installation.

5.3 Consuming devices

5.3.1 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.

5.3.2 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.

5.3.3 The remote stops foreseen are to be tested.

5.3.4 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).

5.4 Communication systems

5.4.1 Communication systems, order transmitters and mechanical engine-order telegraphs are to be tested to verify their suitability.

5.5 Installations in areas with a risk of explosion

5.5.1 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.

5.6 Voltage drop

5.6.1 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 Sec 3, [9.11.4]).

APPENDIX 1 INDIRECT TEST METHOD FOR SYNCHRONOUS MACHINES

1 General

1.1 Test method

1.1.1 The machine is to subjected to the three separate running tests specified below (see Fig 1) when it is completed (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:

- Test N° 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 case, on the magnetic circuit losses and mechanical losses due to ventilation, where:
  - Δt_{s1} is the stator temperature rise
  - Δt_{r1} is the rotor temperature rise
- Test N° 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:
  - Δt_{s2} is the stator temperature rise
  - Δt_{r2} is the rotor temperature rise, which for test N° 2 is negligible
- Test N° 3: Zero excitation. The temperature of all windings depends on the mechanical losses due to friction and ventilation, where:
  - Δt_{s3} is the stator temperature rise
  - Δt_{r3} 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 1°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.

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:

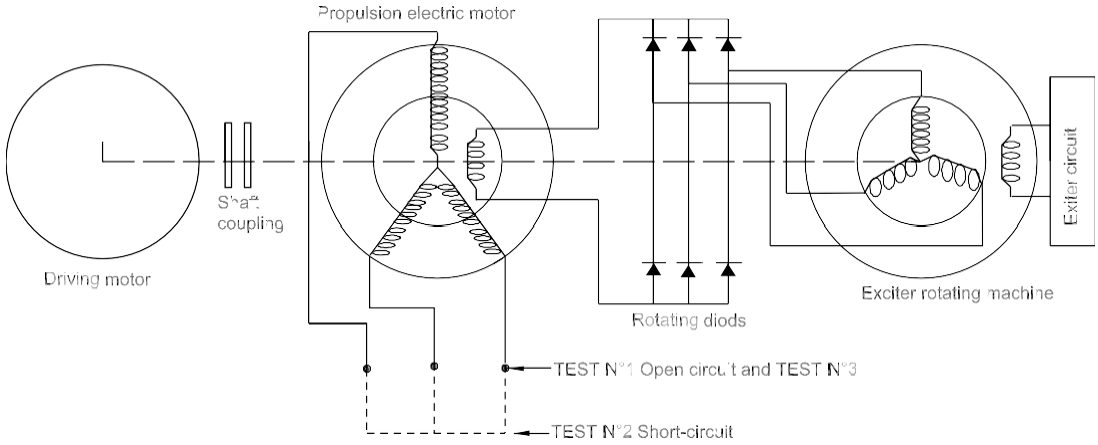
  $\Delta t_{\ stator} = \Delta t_{s1} + \Delta t_{s2} - \Delta t_{s3}$

  $\Delta t_{\ stator}$ winding is to be corrected by the supplementary temperature rise due to current harmonics evaluated by the manufacturer
- Considering that in test N° 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:

  $\Delta t_{\ rotor} = (\Delta t_{r1} - \Delta t_{r3})$ x (rated loading conditions Ir/ test loading conditions Irt)^2 + Δt_{r3}

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.

Figure 1 : Schematic diagram used for the test



APPENDIX 2 BATTERY POWERED SHIPS

1 General

1.1 Application

1.1.1 *(1/1/2022)*
The provisions of this Appendix apply to ships where batteries, other than Lead and Nickel-Cadmium and Nickel-Metal-Hydride batteries, are installed to supply essential or not-essential services and emergency services, except batteries embedded in consumer products like computers and similar appliances.

1.1.2 *(1/1/2019)*
The requirements in this Appendix are applicable to installations with a variety of lithium battery chemistry; since the battery technology is under development, additional requirements may be required by the Society on a case by case basis.

1.1.3 *(1/1/2022)*
The Society may consider different arrangements than those stated in this Appendix, provided that they ensure an equivalent level of safety, to be demonstrated by appropriate risk analysis techniques.

1.2 Definitions

1.2.1 *(1/1/2022)*
The following definitions and abbreviations are additional to those given in the other Parts of the Rules:

- Battery Management System (BMS): an electronic system that controls and monitors the state of the batteries by protecting the batteries from operating outside its safe operating area.
- Energy Management System (EMS): a system providing monitoring and control of the energy.
- Cell: an individual electrochemical unit of a battery consisting of electrodes, separators, electrolyte, container and terminals.
- Battery: assembly of cells ready for use as storage of electrical energy characterized by its voltage, size terminal arrangement, capacity and rate capability.
- Battery space: compartments (rooms, lockers or boxes) used primarily for accommodation of batteries .
- Battery system: the battery installation including battery banks, electrical interconnections, BMS and other safety features.
- Module: group of cells connected together either in a series and/or parallel configuration.
- State of Charge (SOC): state of charge expressed as a percentage of the rated capacity giving an indication of the energy available from the battery.
- State of Health (SOH): general condition of a battery, including its ability to deliver the specified performance compared with a new battery.
- Venting: release of excessive internal pressure from a cell/battery in a manner intended by design to preclude rupture or explosion.
- Explosion: failure that occurs when a cell container or battery case opens violently and major components are forcibly expelled.
- Fire: the emission of flames from a cell or battery.
- Upper limit of the charging voltage: the highest allowable charging voltage as specified by the cell Manufacturer.

1.3 Documentation to be submitted

1.3.1 *(1/1/2019)*
In addition to the documents required in Sec 1, for battery powered ships the plans and documents listed in Tab 1 are to be submitted.

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 systems and components.

2 System design

2.1 General

2.1.1 *(1/1/2019)*

Battery installations may replace generator sets in the main source of electrical power on condition that the capacity of the battery installation is sufficient for the intended operation of the ship and such design capacity is stated in the class certificate as an operational limitation.

2.1.2 *(1/1/2019)*

In ships or units where the main source of electrical power is based on battery installations only, the battery installation is to be divided into at least two independent battery systems located in two separate battery spaces, each having a capacity sufficient for the intended operation of the ship.

Table 1 : Documentation to be submitted *(1/1/2022)*

No.	A/I **(1)**	Document
1	A	Block diagram and electrical wiring diagram of the battery system and system interfaced to the battery system, including control, monitoring and alarm system, emergency shutdown, PMS, etc.
2	I	Technical specification of the batteries, including technical data (electrical characteristics like voltage and capacity, discharge and recharge rates), battery chemistry and functional description of cell/battery system including at least cell/batteries configuration, safety devices (BMS), interfaces to monitoring/safety, diagnostic, including the list of controlled and monitored parameters.
3	I	Functional description of the energy management system (EMS), when required (see [2.1.3].
4	A	A risk assessment addressing all potential hazards represented by the type (chemistry) of batteries, the evaluation of the risk factors and measures to control and reduce the identified risks. Note: for the Risk Assessment reference is to be made to TASNEEF "Guide for Risk Analysis".
5	A	Test program Note: the test program is to include the functional tests as per [5.2] (alarm system, safety system, control system, etc.) [5] and further tests, if any, resulting from the Risk Assessment for the specific battery system.
6	A	Electrical load balance capable of reflecting the operational mode stated in the battery system operating philosophy (maximum designed deterioration rate is to be included).
7	A	A general arrangement plan of battery installation including the indication of structural fire protection and the safety systems **(2) (3)**.
8	I	Battery Manufacturer's instructions on active fire extinguishing system and confirmation about suitability of the proposed extinguishing agent for the specific type of batteries.
9	I	Statement of conformity of the batteries to IEC 62619, IEC 62620 and IEC 60529.
10	I	Copy of type approval certificate of the battery systems, when the aggregate capacity exceeds 20 kWh
11	I	An overall description of the battery system operating philosophy for each operational mode (including charging).
12	I	Operation and maintenance manuals including instructions for the safe connection/disconnection of batteries (see [5.4]).
13	A	Hazardous area classification (if applicable to the specific battery chemistry) and list of certified safety type electrical equipment installed in hazardous areas (as applicable).

(1) A: to be submitted for approval I: to be submitted for information

(2) Where a battery space is provided, based on the Risk Assessment (see [4.2]), evidence of the solution adopted for the battery space is to be given in the ship's active (detection and fighting) and passive fire protection, gas detection system and ventilation system drawings.

(3) The plan has to show:

- the battery pack arrangement with respect to the space it is being installed in
- the clearance distances between the other ancillary equipment in the space and the battery pack.

No.	A/I **(1)**	Document
14	I	Test Report of battery system at cellular, modular and system level in order to identify the damage potential of a possible thermal runaway event (Propagation Test) including gas analysis and explosion analysis as appli-cable and depending on the safety concept adopted.
15	I	Battery system maker statement confirming suitability of the selected fire extinguishing system and ventila-tion arrangement for the specific project.

(1) A: to be submitted for approval I: to be submitted for information

(2) Where a battery space is provided, based on the Risk Assessment (see [4.2]), evidence of the solution adopted for the battery space is to be given in the ship's active (detection and fighting) and passive fire protection, gas detection system and ventilation system drawings.

(3) The plan has to show:

- the battery pack arrangement with respect to the space it is being installed in
- the clearance distances between the other ancillary equipment in the space and the battery pack.

2.1.3 *(1/1/2022)*

When batteries are used as storage of power for the propulsion or dynamic positioning system or as part of the main source of electrical power, an Energy Management System (EMS) according to [3.5] is to be provided.

2.1.4 *(1/1/2019)*

Where the batteries are used for propulsion and steering of the ship, the system is to be so arranged that the electrical supply to equipment necessary for propulsion and steering will be maintained or immediately restored in the case of battery system failure.

2.1.5 *(1/1/2022)*

Cables connecting each battery system to the main switchboard are to be arranged as per Sec 11, [5.2].

2.1.6 *(1/1/2022)*

A Risk Assessment, to be initiated in the design phase, is to be carried out to cover, but not limited to:

- evaluation of the risk factors,
- measures to control and reduce the identified risk, including potential gas development (e.g. toxic, corrosive), fire and explosion risk and
- action to be implemented.

The outcome of the assessment will give the additional measures to be adopted for minimizing the risks related to the use of batteries and among such measures, if the battery system needs to be installed in a space assigned to batteries only.

2.1.7 *(1/1/2022)*

The risk assessment has:

- to identify risks due to external heating, fire or flooding
- to identify any fault in the battery system that may cause malfunction to essential services including but not limited to propulsion and steering or to emergency services and measures to mitigate the related risk,
- to evaluate any risk related to the location of batteries in the same spacewith other system supporting ship's essential or emergency services, including pipes and electrical cables, distribution switchboards and so on, including but not limited to thermal runaway of the battery system, external and internal short-circuit,
- to evaluate any risk related to the location, in the same space, of batteries and other systems related to non essential services,
- to address sensor failures (e.g. temperature measurement sensor failure, individual cell voltage measurement sensor failure) and alarm, control and safety system failures (e.g. BMS and EMS failures including power and communication failures),
- to assess the selected fire extinguishing and ventilation arrangement according to battery system maker guidelines considering the specific design features of the ship.

2.1.8 *(1/1/2019)*

Battery cells of different physical characteristics, chemistries and electrical parameters are not to be used in the same electrical circuit.

2.1.9 *(1/1/2019)*

The batteries are to be properly located (see [4]) and, where necessary, insulated to prevent overheating of the system.

2.1.10 *(1/1/2022)*

The minimum required degree of protection is to be, in relation to place of installation of the battery system, according to Sec 3, [4]. Where water-based fire extinguishing system is used in the battery space, IP 44 is required as a minimum (see Note 1 and Note 2).

Note 1: if other fire-extinguish systems are used, the minimum IP can be reduced as result of the risk assessment.

Note 2: where the risk assessment identifies risks from water immersion (e.g. when batteries are installed below the freeboard deck), the batteries are to have a minimum degree of protection IP X7.

2.2 Constructional requirements

2.2.1 *(1/1/2019)*

Battery enclosure covering modules and cells are to be made of flame retardant materials.

2.2.2 *(1/1/2019)*

Each cell or battery case is to incorporate a pressure relief mechanism or is to be constructed in such a way to relieve excessive internal pressure at a value and rate that will be precluded rupture, explosion and self-ignition.

2.2.3 *(1/1/2019)*

A thermal protection device, capable to disconnect the battery in case of high temperature, is to be provided in the battery.

2.2.4 *(1/1/2022)*

The design and construction of battery modules have to reduce the risk of a thermal propagation due to a cell thermal runaway, maintaining it confined at the lowest possible level (e.g. confined within a module). This may be achieved by means of partition plates or sufficient distance in accordance with maker recommendation to prevent escalation between battery modules in case of a thermal runaway.

2.2.5 *(1/1/2019)*

Terminals are to have clear polarity marking on the external surface of the battery. The size and shape of the terminal contacts are to ensure that they can carry the maximum cur- rent. External terminal contact surfaces are to be made of conductive materials with good mechanical strength and corrosion resistance. Terminal contacts are to be arranged so as to minimize the risk of short circuits.

2.2.6 *(1/1/2022)*

The battery system is to be provided with a Battery Management System (BMS) according to [3.2].

2.3 Electrical protection

2.3.1 *(1/1/2022)*

The outgoing circuits of the battery system are to be protected against overload and short-circuit by means of fuses or multi- pole circuit breakers having isolating capabilities.

2.3.2 *(1/1/2022)*

An emergency shutdown system is to be installed and capable of disconnecting the battery system in an emergency.

2.3.3 *(1/1/2022)*

The battery system is to have means for isolating purpose for maintenance purposes. This isolating device is to be independent of the emergency shutdown arrangement.

2.4 Battery charger

2.4.1 *(1/1/2022)*

Battery chargers are to comply with the requirements of Sec 7.

2.4.2 *(1/1/2019)*

The battery charger is to be designed to operate without exceeding the limits given by the battery system Manufacturer (e.g. current and voltage level).

2.4.3 *(1/1/2022)*
The battery charger is to be interfaced with and controlled by the BMS.

2.4.4 *(1/1/2022)*
Any failure in the battery charger, including charging/discharging failure, is to give an alarm in a continuously manned control position.

3 Control, monitoring, alarm and safety systems

3.1 General

3.1.1 *(1/1/2019)*
For the purpose of these rules, unless differently state in the text, a required alarm is to be intended as an audible and visual alarm and is to be given in a continuously manned control position.

3.1.2 *(1/1/2022)*
Control, monitoring, alarm and safety systems are to comply with the requirements of Chapter 3 and are to be type approved or type tested according to Ch 3, Sec 8.

3.2 Battery management systems (BMS)

3.2.1 *(1/1/2019)*
The BMS and related monitoring and safety systems (see [3.4]) are to have self-check facilities.

In the event of a failure, an alarm is to be activated.

3.2.2 *(1/1/2019)*
The BMS is to be continuously powered so that a single failure of the power supply system does not cause any degradation of the BMS functionality; an alarm is to be given in the event of failure of any of the power supplies.

Unless the power supply is derived from different strings of batteries, one of the power supplies is to be derived from the emergency source of electrical power.

Where each battery is fitted with a BMS card, the individual cards may have a single power supply from the relevant battery.

An alarm is to be given and safety action taken in the event of loss of all the power supplies.

3.2.3 *(1/1/2022)*
The battery management system (BMS) is to:

- provide limits for charging and discharging of the battery,
- protect against over-current, over-voltage and under-voltage by disconnection of the battery system,
- protect against over-temperature by disconnection of the battery system,
- provide cell and module balancing.

3.2.4 *(1/1/2022)*
The following parameters are to be continuously monitored and indications are to be provided at a local control panel and in a continuously manned control position for:

- system voltage,
- max, min, average cell voltage,
- max, min and average cell or module temperature,
- battery string current.

3.2.5 *(1/1/2019)*
When battery system is used as storage of power for the propulsion system or as part of the main source of electrical power, State of Charge (SOC) and State of Health (SOH) of the batteries are to be displayed at a continuously manned control station.

3.3 Alarm system

3.3.1 *(1/1/2019)*
Abnormal conditions which can develop into safety hazards are to be alarmed before reaching the hazardous level.

3.3.2 *(1/1/2019)*
Any abnormal condition in the battery system is to initiate an alarm.

3.3.3 *(1/1/2019)*
At least the following conditions or events have to initiate an alarm at a local control panel and in a continuously manned control position:

- safety intervention of the BMS of the battery system,
- high ambient temperature,
- failure of cooling system or leakage of liquid cooling system,
- low ventilation flow inside the battery room,
- overvoltage and undervoltage,
- cell voltage unbalance,
- high cell temperature,
- other safety protection functions.

Other possible abnormal conditions are to be considered on the basis of the outcome of the Risk Assessment (see [2.1.7]) and relevant mitigating measures are to be adopted.

3.3.4 *(1/1/2019)*
When batteries are used as storage of power for the propulsion or dynamic positioning systems or as part of the main source of electrical power, an alarm is to be given on the bridge when State of Charge (SOC) reaches minimum required capacity for ship intended operations.

3.4 Safety system

3.4.1 *(1/1/2022)*
The safety systems are to be:

- designed so as to limit the consequence of internal failures (e.g. failure in the safety system is not to cause shut down of battery system)
- self-monitoring,
- capable of acting on the controlled system following the fail-to safety principle,
- capable of detecting sensor malfunctions.

3.4.2 *(1/1/2019)*
The safety systems are to be activated automatically in the event of identified conditions which could lead to damage of the battery system. Activation of any automatic safety actions is to activate an alarm. Manual override of safety functions is not to be possible.

3.4.3 *(1/1/2019)*
Voltage of any one of the single cells is not to exceed the upper limit of the charging voltage as specified by the cell Manufacturer. The battery charger is to be stopped when the upper limit of the charging voltage is exceeded for any one of the single cells.

3.4.4 *(1/1/2022)*
An emergency shutdown (ESD) system is to be arranged as a separated hardwired circuit and it is to be independent from the control system.

3.4.5 *(1/1/2019)*
Activation means of the ESD are to be provided locally, from outside the battery space, and from a continuously manned control station.

3.4.6 *(1/1/2019)*
When battery installation is used as storage of power for the propulsion or dynamic positioning systems or as part of the main source of electrical power, the emergency shutdown is also to be located on the bridge.

3.4.7 *(1/1/2019)*
When battery installation is used as storage of power for the propulsion or DP systems or as part of the main source of electrical power, in case of over temperature in the battery system, an alarm and a request of manual load reduction is to be given on the bridge at a temperature lower than the one causing intervention of the BMS. As an alternative an automatic load reduction system may be provided. Its intervention is to generate an alarm.

3.4.8 *(1/1/2019)*
Other possible abnormal conditions, which could lead to damage or additional hazards to battery system, are to be considered on the basis of the outcome of the Risk Assessment.

3.4.9 *(1/1/2019)*
Sensors are to be designed to withstand the local environment.

3.4.10 *(1/1/2019)*
The enclosure of the sensor and the cable entry are to be appropriate to the space in which they are located.

3.4.11 *(1/1/2019)*
Cables to be operable under fire conditions (e.g. where required as result of the Risk Assessment), are to be of a fire-resistant type complying with IEC Publication 60331 series.

3.5 Energy Management system

3.5.1 *(1/1/2022)*
When required per [2.1.3], an energy management system (EMS) is to be provided complying with the requirements of Chapter 3 consisting of several levels of controls and alarm functions, such as:

- monitoring and alarm functions of all power sources, inverters and disconnectors;
- voltage and power control for DC distribution system;
- available power and charge/discharge status of the storage energy source;
- interface with Power Management System (PMS) for combinations of AC and DC distribution systems;
- inverter control for the overall system.

The energy management system (EMS) is to be independent from the battery management system (BMS) for lithium batteries, however EMS may be integrated in the PMS.

The EMS is to be continuously supplied by uninterruptible power supply systems (UPS) and a failure is to initiate an alarm in a manned location.

The energy management system is to be type tested or type approved according to the tests listed in Ch 3, Sec 8, Tab 1, as far as applicable (see Note 1).

Note 1: If the energy management functionality is implemented in another system, e.g. as part of the power management system (PMS), then the systems are to be certified together.

3.5.2 *(1/1/2019)*
The EMS is to be capable to provide at least the following information on the bridge:

- energy available from batteries (SOC),
- power available from batteries,
- time or range for which the battery can provide energy according to actual operational conditions,
- alarm for minimum capacity reached,
- battery state of health (SOH).

4 Location

4.1 General

4.1.1 *(1/1/2022)*
Batteries are to be arranged aft of collision bulkhead and in such a way that danger to persons and damage to vessel due to failure of the batteries (e.g. caused by gassing, explosion, and fire) is minimized.

4.1.2 *(1/1/2019)*
Batteries are not to be located in a battery box on the open deck exposed to sun and frost.

They are to be located where they are not exposed to excessive heat, extreme cold, spray, steam, shocks or vibration or other conditions which would impair their safety, performance or accelerate deterioration.

4.1.3 *(1/1/2019)*
Batteries are to be located in such a way that the ambient temperature remains within the Manufacturer's specification at all times.

4.1.4 *(1/1/2022)*
Batteries are to be suitably housed by means of compartments (rooms, lockers or boxes) which are to be properly constructed and efficiently ventilated and cooled (as necessary) in such a way to keep the battery system at a specified set of environmental conditions.

4.1.5 *(1/1/2019)*
Battery system is to be arranged following the Manufacturer's prescriptions in particular to prevent cascade effects in case of a thermal runaway (e.g. partition plates or distance in accordance with Manufacturer's recommendations).

4.1.6 *(1/1/2022)*
Batteries, used as storage of power for the propulsion or dynamic positioning systems or as part of the main source of electrical power, are to be located in a battery space placed within the extreme borders of the main machinery space or adjacent to it.

4.1.7 *(1/1/2022)*
When the main source of electrical power is based on battery installations only, one of the two battery systems required in [2.1.2] is to be placed in a battery space located in the same machinery space of the main switchboard.

4.1.8 *(1/1/2019)*
Depending on the battery chemistry, it may be necessary to define a hazardous area for the installation of appropriate equipment (see Tab 1 No. 6).

4.2 Battery space

4.2.1 *(1/1/2019)*
When required, based on [4.1.6] or the Risk Assessment (see [2.1.6]), a space assigned to batteries only is to be foreseen.

4.2.2 *(1/1/2019)*
Access to this space is to be through self-closing doors. As an alternative normally closed doors with alarm may be considered.

4.2.3 *(1/1/2019)*
External hazards, such as fire and water ingress are to be taken into account in the Risk Assessment, in order to assess the risk associated with an external event (e.g. a fire spreading from adjacent rooms to the battery space, water flooding and so on) and possible countermeasures (e.g. suitable segregation of the battery space).

No heat sources or high fire risk equipment are to be located in battery spaces.

4.2.4 *(1/1/2022)*
A fire detection system and a fixed fire extinguishing system appropriate to the battery chemistry are to be provided in the battery space.

The type is to be chosen following the battery Manufacturer's instructions.

Examples of fire extinguishing systems may be a powder or a gas based or water-based fixed fire extinguishing system provided that the suitability of the extinguishing agent for the specific type of batteries is confirmed by the battery Manufacturer.

Automatic release is only acceptable for small, not accessible, battery spaces.

Where an automatic release of fire extinguishing media is accepted, its activation is to be confirmed by more than one sensor.

4.2.5 *(1/1/2022)*
The battery spaces are to be fitted with a forced ventilation system of extraction type, which is to be:

- independent from any other ventilation system serving other ship's spaces,
- provided with local manual stop, still available in case of failure of the automatic and or remote control system,
- provided with indication of ventilation running and of battery space ambient temperature,
- with a capacity (rate) according to battery manufacturer guidelines on the basis of the gas release identified in the gas analysis or propagation test,
- fitted with inlet from open air,
- fitted with exhaust outlet to open air far from accommodation and machinery ventilation inlets,

- fitted with non-sparking fans driven by a certified safe type electric motor in case the ventilation duct is considered to contain ex-plosive atmosphere in case of thermal runaway.

4.2.6 *(1/1/2019)*

Appropriate means to maintain the battery working temperature within the Manufacturer's declared limits are to be provided (e.g. by means of liquid cooled solutions or ventilation systems provided with control of air temperature).

4.2.7 *(1/1/2022)*

Battery modules with liquid cooling are to be designed such that the risk of a cooling liquid leakage inside the module is minimized.

The cooling system is to include at least two pumps for each primary and secondary circuits: one main and one standby. The standby pump can be omitted only if the consequences of main pump failure are addressed in the risk assessment [2.1.7].

4.2.8 *(1/1/2022)*

In case of liquid cooled solutions, a ventilation system is anyway required to extract possible gases or vapours in consequence of a battery abnormal condition.

4.2.9 *(1/1/2019)*

Depending on the battery chemistry, a gas detection system, for the gases that may be emitted from the battery system in the event of a serious fault, may be requested as an outcome of the risk assessment.

In this case,

- an alarm at 30% of LEL and automatic disconnection of batteries are to be provided,
- an alarm at 60% of LEL and automatic disconnection of all electrical equipment non certified of safety type for the specific hazardous area, gas, vapour are to be provided.

A failure in the gas detection system is to be alarmed but is not to cause above mentioned automatic disconnections.

4.2.10 *(1/1/2022)*

Depending on the battery chemistry, appropriate ventilation to prevent the formation of explosive atmospheres in the battery space (e.g. to limit the concentration of flammable gasses and thereby reduce the risk for fire) is to be provided.

At this purpose the highest rate of gas emissions is to be considered.

4.2.11 *(1/1/2019)*

Depending on the battery chemistry, when a hazardous area is to be considered, mechanical exhaust non-sparking fan driven by a certified safe type electric motor, and inlet from open air are to be arranged.

4.2.12 *(1/1/2019)*

Battery spaces on passenger ships carrying more than 36 passengers are to be treated as a cat.11 space (auxiliary machinery space with high fire risk).

4.2.13 *(1/1/2022)*

Battery spaces on passenger ships carrying not more than 36 passengers, and on cargo shipsare to be insulated in way of other spaces as indicated in Tab 2.

4.2.14 *(1/1/2019)*

Battery spaces are to be considered as spaces not normally manned.

4.2.15 *(1/1/2022)*

The battery space is not to contain other systems supporting essential or emergency services, including piping and electric cables serving such systems, in order to prevent their loss upon possible failures (e.g. thermal runaway) in the battery system.

Table 2 *(1/1/2019)*

Bulk-head	Control Station 1	Corrid or 2	Accom-moda-tion spaces 3	Stair-ways 4	Service spaces (low risk) 5	Machi nery Space of cat A 6	Machi nery Space 7	Cargo 8	Service spaces (high risk) 9	Open deck 10	Special categor y/ Roro spaces 11	Muster stations
Li Bat-tery Space	A60	A15	A30	A15	A0	A60	A0	A60	A30	A0	A60	A60
Li Bat-tery Space Below	A60	A60	A30	A60	A0	A60	A0	A60	A30	A0	A60	A60
Li Bat-tery Space Above	A0	A0	A0	A0	A0	A60	A0	A60	A0	A0	A60	A60

5 Testing

5.1 General

5.1.1 *(1/1/2022)*
Battery systems are to be tested by the Manufacturer.

5.1.2 *(1/1/2022)*
Batteries are to be subjected to functional and safety tests according to IEC Publication 62619 and 62620 or in accordance with other equivalent national or international standards.

5.1.3 *(1/1/2022)*
When the aggregate capacity of a battery system exceeds the rating of 20 kWh, the battery system is to be of a type approved in accordance with the Society "Rules for the type approval certification of lithium battery systems".

5.2 Testing and inspection at Manufacturer premises

5.2.1 *(1/1/2022)*
Battery systems are to be tested by the Manufacturer according to a test program proposed by the Manufacturer and approved by the Society and which is to include at least functional tests of battery system/BMS and control, monitoring and safety systems and further tests, if any, resulting from the Risk Assessment.

Table 3 *(1/1/2022)*

No.	Test/inspection
1	Examination of the technical documentation, as appropriate, and visual inspection
2	Functional test of the BMS, including safety functions and applicable alarms listed in [3.3.3]
3	Dielectrical strength (high voltage test) **(1)**
4	Insulation resistance test **(1)**
5	Sensor failure test (e.g. power supply failure, disconnection, short circuit, etc.)
6	Emergency shutdown (ESD) functional test
7	Communication failure between BMS and battery charger
8	Testing of the cooling system when submitted to acceptance testing together with the battery system
9	Check of test certificate for prescribed degree of protection
(1) Refer to Sec 8, [3.3] and Sec 8, [3.4]. In order to prevent damages to the electronic components of the battery system, the electronic components can be disconnected during the high voltage test.	

5.3 Testing and inspection after installation on board

5.3.1 *(1/1/2022)*

After installation, and after any important repair or alteration which may affect the safety of the arrangement, following a check of compliance with the plans, the battery system is to be subjected to tests and inspections, to the satisfaction of the Surveyor in charge.

5.3.2 *(1/1/2022)*

Performance tests are to be carried out on the battery system; the test program is to include functional tests as per Tab 4 and further tests, if any, resulting from the Risk Assessment.

5.4 Plans to be kept on board

5.4.1 *(1/1/2022)*

An operation manual is to be kept on board which includes at least:

- charging procedure,
- normal operation procedures, including instructions for the safe connection/disconnection of batteries,
- emergency operation procedures,
- estimated battery deterioration (ageing) rate curves, considering modes of operation.

5.4.2 *(1/1/2022)*

A maintenance manual for systematic maintenance and functional testing is to be kept on board which includes at least:

- tests on all the equipment affecting the battery system (e.g. instrumentation, sensors, etc.),
- recommended test intervals to reduce the probability of failure,
- recommended survey plan (annual and renewal surveys),
- functional tests of control, monitoring, safety and alarm system,
- verification of the State of Health (SOH),
- instructions for Software Maintenance.

Table 4 *(1/1/2022)*

No.	Test/verification
1	Insulation resistance test as per Sec 15, [3.3]
2	Test of the functionality of the battery system and BMS and its auxiliaries, including alarms, and safety functions, emergency stop, including simulation of changes in parameters and simulation of sensor failure and of communication failure (e.g. with battery charger)
3	Test of the functionality of the auxiliary services in the battery space (e.g. ventilation, liquid cooling, gas detection, fire detection, leakage detection)
4	Verification of proper calculation and indication of SOC and SOH (when required per [3.2.4]) **(1)**
5	Verification of correct regulation of charging and discharging currents
6	Verification of the functionality of the EMS (when required per [2.1.3])
7	Test of the independent disconnecting device as per [2.3.3]
(1) Tests for the verification of the battery SOH are to be carried out (e.g. complete charge/discharge cycle or other methods as per Manufacturer's indications).	

APPENDIX 3 FUEL CELL POWERED SHIPS

1 General

1.1 Scope

1.1.1 Application *(1/1/2023)*

The provisions of this Appendix apply to the arrangement, installation, control, monitoring and safety systems of ships using fuel cell power installations. These Rules are applicable to installations with several different configurations of fuel cell power installations. Since the fuel cell is a novel technology under continuous development, additional requirements to those specified in these Rules may be required by TASNEEF on a case-by-case basis depending on the design principles of the fuel cell in subject. Where the fuel cell power installations consist of the fuel cell power systems which are enclosed in modules, the TASNEEF "Rules for the Type Approval of Fuel Cell Power Modules" apply in conjunction with this Appendix.

1.1.2 Acceptance by the flag Administration *(1/1/2023)*

The use of fuel cells on ships requires acceptance by the Administration of the State whose flag the ship is entitled to fly.

1.1.3 MSC.1/Circ.1647 requirements and the Society's rules *(1/1/2023)*

For fuel cell powered ships, the requirements of the IMO Interim Guidelines for the Safety of Ships using Fuel Cell Power Installations set out in the annex of IMO circular MSC.1/Circ.1647 (hereinafter named "MSC.1/Circ.1647") are to be applied as class requirements as specified and with the deviations given in this Appendix.

For the scope of classification, when reference is made to paragraphs of MSC.1/Circ.1647 where the wording "Administration" is used, it is to be regarded as referring to the "Society".

In general, this Appendix applies to fuel cell power installations and to their interfaces with the other ship systems. Unless otherwise specified, the machinery, equipment and systems of fuel cell powered ships are also to comply with the requirements given in Part C.

The fuel cell power installations designed to use low-flashpoints fuels as primary fuel (e.g. LNG, LPG, NH3, methyl/ethyl alcohol, hydrogen) are additionally to comply with the following requirements, as applicable:

- Ch 1, App 7 (LNG or CNG Fuelled Ships)
- Ch 1, App 13 (LPG or NH3 Fuelled Ships)
- Ch 1, App 14 (Hydrogen Fuelled Ships)
- Ch 1, App 15 (Methyl/Ethyl Alcohol Fuelled Ships).

The electrical equipment needed for the conditioning of the electrical output from the fuel cell power installation such as e-filters, inverters, converters and transformers are to comply with Sec 5 and Sec 6. The reforming equipment as well auxiliary systems are to comply with Ch 1, Sec 3 and Ch 1, Sec 10.

1.1.4 MSC.1/Circ.1647 requirements not within the scope of classification *(1/1/2023)*

The following requirements of MSC.1/Circ.1647 are not within the scope of classification:

- Section 3 - Fire Safety

These requirements are applied by the Society when acting on behalf of the flag Administration, within the scope of delegation (see [1.1.6]).

1.1.5 Correspondence of the MSC.1/Circ.1647 with the Rules *(1/1/2023)*

All the requirements of this Appendix are cross referenced to the applicable paragraphs of MSC.1/Circ.1647, as appropriate.

1.1.6 Statutory certificates *(1/1/2023)*

The responsibility for interpretation of the MSC.1/Circ.1647 requirements for the purpose of issuing statutory certificates for fuel cell powered ships lies with the Administration of the State whose flag the ship is entitled to fly.

Whenever the Society is authorized by an Administration to issue on its behalf the statutory certificates for fuel cell powered ships, or where the Society is authorized to carry out investigations and surveys on behalf of an Administration

on the basis of which the statutory certificates for fuel cell powered ships will be issued by the Administration, or where the Society is requested to certify compliance with MSC.1/Circ.1647, the full compliance with the requirements of MSC.1/Circ.1647, including the fire safety requirements mentioned in [1.1.4], will be granted by the Society, subject to [1.1.2].

1.1.7 FUEL CELL POWERED SHIP additional class notation *(1/1/2023)*

The **FUEL CELL POWERED SHIP** additional class notation is assigned to ships where fuel cells are installed to supply essential or not-essential services, in compliance with the design and constructional requirements of this Appendix, as follows:

- **FUEL CELL POWERED SHIP (E)** when fuel cell is used to power at least one of the essential services defined in Sec 1, [3.2.1] and is necessary to ensure the compliance of the main source of electrical power to the requirements in Sec 3, [2.2.3]
- **FUEL CELL POWERED SHIP (NE)** when fuel cell is used to power only services not falling under the definition of essential services in Sec 1, [3.2.1].

1.2 Documentation to be submitted

1.2.1 *(1/1/2023)*

Tab 1 lists the plans, information, analysis, etc. which are to be submitted in addition to the information required in the other Parts of the Rules, for the portion of the ship not involved in fuel cell power installations.

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.

Table 1 : Documents to be submitted *(1/1/2023)*

No.	I/A **(1)**	Document
1	I	Technical specification of the fuel cell power installation, including technical data as power output parameters including min./max. design voltage and current, information about min/max temperature/pressure/rate of process air/cooling water/ventilation.
2	I	List of mechanical and electrical components which are part of the fuel cell power installation with specification of the pumps, compressors and fans.
3	A	P&I diagrams of systems conveying fuel (primary and reformed type), exhaust air/gas, cooling media, process air, technical water, ventilation, inerting and of other systems in the fuel cell power installation.
4	I	Description of thermal insulation and heat tracing, if any.
5	A	Construction details with strength analysis of fuel cell power installation frame and foundation, if any.
6	A	Construction drawings of all components of the reforming equipment considered as pressure vessel e.g. burner, reformer, heat exchangers.
7	I	Functional description of the fuel cell power installation including at least its design, safety principles, ventilation and gas detection concept, auxiliary systems arrangement (e.g. cooling medium, process air, ventilation, venting, process water, inert gas, as applicable).
8	A	Block diagram of the safety, control and monitoring system of the fuel cell power installation.
9	A	Wiring diagrams of power supply and automation system of the fuel cell power installation.
10	I	List of controlled and monitored parameters and cause and effect matrix with normal/emergency shutdown functions.
11	A	Hazardous zones categorization study with calculation according to IEC 60079-10 (using CFD simulations or empirical formula) and list of EX equipment with relevant EX certificates, as applicable.
12	A	Service profile description of the fuel cell power installations, highlighting if the fuel cell power generation is used for essential or non-essential ship services.
13	I	A FMEA according to the TASNEEF "Guide for Failure mode and Effect Analysis" or other equivalent methods for the fuel cell power installation.
14	I	Lifecycle operational, maintenance and inspection manual of the fuel cell power installation.
15	I	Testing reports or type approval reference of the fuel cell power installation components such as fuel cell stacks, reforming equipment according to applicable international recognized standards.

(1) A = to be submitted for approval
I = to be submitted for information

1.3 Definitions

MSC.1/Circ.1647 REFERENCE: para. 1.4

1.3.1 *(1/1/2023)*

The terms used in this Appendix have the meanings defined in MSC.1/Circ.1647, para. 1.4 and in the TASNEEF "Rules for the Type Approval of Fuel Cell Power Modules".

Terms not defined have the same meaning as in SOLAS chapter II-2 and the IGF Code.

1.3.2 *(1/1/2023)*

Certified safe type: means electrical equipment that is certified safe by the relevant recognized authorities for operation in a flammable atmosphere based on a recognized standard.

Note 1: Refer to IEC 60079 series, Explosive atmospheres and IEC 60092-502:1999 Electrical Installations in Ships - Tankers - Special Features.

1.3.3 *(1/1/2023)*

Fuel cell power module: is the fuel cell power system or parts of fuel cell power system and relevant enclosure.

1.3.4 *(1/1/2023)*

Fuel cell module: is the assembly incorporating one or more fuel cell stacks and auxiliary systems.

1.3.5 *(1/1/2023)*

Fuel supply module: is the enclosure containing the fuel reforming and fuel conditioning equipment.

1.3.6 *(1/1/2023)*

Service profile: is a description of the use of the fuel cell for the power supply to on-board systems considering the operational profile of the ship (navigation, maneuvering and port stay).

2 Goal and functional requirements

MSC.1/Circ.1647 REFERENCE: para. 1.2 and 1.3

2.1 Goal

2.1.1 *(1/1/2023)*

The goal of this Appendix is to provide for safe and reliable delivery of electrical and/or thermal energy through the use of fuel cell technology.

2.2 Functional requirements

2.2.1 *(1/1/2023)*

The safety, reliability and dependability of the systems is to be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery installations, regardless of the specific fuel cell type and fuel.

A FMEA consistent with the TASNEEF ·Guide for Failure Mode and Effect Analysis" is to be carried out for the whole fuel cell power installation to check the potential existence of failure modes that can jeopardize the ship's safety. The results of the FMEA are then to be used to establish a trial program.

2.2.2 *(1/1/2023)*

The probability and consequences of fuel-related hazards are to be limited to a minimum through arrangement and system design, such as ventilation, detection and safety actions. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions are to be initiated.

2.2.3 *(1/1/2023)*

The design philosophy is to ensure that risk reducing measures and safety actions for the fuel cell power installation do not lead to an unacceptable loss of power.

2.2.4 *(1/1/2023)*

Hazardous areas are to be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment.

2.2.5 *(1/1/2023)*

Equipment installed in hazardous areas are to be minimized to that required for operational purposes and are to be suitably and appropriately certified.

2.2.6 *(1/1/2023)*
Unintended accumulation of explosive, flammable or toxic gas concentrations are to be prevented.

2.2.7 *(1/1/2023)*
System components are to be protected against external damages.

2.2.8 *(1/1/2023)*
Sources of ignition in hazardous areas are to be minimized to reduce the probability of explosions.

2.2.9 *(1/1/2023)*
Piping systems and overpressure relief arrangements that are of suitable design, construction and installation for their intended application are to be provided.

2.2.10 *(1/1/2023)*
Machinery, systems and components are to be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.

2.2.11 *(1/1/2023)*
Fuel cell spaces are to be arranged and located such that a fire or explosion in either will not lead to an unacceptable loss of power or render equipment in other compartments inoperable.

2.2.12 *(1/1/2023)*
Suitable control, alarm, monitoring and shutdown systems are to be provided to ensure safe and reliable operation.

2.2.13 *(1/1/2023)*
Fixed leakage detection suitable for all spaces and areas concerned is to be arranged.

2.2.14 *(1/1/2023)*
Fire detection, protection and extinction measures appropriate to the hazards concerned are to be provided.

2.2.15 *(1/1/2023)*
Commissioning, trials and maintenance of fuel systems and gas utilization machinery are to satisfy the goal in terms of safety, availability and reliability.

2.2.16 *(1/1/2023)*
The technical documentation is to permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.

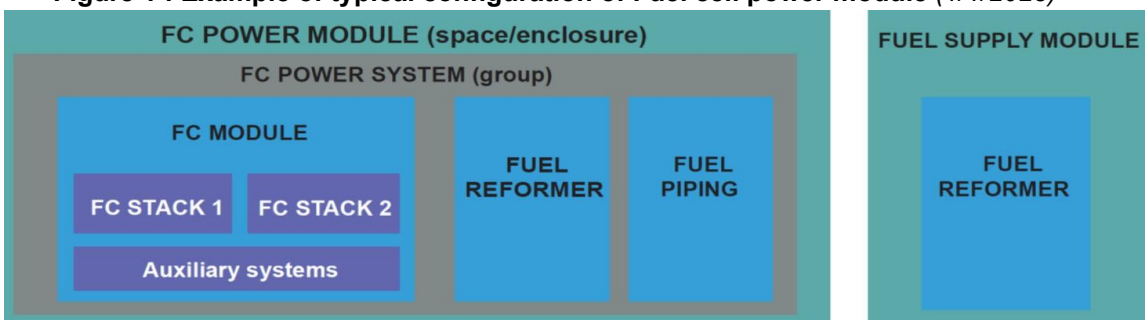
2.2.17 *(1/1/2023)*
A single failure in a technical system or component is not to lead to an unsafe or unreliable situation.
The fuel cell power installations that:

- are used to power at least one essential service as defined in Sec 1, [3.2.1] , and
- are necessary to ensure the compliance of the main source of electrical power to the requirements in Sec 3, [2.2.3]

are to be specifically considered in terms of reliability, availability and redundancy.

2.2.18 *(1/1/2023)*
Safe access is to be provided for operation, inspection and maintenance.

Figure 1 : Example of typical configuration of Fuel cell power module *(1/1/2023)*



3 Alternative design

MSC.1/Circ.1647 REFERENCE: para. 1.5

3.1 Deviation, equivalence and operational measures

3.1.1 *(1/1/2023)*

Appliances and arrangements of fuel cell power systems may deviate from those set out in this Appendix provided that they meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant paragraphs.

3.1.2 *(1/1/2023)*

The equivalence of the alternative design is to be demonstrated as specified in SOLAS regulation II-1/55, and approved by the Society. However, the Society will not allow operational methods or procedures as an alternative to a particular fitting, material, appliance, apparatus, item of equipment, or type thereof which is prescribed by this Appendix.

4 Design principles for fuel cell power installations

MSC.1/Circ.1647 REFERENCE: para. 2

4.1 Fuel cell spaces

4.1.1 *(1/1/2023)*

The requirements in MSC.1/Circ.1647 para. 2.1 apply.

4.2 Arrangement and access

4.2.1 *(1/1/2023)*

The requirements in MSC.1/Circ.1647 para. 2.2 apply.

4.3 Atmospheric control of fuel cell spaces

4.3.1 General *(1/1/2023)*

The requirements in MSC.1/Circ.1647 para. 2.3.1 apply.

4.3.2 **Ventilation of fuel cell spaces** *(1/1/2023)*

The requirements in MSC.1/Circ.1647 para. 2.3.2 apply.

When applying the requirements in MSC.1/Circ.1647 para. 2.3.2.3, reference is to be made to IEC 60079-10 standard.

4.3.3 **Inerting of fuel cell spaces for fire protection purposes** *(1/1/2023)*

The requirements in MSC.1/Circ.1647 para. 2.3.3 apply.

4.4 Materials

4.4.1 *(1/1/2023)*

The requirements in MSC.1/Circ.1647 para. 2.4 apply.

4.4.2 *(1/1/2023)*

The use of plastic materials for piping and pressure vessels is in general not allowed. Specific application may be evaluated on case-by-case basis.

4.5 Piping arrangement for fuel cell power system

4.5.1 *(1/1/2023)*

The requirements in MSC.1/Circ.1647 para. 2.5 apply.

4.5.2 *(1/1/2023)*

Where the fuel cell stacks are subject to specific air quality requirements (e.g., limits on dust, humidity, salinity, temperature), arrangements for air conditioning, air drying and air filtering are to be fitted and the air quality parameters are to be monitored.

4.5.3 *(1/1/2023)*
Where the primary fuel is subject to specific quality requirements (e.g., maximum Sulphur content) not to impair the performances of the fuel cell power system, arrangements for fuel conditioning system are to be fitted.

4.5.4 *(1/1/2023)*
If enclosed fuel supply modules and enclosed fuel cell modules are installed, they are to be fitted with sampling point connections for detecting explosive atmosphere by means of portable equipment.

4.5.5 *(1/1/2023)*
Where the pressure vessels and the piping in the fuel cell power module may be subject to overpressure, they are to be suitably protected by pressure relief arrangements. The discharge of possible hazardous gases is to be routed to open air.

4.6 Exhaust gas and exhaust air

4.6.1 *(1/1/2023)*
Exhaust gases and exhaust air from the fuel cell power systems should not be combined with any ventilation and should be led to a safe location in the open air.

4.6.2 *(1/1/2023)*
The arrangement of the process air treatment system is to be subject to the risk assessment as required in [6.3].

5 Fire safety

MSC.1/Circ.1647 REFERENCE: para. 3

5.1 Application

5.1.1 *(1/1/2023)*
This paragraph is void, as the provisions of MSC.1/Circ.1647 para. 3 are not within the scope of classification.

These provisions are applied by the Society when acting on behalf of the flag Administration, within the scope of delegation (see [1.1.6]).

6 Electrical systems

MSC.1/Circ.1647 REFERENCE: para. 4

6.1 General provisions on electrical systems

6.1.1 *(1/1/2023)*
The requirements in MSC.1/Circ.1647 para. 4.1 apply.

6.1.2 *(1/1/2023)*
For the casing of the fuel cell stack to be mounted in the fuel cell space, a minimum enclosure notation of IP54 is required to protect against:

a) ingress of dust in sufficient quantity to interfere with satisfactory operation of the fuel cell; and

b) water splashed against the fuel cell stack from any direction.

6.1.3 *(1/1/2023)*
The equipment and installations in hazardous areas are to comply with recognized international standards including but not limited to the following:

- IEC 60079-0 General requirements
- IEC 60079-1 Flameproof enclosure 'Ex d'
- IEC 60079-7 Increased safety 'Ex e'
- IEC 60079-11 Intrinsic safety 'Ex i'
- IEC 60079-14 Installations
- IEC 60079-17 Electrical Installations inspection and maintenance
- IEC 60079-18 Molded encapsulation 'Ex m'
- IEC 60079-25 Intrinsically safe systems
- IEC 60079-29 Gas detection

The equipment is to be properly EX certified considering the hazardous zone categorization defined by manufacturer according to IEC 60079-10 or according to [6.2].

6.1.4 *(1/1/2023)*
Earthing and bonding are to be arranged according to recognized international standards.

6.2 Area classification

6.2.1 General *(1/1/2023)*
The requirements in MSC.1/Circ.1647 para. 4.2.1 apply.

6.2.2 **Hazardous areas zone 0** *(1/1/2023)*
The requirements in MSC.1/Circ.1647 para. 4.2.2 apply.

6.2.3 **Hazardous areas zone 1** *(1/1/2023)*
The requirements in MSC.1/Circ.1647 para. 4.2.3 apply.

6.2.4 **Hazardous areas zone 2** *(1/1/2023)*
The requirements in MSC.1/Circ.1647 para. 4.2.4 apply.

6.2.5 **Ventilation ducts** *(1/1/2023)*
The requirements in MSC.1/Circ.1647 para. 4.2.5 apply.

6.3 Risk assessment

6.3.1 *(1/1/2023)*
The requirements in MSC.1/Circ.1647 para. 4.3 apply.

6.3.2 *(1/1/2023)*
Guidance on risk assessment techniques can be found in the TASNEEF "Guide for Risk Analysis".

6.3.3 *(1/1/2023)*
The assumptions for the risk assessment are to be agreed by a team of experts acceptable to the Society. It may include a representative of Class, Flag Administration, owner, builder or designer, and consultants having the necessary knowledge and experience in safety, design and/or operation as necessary for the specific evaluation at hand. Other members may include marine surveyors, ship operators, safety engineers, equipment manufacturers, human factors experts, naval architects and marine engineers, according to the problem under scope.

6.3.4 *(1/1/2023)*
The risk assessment can be qualitative or quantitative and is to cover the following aspects:

- Accidental release and dispersion (hydrogen leakages due to tank and piping rupture and permeability, hydrogen dilution in enclosed space, hydrogen effects on material e.g. embrittlement or permeation)
- Ignition (spontaneous ignition of hydrogen during sudden release, minimum energy for ignition)
- Deflagration and detonation (hydrogen explosion hazards)
- Fires (jet fire, radiative heat fluxes, fire resistance of hydrogen system)
- Impact on people, asset and environment (severity of hydrogen incidents)
- Mitigation techniques (detection method, barriers, ventilation level)
- Emergency operation (strategy control of incident)
- Oxygen enrichment due to cryogenic hydrogen temperature.

6.3.5 *(1/1/2023)*
The risk assessment is to follow the steps outlined below.

a) The team of experts is to conduct a Hazard Identification (HAZID) to agree on the scenarios to be subjected to the risk assessment, and on the assumptions regarding the most critical events (typically, connection failures causing an hydrogen or primary fuel release) considering also available internationally recognized standard (e.g. ISO/TR 15916) for the identification of hazards and risks.

b) Reasonable assumptions on the extent of connection failures or other selected events and the process parameters of the hydrogen and primary fuel are to be made by the team of experts, preferably on the basis of statistics available in the public domain or provided and documented by stakeholders.

c) Reasonable assumptions on the operation of ventilation system are to be made according to layout and procedures of the affected space.

d) In order to verify that the hydrogen and primary fuel release will not create flammable concentrations and to demonstrate the drip tray capacity for a liquid leakage, a specific simulation is to be set up, aimed at evaluating the maximum amount of hydrogen spilled and its cloud, the evaporation rate and the possibility to fully accommodate the liquid leakage in the drip tray. The dispersion of vapors resulting from hydrogen evaporation in the affected space is also to be ascertained in respect of explosive atmosphere.

e) The simulation is to be conducted by commercially available and validated tools (typically, by CFD tools). It is to focus on the calculation of the amount of hydrogen or primary fuel spilled before the stop of hydrogen and primary fuel flow. Other calculation methods (e.g. empirical formulas based on literature) will be subject to special consideration.

f) Reasonable assumptions are to be made by the expert team regarding detection time, hydrogen and primary fuel flow stop time and human reaction time, in case operators are credited in the emergency.

g) If the simulation demonstrates that the drip tray cannot accommodate the liquid spill, mitigating measures are to be provided and subjected to the same simulation process, to appreciate the risk reduction.

7 Control, monitoring and safety systems

MSC.1/Circ.1647 REFERENCE: para. 5

7.1 General provisions on control, monitoring and safety systems

7.1.1 *(1/1/2023)*

The requirements in MSC.1/Circ.1647 para. 5.1 apply.

7.1.2 *(1/1/2023)*

The fuel cell power installation is to be provided with a safety system with the following characteristics:

- "fail safe" design, so that any failure of the safety system cannot result in an unsafe status for the fuel cell module
- independent from control and alarm system
- compliant with the requirements in Ch 3, Sec 2, [7].

7.2 Gas or vapour detection

7.2.1 *(1/1/2023)*

The requirements in MSC.1/Circ.1647 para. 5.2 apply.

7.3 Ventilation performance

7.3.1 *(1/1/2023)*

The requirements in MSC.1/Circ.1647 para. 5.3 apply.

7.4 Bilge wells

7.4.1 *(1/1/2023)*

The requirements in MSC.1/Circ.1647 para. 5.4 apply.

7.5 Manual emergency shutdown

7.5.1 *(1/1/2023)*

The requirements in MSC.1/Circ.1647 para. 5.5 apply.

7.6 Actions of the alarm system and safety system

7.6.1 *(1/1/2023)*

The requirements in MSC.1/Circ.1647 para. 5.6 apply.

7.7 Alarms

7.7.1 *(1/1/2023)*
The requirements in MSC.1/Circ.1647 para. 5.7 apply.

7.8 Safety actions

7.8.1 *(1/1/2023)*
The requirements in MSC.1/Circ.1647 para. 5.8 apply.

8 Tests on board

8.1 Functioning Tests

8.1.1 *(1/1/2023)*
Where the fuel cell power installation provides power to the electric propulsion system, it is to be verified that the ship has adequate management system of propulsion power in all sailing conditions including maneuvering, according to Ch 1, Sec 16, [3.7].

8.1.2 *(1/1/2023)*
The fuel cell space ventilation system is to be tested prior to the commencement of the sea trials with the verification of the following items:

- air flow of all fans according to the required capacity as per hazardous zone categorization
- alarms and/or automatic shutdown in case of loss or reduction of required ventilation rate
- gas tightness of all flexible connections of fans to duct
- local and remote functioning test of dampers.

8.1.3 *(1/1/2023)*
The fuel cell space inerting system is to be tested prior the commencement of the sea trials with the verification of the following items:

- functioning of inert gas generator or inert gas storage means (e.g. bottles)
- purging of fuel cell space piping conveying hydrogen and primary fuel.

8.1.4 *(1/1/2023)*
The fuel cell space gas detection system is to be tested according to international recognized standard prior the commencement of the sea trials.

8.1.5 *(1/1/2023)*
The following fuel cell power system items are to be tested:

- all automatic safety shutdowns
- emergency safety shutdown (manual ESD) at maximum power load
- protective devices (e.g. safety and automatic shut-off valves)
- measurements systems (e.g. level indicators, temperature measurement devices, pressure gauges).

8.1.6 *(1/1/2023)*
The performance test for the fuel cell power system is to be carried out considering the service profile and is to demonstrate that the fuel cell generated power will meet the performance requirements to be previously agreed with TASNEEF. During all testing the ambient conditions (air temperature, air pressure and humidity) are to be recorded. Moreover, as a minimum, the following fuel cell power module data are to be measured, recorded and compared with the targeted values:

- Nominal Load Point [A]
- Total Voltage [V]
- Total Current [A]
- Total Power [kW]
- Primary Fuel Consumption [kg/h]
- Fuel Inlet Pressure [bar]
- Fuel Inlet Temperature [C°]
- Cooling Water Inlet Temperature [C°]

- Cooling Water Outlet Temperature [C°]
- Ventilation air flow
- Process air flow

The typical polarization curve (cell voltage vs current) of the fuel cell power system, as created during factory acceptance test, is to be made available on board for prompt reference.

8.1.7 *(1/1/2023)*

The performance tests are to be carried out considering the following conditions:

- start up, ramp up, rump down and automatic shutdown of the fuel cell power system
- load variations and load shedding as per service profile
- interactions with other sources of power, including change-over with the emergency power source.

8.2 Hot spot verification

8.2.1 *(1/1/2023)*

Thermal imaging scanning of equipment where hot surfaces may be expected is to be carried out within the fuel cell power installation under steady and normal operating conditions, according to Ch 1, Sec 2, [6.10.9]. The requirements in Ch 1, Sec 1, [3.7.1] apply.

9 Material Test, Workshop inspections and testing

9.1 General principles

9.1.1 *(1/1/2023)*

The provisions in this section are to be used in conjunction with the applicable requirements on materials and testing in other parts of these Rules and TASNEEF "Rules for Testing and Certification of Marine Materials and Equipment".

9.1.2 *(1/1/2023)*

Inspection and testing of fuel piping systems are to comply with Ch 1, Sec 10, [21].

9.1.3 *(1/1/2023)*

All pressure vessels and piping conveying the primary fuel and the reformed fuel belong to Class I piping systems according to Ch 1, Sec 3 and Ch 1, Sec 10.

Outer pipes of double wall fuel piping arrangements are to be considered to belong to Class II piping systems.

9.1.4 *(1/1/2023)*

The venting and ventilation lines conveying the exhaust air from fuel cell stack cathode side and the exhaust gas from reforming equipment or from fuel cell stack anode side are to be connected with butt welded joints as far as practicable. Alternatively, the use of type approved mechanical joints or other type of connections may be evaluated on case-by-case basis. These lines, if categorized as hazardous, are to be considered to belong to Class I piping systems.

9.2 Type approval

9.2.1 *(1/1/2023)*

Fuel cell modules are to be provided with type approval certificate according to TASNEEF "Rules for the Type Approval of Fuel Cell Power modules".

9.2.2 *(1/1/2023)*

The piping components such as flexible hoses, mechanical joints and plastic pipes are to be provided with type approval certificates according to Ch 1, Sec 10.

9.2.3 *(1/1/2023)*

The electronic and electrical components (e.g. sensors, cables, panels) are to be provided with type approval certificates according to Sec 15, [2].

9.3 Production testing

9.3.1 *(1/1/2023)*
The fuel cell power system is subject to functioning test at workshop under TASNEEF surveyor´s attendance on the basis of previously agreed test program taking into consideration the service profile and the availability of the type approval certificates for the fuel cell modules.

9.3.2 *(1/1/2023)*
Pressure vessels belonging to the fuel cell power system are subject to testing according to Ch 1, Sec 3, [7].

9.3.3 *(1/1/2023)*
The electrical installations for the fuel cell power conditioning are subject to testing according to Sec 15.

9.3.4 *(1/1/2023)*
The automation system components are subject to testing according to Ch 3, Sec 8.

Chapter 3
AUTOMATION

SECTION 1 GENERAL REQUIREMENTS

1 General

1.1 Field of application

1.1.1 The following requirements apply to automation systems, installed on all ships, intended for essential services as defined in Ch 2, Sec 1. They also apply to systems required in Chapter 1 and Chapter 2, installed on all ships.

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.

1.1.3 Requirements for unattended machinery spaces and for additional notations are specified in Part F.

1.1.4 *(1/7/2024)*
Requirements for Computer-based systems and Cyber resilience of ships are specified in Sec 3, Sec 4 and Sec 5.

1.2 Regulations and standards

1.2.1 The regulations and standards applicable are those defined in Ch 2, Sec 1.

1.3 Definitions

1.3.1 Unless otherwise stated, the terms used in this chapter have the definitions laid down in Ch 2, Sec 1 or in the IEC standards. The following definitions also apply:

- Alarm indicator is an 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 is a system intended to give a signal in the event of abnormal running condition.
- Application software is a software performing tasks specific to the actual configuration of the programmable electronic system and supported by the basic software.
- Automatic control is the control of an operation without direct or indirect human intervention, in response to the occurrence of predetermined conditions.
- Automation systems are systems including control systems and monitoring systems.
- Basic software is the minimum software, which includes firmware and middleware, required to support the application software.
- Cold standby system is a 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.
- Programmable electronic system is a system of one or more computers, associated software, peripherals and interfaces, and the computer network with its protocol.
- Control station is a group of control and monitoring devices by means of which an operator can control and verify the performance of equipment.
- Control system is a system by which an intentional action is exerted on an apparatus to attain given purposes.
- Expert system is an 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 is a design property of an item in which the specified failure mode is predominantly in a safe direction with regard to the safety of the ship, as a primary concern.
- Full redundant is 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 is 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 change-over switch.
- Instrumentation is a sensor or monitoring element.

- Integrated system is a 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 is control of an operation at a point on or adjacent to the controlled switching device.
- Manual control is control of an operation acting on final control devices either directly or indirectly with the aid of electrical, hydraulic or mechanical power.
- Monitoring system is a system designed to observe the correct operation of the equipment by detecting incorrect functioning (measure of variables compared with specified value).
- Safety system is a system intended to limit the consequence of failure and is activated automatically when an abnormal condition appears.
- Software is the program, procedures and associated documentation pertaining to the operation of the computer system.
- Redundancy is the existence of more than one means for performing a required function.
- Remote control is the control from a distance of apparatus by means of an electrical or other link.

1.4 General

1.4.1 The automation systems and components, as indicated in Ch 2, Sec 15, [2], are to be chosen from 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.

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 *Main and auxiliary machinery essential for the propulsion, control and safety of the ship shall be provided with effective means for its operation and control.*

1.4.3 Control, alarm and safety systems are to be based on the fail-to-safety principle.

1.4.4 Failure of automation systems is to generate an alarm.

1.4.5 Detailed indication, alarm and safety requirements regarding automation systems for individual machinery and installations are to be found in Chapter 1.

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.

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	A	The general specification for the automation of the ship
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 : Documentation to be submitted for programmable electronic systems *(1/1/2008)*

No.	I/A **(1)**	Documentation **(2)**
1	A	System block diagram, showing the arrangement of individual parts, input and output devices and interconnections
2	A	Wiring connection diagrams, including details of electrical power supplies, and of input and output devices
3	A	System functional description
4	I	Software system description and documentation
5	I	User interface description
6	I	Test programs
(1) A = to be submitted for approval; I = to be submitted for information. **(2)** See as guidance IEC 60092-504 clause 10.11		

2.3 Documents for programmable electronic system

2.3.1 General

For programmable electronic 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 (Mean Time Between Failure)
- 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 programmable electronic 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 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 2, 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 2, Sec 2.

3.2.2 Pneumatic power supply

For pneumatic equipment, the operational characteristics are to be maintained under permanent supply pressure variations of ± 20% of the rated pressure.

Detailed requirements are given in Ch 1, Sec 10.

3.2.3 Hydraulic power supply

For hydraulic equipment, the operational characteristics are to be maintained under permanent supply pressure variations of ± 20% of the rated pressure.

Detailed requirements are given in Ch 1, Sec 10.

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 2, Sec 15.

SECTION 2 DESIGN REQUIREMENTS

1 General

1.1 General requirements

1.1.1 *All control systems essential for the propulsion, control and safety of the ship shall be independent or designed such that failure of one system does not degrade the performance of another system.*

1.1.2 Controlled systems are to have manual operation.

Failure of any part of such systems shall not prevent the use of the manual override.

1.1.3 Automation systems are to have constant performance.

1.1.4 Safety functions are to be independent of control and monitoring functions. As far as practicable, control and monitoring functions are also to be independent.

1.1.5 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.

1.1.6 When a programmable electronic system is used for control, alarm or safety systems, it is to comply with the requirements of Sec 3.

2 Power supply of automation systems

2.1 General

2.1.1 *(1/7/2020)*

Automation systems are to be powered from two sources of power by means of two independent feeders. Failure of each of these power supplies is to generate an alarm.

Batteries or pneumatic or hydraulic accumulators, installed to allow the system to be continuously powered, are not considered as a duplication of the power supply.

Note 1: batteries constituting the emergency source of electrical power may be considered as one of the two required sources.

2.1.2 *(1/7/2020)*

Power supply circuits are to be such that no direct connections to any point of the ship's main power supply system are provided (e.g. by means of isolating transformers).

2.1.3 *(1/7/2020)*

Each automation system is to be have separate power supplies with short circuit and overload protection.

Safety systems are to have power supplies as far as possible separate from control and alarm system, or an equivalent safety level is to be ensured.

2.1.4 *(1/7/2020)*

In addition to what above, the automation systems are to be continuously powered by means of batteries or pneumatic or hydraulic accumulators.

2.1.5 *(1/7/2020)*

The capacity of the batteries, or pneumatic or hydraulic accumulators is to be sufficient to allow the normal operation of the alarm and safety system for at least half an hour.

3 Control systems

3.1 General

3.1.1 In the case of failure, the control systems used for essential services are to remain in their last position they had before the failure.

3.2 Local control

3.2.1 Each system is to be able to be operated manually from a position located so as to enable visual control of operation. For detailed instrumentation for each system, refer to Chapter 1and Chapter 2.

It shall also be possible to control the auxiliary machinery, essential for the propulsion and safety of the ship, at or near the machinery concerned.

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 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.*

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 [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 Supply failure (voltage, fluid pressure, etc.) in propulsion plant remote control is to activate an alarm at the control position. In the event of remote control system failure and unless the Society considers it impracticable, the preset speed and direction of thrust are to be maintained until local control is in operation. This applies in particular in the case of loss of electric, pneumatic or hydraulic supply to the system.

4.1.4 *Propulsion machinery orders from the navigation bridge shall be indicated in the main machinery control room, and at the manoeuvring platform.*

4.1.5 *The control shall be performed by a single control device for each independent propeller, with automatic performance of all associated services, including, where necessary, means of preventing overload of the propulsion machinery. Where multiple propellers are designed to operate simultaneously, they must be controlled by one control device.*

4.1.6 *Indicators shall be fitted on the navigation bridge,* in *the main machinery control room and at the manoeuvring platform, for:*

propeller speed and direction of rotation in the case of fixed pitch propellers; and

propeller speed and pitch position in the case of controllable pitch propellers.

4.1.7 *The main propulsion machinery shall be provided with an emergency stopping device on the navigation bridge which shall be independent of the navigation bridge control system.*

In the event that there is no reaction to an order to stop, provision is to be made for an alternative emergency stop. 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 navigating bridge

4.2.1 Where propulsion machinery is controlled from the navigating bridge, the remote control is to include an automatic device such that the number of operations to be carried out is reduced and their nature is simplified and such that control is possible in both the ahead and astern directions. Where necessary, means for preventing overload and running in critical speed ranges of the propulsion machinery is to be provided.

Note 1: Arrangements which are not in compliance with the provisions of this Article may be considered for the following ships:

- ships of less than 24 m in length
- cargo ships of less than 500 tons gross tonnage
- ships to be assigned restricted navigation notations
- non-propelled units.

4.2.2 On board ships fitted with remote control, direct control of the propulsion machinery is to be provided locally. The local direct control is to be independent from the remote control circuits, and takes over any remote control when in use.

4.2.3 Each local control position, including partial control (e.g. local control of controllable pitch propellers or clutches) is to be provided with means of communication with each remote control position. The local control positions are to be independent from remote control of propulsion machinery and continue to operate in the event of a blackout (see Note 1 in [4.2.1]).

4.2.4 *Remote control of the propulsion machinery shall be possible only from one location at a time; at such locations interconnected control positions are permitted.*

4.2.5 *The transfer of control between the navigating bridge and machinery spaces shall be possible only in the main machinery space or the main machinery control room. The system shall include means to prevent the propelling thrust from altering significantly, when transferring control from one location to another* (see Note 1 in [4.2.1]).

4.2.6 At the navigating bridge, the control of the routine manoeuvres for one line of shafting is to be performed by a single control device: a lever, a handwheel or a push-button board. However each mechanism contributing directly to the propulsion, such as the engine, clutch, automatic brake or controllable pitch propeller, is to be able to be individually controlled, either locally or at a central monitoring and control position in the engine room (see Note 1 in [4.2.1]).

4.2.7 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.

4.2.8 As a general rule, the navigating bridge panels are not to be overloaded by alarms and indications which are not required.

4.3 Automatic control

4.3.1 The requirements in [3] are applicable. In addition, the following requirements are to be considered, if relevant.

4.3.2 *Main turbine propulsion machinery and, where applicable, main internal combustion propulsion machinery and auxiliary machinery shall be provided with automatic shutoff arrangements in the case of failures such as lubricating oil supply failure which could lead rapidly to complete breakdown, serious damage or explosion.*

4.3.3 The automatic control system is to be designed on a fail safe basis, and, in the event of failure, the system is to be adjusted automatically to a predetermined safe state.

4.3.4 When the remote control system of the propulsion machinery includes automatic starting, the number of automatic consecutive attempts is to be limited at a preset value of the starting air pressure permitting 3 attempts, and an alarm is to be provided, on the navigation bridge and in the machinery space.

4.3.5 Operations following any setting of the bridge control device (including reversing from the maximum ahead service speed in case of emergency) are to take place in an automatic sequence and with acceptable time intervals, as prescribed by the manufacturer.

4.3.6 *(1/1/2025)*
For steam turbines, a slow turning device is to be provided which operates automatically if the turbine is stopped longer than admissible. Discontinuation of this automatic turning from the bridge is to be possible.

Note 1: For attended machinery spaces, the slow turning device may be arranged to be operated manually.

4.4 Automatic control of propulsion and manoeuvring units

4.4.1 When the power source actuating the automatic control of propelling units fails, an alarm is to be triggered. In such case, the preset direction of thrust is to be maintained long enough to allow the intervention of engineers. Failing this, minimum arrangements, such as stopping of the shaft line, are to be provided to prevent any unexpected reverse of the thrust. Such stopping may be automatic or ordered by the operator, following an appropriate indication.

4.5 Clutches

4.5.1 Where the clutch of a propulsion engine is operated electrically, pneumatically or hydraulically, an alarm is to be given at the control station in the event of loss of energy; as far as practicable, this alarm is to be triggered while it is still possible to operate the equipment (see Note 1 in [4.2.1]).

4.5.2 When only one clutch is installed, its control is to be fail-set. Other arrangements may be considered in relation to the configuration of the propulsion machinery.

4.6 Brakes

4.6.1 Automatic or remote controlled braking is to be possible only if:

- propulsion power has been shut off
- the turning gear is disconnected
- the shaftline speed (r.p.m.) is below the threshold stated by the builder (see Note 1 in [4.2.1]).

5 Remote control of valves

5.1 General requirements

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 In case of failure of manually operated or automatic remote control systems, the local control of valves is to be possible.

5.1.5 Equipment located in places which may be flooded is to be capable of operation even if submerged.

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.

6.2 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).

6.2.5 Engineers' alarm

An engineers' alarm shall be provided to be operated from the engine control room or at the manoeuvring platform as appropriate, and shall be clearly audible in the engineers' accommodation.

6.2.6 Transfer of responsibility

Where several alarm control stations located in different spaces are provided, responsibility for alarms is not to be transferred before being acknowledged by the receiving location. Transfer of responsibility is to give an audible warning. At each control station it is to be indicated which location is in charge.

6.2.7 Alarm systems with limited number of monitored positions

For alarms with a limited number of monitored positions, relaxation to the requirements of [6.2] may be granted at judgement of the Society

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. It is to be constructed on the fail-to-safety principle.

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 Function

7.2.1 Safety activation

The safety system is to be activated automatically in the event of identified conditions which could lead to damage of associated machinery or systems, such that:

- normal operating conditions are restored (e.g. by the starting of the standby unit), or
- the operation of the machinery is temporarily adjusted to the prevailing abnormal conditions (e.g. by reducing the output of the associated machinery), or
- the machinery is protected, as far as possible, from critical conditions by shutting off the fuel or power supply, thereby stopping the machinery (shutdown), or appropriate shutdown.

7.2.2 Safety indication

When the safety system has been activated, it is to be possible to trace the cause of the safety action. This is to be accomplished by means of a central or local indication.

When a safety system is made inoperative by a manual override, this is to be clearly indicated at corresponding control stations.

Automatic safety actions are to activate an alarm at predefined control stations.

7.3 Shutdown

7.3.1 For shutdown systems of machinery, the following requirements are to be applied:

- when the system has stopped a machine, the latter is not to be restarted automatically before a manual reset of the safety system has been carried out
- the shutdown of the propulsion system is to be limited to those cases which could lead to serious damage, complete breakdown or explosion.

7.4 Standby systems

7.4.1 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)
- automatic starting is to be prevented when conditions are present which could endanger the standby machine.

7.5 Testing

7.5.1 The safety systems are to be tested in accordance with the requirements in Sec 8.

SECTION 3 COMPUTER BASED SYSTEMS

1 Scope

1.1 General

1.1.1 *(1/7/2024)*

These requirements apply to design, construction, commissioning and maintenance of computer based systems where they depend on software for the proper achievement of their functions.

1.1.2 *(1/7/2024)*

These requirements apply to systems which provide control, alarm, monitoring, safety or internal vessel communication functions that are subject to classification requirements.

1.1.3 *(1/7/2024)*

Computer-based systems that are covered by statutory regulations are excluded from the requirements of this Section.

Guidance:

Examples of such systems are navigation systems and radio communication system required by SOLAS chapter V and IV, and vessel loading instrument/stability computer.

For loading instrument/stability computer, IACS recommendation no. 48 may be considered.

1.2 Reference to other regulations and standards

1.2.1 *(1/7/2024)*

For the purposes of this Section, the applicable requirements in Sec 4, Sec 5 and Sec 8 are to be complied with.

1.2.2 Informative standards *(1/7/2024)*

For the purposes of this Section, the following standards are listed for information and may be used for the development of hardware/software of computer based systems:

- IEC 61508:2010 "Functional safety of electrical/electronic/programmable electronic safety related Systems"
- ISO/IEC 12207:2017 "Systems and software engineering - Software life cycle processes"
- ISO 9001:2015 "Quality Management Systems - Requirements"
- ISO/IEC 90003:2018 "Software engineering - Guidelines for the application of ISO 9001:2015 to computer software"
- IEC 60092-504:2016 "Electrical installations in ships - Part 504: Special features - Control and instrumentation"
- ISO/IEC 25000:2014 "Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Guide to SQuaRE"
- ISO/IEC 25041:2012 "Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Evaluation guide for developers, acquirers and independent evaluators"
- IEC 61511:2016 "Functional safety - Safety instrumented systems for the process industry sector"
- ISO/IEC 15288:2015 "Systems and software engineering - system life cycle process"
- ISO ~~9~~10007:2017 Quality management – Guidelines for configuration management
- ISO 24060:2021 Ships and marine technology - Ship software logging system for operational technology.

Other industry standards may also be considered.

1.3 Structure

1.3.1 *(1/7/2024)*

The general certification requirements for computer-based systems and the relation to type approval is described in [2]. The requirements and extent of verification of a computer-based system depends on its categorization into one of three categories. The categories are described in [3].

The requirements of this Section cover the lifecycle of computer-based system from design through operations. The requirements are split into groups representing the different phases of the life cycle and the roles responsible for fulfilling the requirements.

The activities related to the development and delivery of a computer-based system is described in [4], while the activities related to the maintenance in the operational phase are described in [5].

Management of changes to software and systems is given special attention in this Section, and the main aspects of a management of change process are described in [6].

Most requirements in this Section are related to the way of working, and thus focus on activities to be performed, but it also contains some technical requirements. The technical requirements on computer-based systems have been gathered in [8].

Each activity contains a requirement part which describes the minimum requirements on the role in question, and a part which describes the Society's verification of the activity in question.

1.4 Abbreviations

1.4.1 *(1/7/2024)*

For the purpose of this Section the abbreviations in Tab 1 apply.

Table 1 : Abbreviations *(1/7/2024)*

Abbreviation	Expansion
Cat I	Category one systems as defined in
Cat II	Category two systems as defined in [3.1]
Cat III	Category three systems as defined in [3.1]
COTS	Commercial off-the-shelf
FAT	Factory acceptance test
FMEA	Failure mode and effect analysis
IT	Information technology
OT	Operational technology
PMS	Planned maintenance system
SAT	System acceptance test
SOST	System of systems test
SSLS	Ship software logging system

1.5 Definitions

1.5.1 Black-box description *(1/7/2024)*

A description of a system's functionality and behaviour and performance as observed from outside the system in question.

1.5.2 Black-box test methods *(1/7/2024)*

Verification of the functionality, performance, and robustness of a system, sub-system or component by only manipulating the inputs and observing the outputs. This does not require any knowledge of the system's inner workings and focuses only on the observable behaviour of the system/component under test in order to achieve the desired level of verification.

1.5.3 Computer-based system (CBS) *(1/7/2024)*

A programmable electronic device, or interoperable set of programmable electronic devices, organized to achieve one or more specified purposes such as collection, processing, maintenance, use, sharing, dissemination, or disposition of information. CBSs onboard include IT and OT systems. A CBS may be a combination of subsystems connected via network. Onboard CBSs may be connected directly or via public means of communications (e.g. Internet) to ashore CBSs, other vessels' CBSs and/or other facilities.

1.5.4 **Failure mode description** *(1/7/2024)*

A document describing the effects due to failures in the system, not failures in the equipment supported by the system. The following aspects shall be covered:

- list of failures which are subject to assessment, with
- description of the system response to each of the above failures
- comments to the consequence of each of these failures.

1.5.5 Owner *(1/7/2024)*

The organization or person which orders the vessel in the construction phase or the organization which owns or manages the vessel in service. In the context of this Section this is a defined role with specific responsibilities.

1.5.6 **Parameterization** *(1/7/2024)*

To configure and tune system and software functionality by changing parameters. It does not usually require-computer programming and is normally done by the system supplier or a service provider, not the operator or end-user.

1.5.7 **Programmable device** *(1/7/2024)*

Physical component where software is installed.

1.5.8 **Robustness** *(1/7/2024)*

The ability to respond to abnormal inputs and conditions.

1.5.9 **Systems integrator** *(1/7/2024)*

Single organization or a person coordinating interaction between suppliers of systems and sub-systems on all stages of life cycle of computer-based systems in order to integrate them into a verified vessel-wide system of systems and to provide proper operation and maintenance of the computer-based systems. In the context of this Section this is a defined role with specific responsibilities. During the design and delivery phase the Shipyard is the default Systems integrator, during operations phase the Owner is the default.

1.5.10 **Service supplier** *(1/7/2024)*

A person or company, not employed by an IACS Member, who at the request of an equipment manufacturer, shipyard, vessel's owner or other client acts in connection with inspection work and provides services for a ship or a mobile offshore unit such as measurements, tests or maintenance of safety systems and equipment, the results of which are used by surveyors in making decisions affecting classification or statutory certification and services.

1.5.11 Supplier *(1/7/2024)*

A generic term used for any organisation or person that is a contracted or a subcontracted provider of services, system components, or software.

1.5.12 System *(1/7/2024)*

A combination of components, equipment and logic which has a defined purpose, functionality, and performance. In the context of this Section, a specific system is delivered by one system supplier.

1.5.13 **System of systems** *(1/7/2024)*

A system which is made up of several systems.

In the context of this Section, the system of systems encompasses all monitoring, control and safety systems delivered from the Shipyard as a part of a vessel.

1.5.14 **System supplier** *(1/7/2024)*

An organisation or person that is contracted or a subcontracted provider of system components or software under the coordination of the Systems integrator. In the context of this Section this is a defined role with specific responsibilities.

1.5.15 Sub-system *(1/7/2017)*

Identifiable part of a system, which may perform a specific function or set of functions.

1.5.16 **Programmable device** *(1/7/2017)*

Physical component where software is installed.

1.5.17 **Software component** *(1/7/2024)*

A standalone piece of code that provides specific and closely coupled functionality.

1.5.18 Software master files *(1/7/2024)*

The computer-files that constitutes the original source of the software. For custom made software this may be readable source-code files, and for COTS software it may be different forms of binary files.

1.5.19 Software-structure *(1/7/2024)*

Overview of how the different software components interact and is commonly referred to as the Software Architecture, or Software Hierarchy.

1.5.20 Simulation tests *(1/7/2024)*

Monitoring, control, or safety system testing where the equipment under control is partly or fully replaced with simulation tools, or where parts of the communication network and lines are replaced with simulation tools.

1.5.21 Society Certificate *(1/7/2024)*

Compliance document issued by a Class Society stating:

- conformity with applicable rules and requirements
- that the tests and inspections have been carried out on
- the finished certified component itself; or
- on samples taken from earlier stages in the production of the component, when applicable.
- that the inspection and tests were performed in the presence of the Surveyor or in accordance with special agreements, i.e. Alternative Certification Scheme (ACS).

1.5.22 Type approval Certificate *(1/7/2024)*

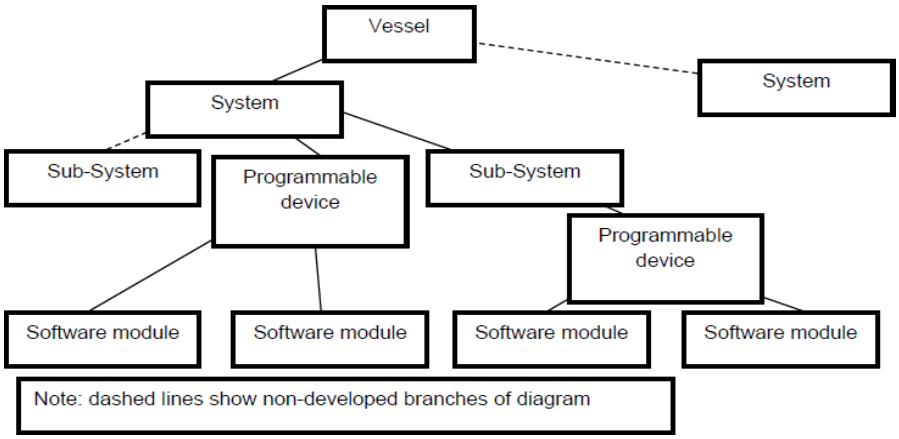
Compliance document issued by the Society by which the Society declares that a product design meets a minimum set of technical requirements.

1.5.23 Vessel *(1/1/2026)*

Ship or offshore unit where the computer-based system is to be installed.

The following diagram (Fig 1) shows the hierarchy and relationships of a typical computer-based system.

Figure 1 : Illustrative System Hierarchy *(1/7/2017)*



2 Approval of system and components

2.1 Type approval and system certification

2.1.1 System certification *(1/7/2024)*

Computer-based systems that are necessary to accomplish vessel-functions of category II or category III (as defined in [3.1.1]) are to be delivered with a vessel-specific Society certificate. The objective of the vessel-specific system certification is to confirm that design and manufacturing of the system has been completed and that the system complies with applicable rules of the Society.

Vessel-specific system certification consist of two main verification activities:

a) Assessment of vessel-specific documentation (see [4.2] and [6])

b) Survey and testing of the system to be delivered to the vessel (see [4.2.7])

The Society may accept Alternative Certification Scheme (ACS) provided that the requirements are met, and that the system is provided with a vessel-specific certificate.

2.1.2 Type approval of computer-based systems *(1/7/2024)*

Computer-based systems that are routinely manufactured and include standardized software functions may be type approved in accordance with specified rules of the Society. Hardware is to be documented according to the requirement in [4.2.4].

The type approval consist of two main verification activities:

a) Assessment of type-specific documentation

b) Survey and testing of the standardized functions.

Type approval will normally not yield exemption from vessel-specific system certification since vessel-specific functions, parameter configurations and installation elements demand vessel-specific verification.

3 System categories

3.1 System category definitions

3.1.1 *(1/7/2024)*

The categorization of a system in the context of this Section is based on the potential severity of the consequences if the system serving the function fails. Tab 2 provides the definitions of the categories.

3.2 Class Societies' scope

3.2.1 *(1/7/2024)*

Category I systems are normally not subject to verification by the Society, as failure of these systems is not to lead to dangerous situations. However, information pertinent to category I systems is to be required upon request to determine the correct category or ensure that they do not influence the operation of systems in category II and category III.

3.3 System category examples

3.3.1 *(1/7/2024)*

The category of a system is always to be evaluated in the context of the specific vessel in question; thus, the categorization of a system may vary from one vessel to the next. This means that the examples of categories below are given as guidance only. For determining the categorization of systems for a specific vessel, see [4.3.3].

Examples of category I systems:

Fuel monitoring system, maintenance support system, diagnostics and troubleshooting system, closed circuit television, cabin security, entertainment system, fish detection system.

Examples of category II systems:

Fuel oil treatment system, alarm monitoring and safety systems for propulsion and auxiliary machinery, Inert gas system, control, monitoring and safety system for cargo containment system.

Examples of category III systems:

Propulsion control system, steering gear control system, electric power system (including power management system), dynamic positioning system (IMO classes 2 and 3).

Note 1: The list of example systems in [3.3.1] is not exhaustive.

4 Requirements on development and certification of computer-based system

4.1 General requirements

4.1.1 Life cycle approach with appropriate standards *(1/7/2024)*

Requirement:

A global top-down approach is to be undertaken in the design and development of both hardware and software and the integration in sub-systems, systems, and system of systems, spanning the complete system lifecycle. This approach is to be based on the standards as listed herein or other standards recognized by the Society.

Society's verification:

This is verified by the Society as a part of the quality management system verification described in [4.1.2].

4.1.2 Quality management system *(1/7/2024)*

Systems integrators and system suppliers are, in the development of computer-based systems for category II and category III, to comply to a recognised quality standard such as ISO 9001; also incorporating principles of IEC/ISO 90003.

The quality management system is as a minimum to include the topics in Tab 3, applicable for both category II and category III systems.

Table 2 : System categories *(1/7/2024)*

Category	Failure Effects	Typical System functionality
I	Those systems, failure of which will not lead to dangerous situations for human safety, safety of the vessel and/or a threat to the environment.	Monitoring, informational and administrative functions
II	Those systems, failure of which could eventually lead to dangerous situations for human safety, safety of the vessel and/or a threat to the environment.	Vessel alarm, monitoring and control functions which are necessary to maintain the vessel in its normal operational and habitable conditions
III	Those systems, failure of which could immediately lead to dangerous or catastrophic situations for human safety, safety of the vessel and/or a threat to the environment.	• Control functions for maintaining the vessel's propulsion and steering • Vessel safety functions

Table 3 : Quality management system *(1/7/2024)*

Area		Role	
N	Topic	System supplier	Systems integrator
1	Responsibilities and competency of the staff	x	x
2	The complete lifecycle of delivered software and of associated hardware	x	x
3	Specific procedure for unique identification of a computer-based system, it's components and versions	x	
4	Creation and update of the vessel's system architecture		x
5	Organization set in place for acquisition of software and related hardware from suppliers	x	x
6	Organization set in place for software code writing and verification	x	
7	Organization set in place for system validation before integration in the vessel	x	
8	Specific procedure for conducting and approving of systems at FAT and SAT	x	x
9	Creation and update of system documentation	x	
10	Specific procedure for software modification and installation on board the vessel, including interactions with shipyard and owner	x	x
11	Specific procedures for verification of software code	x	
12	Procedures for integrating systems with other systems and testing of the system of systems for the vessel	x	x
13	Procedures for managing changes to software and configurations before FAT	x	
14	Procedures for managing and documenting changes to software and configurations after FAT	x	x
15	Checkpoints for the organization's own follow-up of adherence to the quality management system	x	x

Society's verification:

The quality management system may be verified by two alternative means:

a) The Society confirming that the quality management system is certified as compliant to a recognized standard by an organisation with accreditation under a national accreditation scheme.

b) The Society confirming compliance to a standard through a specific assessment of the quality management system. The documentation requirements will be defined per case.

4.2 Requirements on the system supplier

4.2.1 Define and follow a quality plan *(1/7/2024)*

Requirement:

The system supplier is to document that the quality management system is applied for the design, construction, delivery, and maintenance of the specific system to be delivered.

All applicable items described in [4.1.2] (for the system supplier role) are to be demonstrated to exist and being followed, as relevant.

Society's verification:

Category I: No documentation required

Category II and III: The quality plan is to be available during survey (FAT) or submitted for information upon request (I).

4.2.2 Unique identification of systems and software *(1/7/2024)*

Requirement:

A method for unique identification of a system, its different software components and different revisions of the same software component is to be applied. The method is to be applied throughout the lifecycle of the system and the software.

See also [7.2] for related technical requirements on the system in question.

The documentation of the method is typically a part of the quality management system, see [4.1.2].

Society's verification:

Category I: Not required

Category II and III: Application of the identification system is verified as a part of the FAT (see [4.2.7]) and SAT ([4.3.6]).

4.2.3 System description *(1/7/2024)*

Requirement:

The system's specification and design are to be determined and documented in a system description. In addition to serve as a specification for the detailed design and implementation, the purpose of the system description is to document that the entire system-delivery is according to the specifications and in compliance with applicable rules and regulations.

The system description is to contain information of the following:

- Purpose and main functions, including any safety aspects
- System category as defined
- Key performance characteristics
- Compliance with the technical requirements and Society rules
- User interfaces/mimics
- Communication and Interface aspects
  - Identification and description of interfaces to other vessel systems
- Hardware-arrangement related aspects:
  - Network-architecture/topology, including all network components like switches, routers, gateways, firewalls etc.
  - Internal structure with regards to all interfaces and hardware nodes in the system (e.g. operator stations, displays, computers, programmable devices, sensors, actuators, I/O modules etc)
  - I/O allocation (mapping of field devices to channel, communication link, hardware unit, logic function)
  - Power supply arrangement
  - Failure mode description.

Guidance:

The information listed above is in this Section collectively referred to as the system description. It may however be divided into a number of different documents and models.

Society's verification:

Category I: The system description documentation is to upon request be submitted for information (I).

Category II and III: The system description documentation is to be submitted for approval (A).

4.2.4 Environmental compliance of hardware components *(1/7/2024)*

Requirement:

Evidence of environmental type testing according to Sec 8 regarding hardware elements included in the system and sub-systems is to be submitted to the Society.

Society's verification:

Category I: This requirement is not mandatory for category I systems. Reference to Type approval certificate or other evidence of type testing is upon request to be submitted for information (I) see [3.2]

Category II and III: Reference to Type approval certificate or other evidence of type testing is to be submitted for information (I).

4.2.5 Software code creation, parameterization, and testing *(1/7/2024)*

Requirement:

The software created, changed, or configured for the delivery project is to be developed and have the quality assurance activities assessed according to the selected standard(s) as described in the quality plan.

The quality assurance activities may be performed on several levels of the software-structure and is to include both custom-made software and configured components (e.g. software libraries) as appropriate.

The verification of the software is to as a minimum verify the following aspects based on black-box methods:

- Correctness, completeness and consistency of any parameterization and configuration of software components
- Intended functionality
- Intended robustness

For components in systems of Category II and III, the scope, purpose, and results of all performed reviews, analyses, tests, and other verification activities are to be documented in test reports.

Guidance:

Some of the methods utilized in this activity are sometimes referred to as "software unit test" or "developer test" and may also include verification methods like code-reviews and static- or dynamic code analysis.

Society's verification:

Category I: No documentation required

Category II and III: Software test reports are upon request to be submitted for information (I).

4.2.6 Internal system testing before FAT *(1/7/2024)*

Requirement:

The system is to as far as practicable be tested before the FAT. The main purpose of the system test is for the system supplier to verify that the entire system delivery is according to the specifications, approved documentation and in compliance with applicable rules and regulations; and further, that the system is completed and ready for the FAT.

The testing is at least to verify the following aspects of the system:

- Functionality
- Effect of faults and failures (including diagnostic functions, detection, alerts response)
- Performance
- Integration between software and hardware components
- Human-machine interfaces
- Interfaces to other systems

Faults are to be simulated as realistically as possible to demonstrate appropriate system fault detection and system response.

Some of the testing may be performed by utilizing simulators and replica hardware.

The test-environment is to be documented, including a description of any simulators, emulators, test-stubs, test-management tools, or other tools affecting the test environment and its limitations.

Test cases and test results are to be documented in test programs and test reports respectively.

Society's verification:

Category I: No documentation required.

Category II and III: Internal system test report is to be made available during FAT or submitted upon request (I).

4.2.7 Factory acceptance testing (FAT) before installation on board *(1/7/2024)*

Requirement:

A factory acceptance test (FAT) is to be arranged for the system in question. The main purpose of the FAT is to demonstrate to the Society that the system is completed and compliant with applicable classification rules, thus enabling issuance of a Society Certificate for the system.

The FAT test program is to cover a representative selection of the test items from the internal system test (described in [4.2.6]), including normal system functionality and response to failures.

For category II and III systems, network testing to verify the network resilience requirements in [7.3.1] is to be performed. If agreed by all parties, the network testing may be performed as a part of the system test onboard the vessel.

The FAT is as a rule to be performed with the project specific software operating on the actual hardware components to be installed on board, with necessary means for simulation of functions and failure responses, however other solutions such as replica hardware or simulated hardware (emulators) may be agreed with the Society.

For each test-case it is to be noted if the test passed or failed, and the test-results are to be documented in a test report. The test report is also to contain a list of the software (including software versions) that were installed in the system when the test was executed.

Guidance:

For complex systems there may be a large difference in scope between the "Internal system testing before FAT" activity and the FAT, while for some systems the scope may be identical.

Society's verification:

Category I: FAT not required.

Category II and III: The FAT program is to be approved (A) before the test is executed.

The FAT execution is to be witnessed by the Society.

The FAT report is to be submitted for information (I).

Additional FAT documentation including e.g., user manuals and internal system test report is to be made available during FAT or submitted upon request for information (I).

4.2.8 Secure and controlled software installation on the vessel *(1/7/2024)*

Requirement:

The initial installation and subsequent updates of the software components of the system is to be done according to a management of change procedure which has been agreed between the system supplier and the systems integrator.

The management of change procedure is to comply with the requirements in [6].

Cyber security measures are to be observed as described in Sec 4 and Sec 5.

Society's verification:

Category I: Not required.

Category II and III: The management of change procedure is upon request to be submitted for information (I).

4.3 Requirements on the systems integrator

4.3.1 Responsibilities *(1/7/2024)*

For the purposes of this Section, the Shipyard is considered as the systems integrator in the development and delivery phase unless another organization or person is explicitly appointed by the Shipyard.

4.3.2 Define and follow a quality plan *(1/7/2024)*

Requirement:

The systems integrator is to document that the quality management system is applied for the installation, integration, completion, and maintenance of the systems to be installed on board. All applicable items described in [4.1.2] (for the systems integrator role) are to be demonstrated to exist and being followed, as relevant.

Society's verification:

Category I: No documentation required.

Category II and III: The quality plan is to be made available during survey (at SAT/SOST) or upon request submitted for information (I).

4.3.3 Determining the category of the system in question *(1/7/2024)*

Requirement:

For each system delivery to a particular vessel, it is to be decided which category the system falls under based on the failure effects of the system (as defined in [3]). The category for a specific system is to be conveyed to the relevant system supplier. The Society may decide that a risk-assessment is needed to verify the proper system category.

Society's verification:

Category I, II and III: The category for the different systems is upon request to be documented and submitted for approval (A).

4.3.4 Risk assessment of the system *(1/7/2024)*

Requirement:

If requested by the Society, a risk assessment of a specific system in context of the specific vessel in question is to be performed and documented in order to determine the applicable category for the system.

Guidance:

IEC/ISO31010 "Risk management - Risk assessment techniques" may be used as guidance in order to determine method of risk assessment.

Society's verification:

Category I, II and III: The risk assessment report is upon request to be submitted for approval (A).

4.3.5 Define the vessel's system-architecture *(1/7/2024)*

Requirement:

The system of systems (SoS) is to be specified and documented. This architecture specification provides the basis for category determination and development of the different integrated systems by allocating functionality to individual systems and by identifying the main interfaces between the systems. It is also to serve as a basis for the testing of the integrated systems on the vessel level (see [4.3.7]).

The vessel's system architecture is to at least contain description of:

- Overview of the total systems architecture (the system of systems)
- Each system's purpose and main functionality
- Communication and interface aspects between different systems

Guidance:

See also Sec 4 for diagram of security zones and conduits

Society's verification:

Category I, II and III: The vessel's system architecture is upon request to be submitted for information (I).

4.3.6 System acceptance test (SAT) onboard the vessel *(1/7/2024)*

Requirement:

A system acceptance test is to be arranged onboard the vessel. The main purpose of the system acceptance test (SAT) is to verify the system functionality, after installation and integration with the applicable machinery/electrical/process systems on board including possible interfaces with other control and monitoring systems.

For each test-case it is to be noted if the test passed or failed, and the test-results are to be documented in a test report. The test report is also to contain a list of the software (including software versions) that were installed in the system when the test was executed.

Society's verification:

Category I: Not required.

Category II and III: The SAT program is to be submitted for approval (A) before the test is executed.

The SAT execution is to be witnessed by the Society.

The SAT report is to be submitted for information (I).

4.3.7 Testing of integrated systems on vessel-level (SOST) *(1/7/2024)*

Requirement:

Integration tests are to be conducted after installation and integration of the different systems in its final environment on board. The purpose of the tests is to verify the functionality of the complete installation (system of systems) including all interfaces and inter-dependencies in compliance with requirements and specifications.

The testing is at least to verify the following aspects of the system of systems:

- The overall functionality of the interacting systems as a whole
- Failure response between systems
- Performance
- Human-machine interfaces
- Interfaces between the different systems.

Guidance:

For complex systems there may be a large difference in scope between the “System acceptance test (SAT) onboard the vessel” activity and the SOST, while for some systems the scope may be overlapping or identical. It is possible to combine the two activities into one when the test scope is similar.

Society’s verification:

Category I: Not required.

Category II and III: The SOST program is to be submitted for approval (A) before the test is executed.

The SOST execution is to be witnessed by the Society.

The SOST report is to be submitted for information (I).

4.3.8 Change management *(1/7/2024)*

Requirement:

The systems integrator is to follow procedures for management of change to the system as described in [6].

Society’s verification:

Category I: No documentation requirements.

Category II and III: The management of change procedure is upon request to be submitted for information (I).

5 Requirements on maintenance of computer-based systems

5.1 Requirements on the Vessel Owner

5.1.1 Responsibilities *(1/7/2024)*

For the purposes of this Section, the vessel owner is considered to be the systems integrator in the operations phase unless another organization or person is explicitly appointed by the owner.

Accordingly, the Society is in a timely manner to be informed by the owner about the appointed systems integrator which is responsible for implementing any changes to the systems in conjunction with system supplier(s).

5.2 Requirements on the Systems integrator

5.2.1 Change management *(1/7/2024)*

Requirement:

The systems integrator is to ensure that necessary procedures for software and hardware change management exist on board, and that any software modification/upgrade are performed according to the procedure(s). For details about change management please see [6].

Changes to computer-based systems in the operational phase are to be recorded.

The records are to contain information about the relevant software versions and other relevant information as described in [6.11].

Society’s verification:

Category I: No documentation requirements

Category II and III: See [6.12].

5.3 Requirements on the System Supplier

5.3.1 Change management *(1/7/2024)*

Requirement:

The system supplier is to follow procedures for maintenance of the system including procedures for management of change as described in [6].

Society's verification:

Category I: No documentation requirements

Category II and III: See [6.12].

5.3.2 Testing of changes before installation onboard *(1/7/2024)*

Requirement:

The system supplier is to make sure that the planned changes to a system have passed relevant in-house tests before the change is made to systems on board.

Society's verification:

Category I: No documentation requirements

Category II and III: See [6.12].

6 Management of change

6.1 General

6.1.1 *(1/7/2024)*

This Article provides requirements for the management of change throughout the lifecycle of a computer-based system. Different procedures for the management of change may be defined for specific phases in a system's lifecycle as the different phases typically involve different stakeholders. The Society's verification is described in [6.12].

6.2 Documented change management procedures

6.2.1 *(1/7/2024)*

Requirement:

The organization in question is to have defined and documented change management procedures applicable for the computer-based system in question covering both hardware and software. After FAT, the system supplier is to manage all changes to the system in accordance with the procedure. Examples could be qualification of new versions of acquired software, new hardware, modified control logic, changes to configurable parameters.

The procedure(s) is at least to describe the activities listed in [6.3] through [6.11]. The outcome of the impact analysis in [6.8] will determine to what extent the activities in [6.3] to [6.12] are to be performed. Change records (described in [6.11]) are always to be produced.

6.3 Agreement between relevant stakeholders

6.3.1 *(1/7/2024)*

Requirement:

The management of change process is to be coordinated and agreed between the relevant stakeholders along the different stages of the lifecycle of the computer-based system.

Guidance:

Typically, the management of change address at least three different stages:

- Development and internal verification before FAT; involving the system supplier and sub-suppliers.
- From FAT to handover of the vessel to the owner; involving the system supplier, the systems integrator, the Society, and the owner.
- In operation; involving the system supplier, service suppliers, the owner, and the Society

6.4 Approved software shall be under change management

6.4.1 *(1/7/2024)*

Requirement:

If changes are required to a system after it has been approved by applicable stakeholders (typically the systems integrator and the Society at FAT) the modifications are to follow defined change management procedures.

6.5 Unique identification of system and software versions

6.5.1 *(1/7/2024)*

Requirement:

The system supplier is to make sure that each system and software version is uniquely identifiable, see [4.2.2].

6.6 Handling of software master files

6.6.1 *(1/7/2024)*

Requirement:

There are to be defined mechanisms for handling of the files that constitutes the master-files for a software component. Personnel authorities are to be clearly defined along with the tools and mechanisms used to ensure the integrity of the master files.

6.7 Backup and restoration of onboard software

6.7.1 *(1/7/2024)*

Requirement:

It is to be clearly defined how to perform backup and restoration of the software components of a computer-based system onboard the vessel.

6.8 Impact analysis before change is made

6.8.1 *(1/7/2024)*

Requirement:

Before a change to the system is made, an impact analysis is to be performed in order to:

- Determine the criticality of the change.
- Determine the impact on existing documentation.
- Determine the needed verification and test activities.
- Determine the need to inform other stakeholders about the change.
- Determine the need to obtain approval from other stakeholders (e.g. Society and or Owner) before the change is made.

6.9 Roll-back in case of failed software changes

6.9.1 *(1/7/2024)*

Requirement:

When maintenance includes installation of new versions of the software in the system, it is to be possible to perform a rollback of the software to the previous installed version with the purpose of returning the system to a known, stable state.

Roll-backs are to be documented and analysed to find and eliminate the root cause.

6.10 Verification and validation of system changes

6.10.1 *(1/7/2024)*

Requirement:

To the largest degree practically possible, modifications are to be verified before being installed onboard.

After installation, the modification(s) is to be verified onboard according to a documented verification program containing:

- Verification that the new functionalities and/or improvements have had the intended effect.
- Regression test to verify that the modification has not had any negative effects on functionality or capabilities that was not expected to be affected.

6.11 Change records

6.11.1 *(1/7/2024)*

Changes to systems and software are to be documented in change records to allow for visibility and traceability of the changes. The change records is to contain at least the following items:

- The purpose for a change
- A description of the changes and modifications
- The main conclusions from the impact analysis (see [6.8])
- The identity and version of any new system or software version(s) (see [6.5])
- Test reports or tests summaries (see [6.10])

Documentation of the changes to software may be recorded in the planned maintenance system (PMS), in a software registry or equivalent.

6.12 Verification of change management by the Society

6.12.1 **In operation (vessel in service) phase** *(1/7/2024)*

The verification by the Society regarding the management of change in operation is generally performed during the annual survey of the vessel. Procedures for management of change and relevant change records (see [6.11]) are to be made available at the time of survey.

In the cases where the change requires approval from the Society up front, the relevant procedures and documentation for the change in question may be verified at that time.

6.12.2 **During newbuilding** *(1/1/2026)*

The verification of management of change in the newbuilding phase is divided into two; Procedures are verified as a part of the verification of the quality management system ([4.1.2]), while project specific implementation of the procedures are verified during FAT ([4.2.7]), SAT ([4.3.6]), and SOST ([4.3.7]) activities.

7 Technical requirements on computer-based systems

7.1 General

7.1.1 *(1/7/2024)*

The Articles below contain technical requirements on computer-based systems. The compliance to these requirements are to be documented in the design documentation (see [4.2.3]) and verified through the verification activities described in this Section.

7.2 Reporting of system and software identification and version

7.2.1 **System identification** *(1/7/2024)*

The system is to provide means to identify its name, version, identifier, and manufacturer. It is recommended that the system can automatically report the status of its software to a ship software logging system (SSLS) as specified in the international standard ISO 24060.

7.3 Data links

7.3.1 **General requirements for category II and III systems** *(1/7/2024)*

Loss of a data link is to be specifically addressed in risk assessment analysis/FMEA. See [4.2.3].

a) A single failure in data link is not to cause loss of vessel- functions of category III. Any effect of such failures is to meet the principle of fail-to-safe for the vessel-function(s) being served.

b) For vessel-functions of category II and III, any loss of functionality in the remote control system is to be compensated for by local/manual means.

c) The data link is to have means to prevent or cope with excessive communication rates.

d) Data links are to be self-checking, detecting failures or performance issues on the link itself and data communication failures on nodes connected to the link.

e) Detected failures are to initiate an alarm.

7.3.2 Specific requirements for wireless data links *(1/7/2024)*

a) Category III systems are not to use wireless data links unless specifically considered by the Society on the basis of an engineering analysis carried out in accordance with an International or National Standard acceptable to the Society.

Other categories of systems may use wireless data links with the following requirements:

b) Recognised international wireless communication system protocols are to be employed, incorporating:
   1) Message integrity. Fault prevention, detection, diagnosis, and correction so that the received message is not corrupted or altered when compared to the transmitted message.
   2) Configuration and device authentication. It is only to permit connection of devices that are included in the system design.
   3) Message encryption. Protection of the confidentiality and or criticality of the data content.
   4) Security management. Protection of network assets, prevention of unauthorized access to network assets.

c) The internal wireless system within the vessel is to comply with the radio frequency and power level requirements of International Telecommunication Union and flag state requirements.

d) Consideration should be given to system operation in the event of port state and local regulations that pertain to the use of radio-frequency transmission prohibiting the operation of a wireless data communication link due to frequency and power level restrictions.

e) For wireless data communication equipment, tests during harbour and sea trials are to be conducted to demonstrate that radio-frequency transmission does not cause failure of any equipment and does not self-fail as a result of electromagnetic interference during expected operating conditions.

7.4 Verification of technical requirements by the Society

7.4.1 *(1/7/2024)*

The implementation of the technical requirements provided in [7] is verified by the Society as part of the system description (see [4.2.3]), FAT (see [4.2.7]) and SAT (see [4.3.6]) described above.

8 Summary of documentation submittal

8.1 Standard list of documents

8.1.1 *(1/7/2024)*

Tab 4 and Tab 5 summarise the documentation to be submitted to the Society.

8.1.2 *(1/7/2017)*

The Society reserves the right to request the submission of additional documents if it is deemed necessary for the evaluation of the system, equipment or components.

Table 4 : Summary of documentation submittal by the system supplier *(1/7/2024)*

Item		Responsible role	System Category		
Paragraph reference	Document		I	II	III
[4.2.1]	Quality plan	System supplier	- **(2)**	I **(1)**	I **(1)**
[4.2.3]	System description	System supplier	I **(1)**	A	A
[4.2.4]	Environmental compliance	System supplier	I **(1)**	I	I
[4.2.5]	Software test reports	System supplier	-	I **(1)**	I **(1)**
[4.2.6]	System test report	System supplier	-	I **(1)**	I **(1)**
[4.2.7]	FAT program	System supplier	-	A	A

Note 1:
A = Submitted for approval I = Provided (for information)
(1) Upon request from the Society
(2) "-" means: No requirement

Item		Responsible role	System Category		
Paragraph reference	Document		I	II	III
[4.2.7]	FAT report	System supplier	-	I	I
[4.2.7]	Additional FAT docs. (e.g. user manual, etc)	System supplier	-	I **(1)**	I **(1)**
[4.2.8]	Management of change procedure	System supplier	-	I **(1)**	I **(1)**

Note 1:
A = Submitted for approval I = Provided (for information)
(1) Upon request from the Society
(2) "-" means: No requirement

Table 5 : Summary of documentation submittal by the system integrator *(1/7/2024)*

Item		Responsible role	System Category		
Paragraph reference	Document		I	II	III
[4.3.2]	Quality plan	Systems integrator	- **(2)**	I **(1)**	I **(1)**
[4.3.3]	List of system categorizations	Systems integrator	A **(1)**	A **(1)**	A **(1)**
[4.3.4]	Risk assessment report	Systems integrator	A **(1)**	A **(1)**	A **(1)**
[4.3.5]	Vessel's system architecture	Systems integrator	I **(1)**	I **(1)**	I **(1)**
[4.3.6]	SAT program	Systems integrator	-	A	A
[4.3.6]	SAT report	Systems integrator	-	I	I
[4.3.7]	SOST program	Systems integrator	-	A	A
[4.3.7]	SOST report	Systems integrator	-	I	I
[4.3.8]	Change management procedure for software	Systems integrator	-	I **(1)**	I **(1)**

Note 1:
A = Submitted for approval I = Provided (for information)
(1) Upon request from the Society
(2) "-" means: No requirement

9 Summary of test witnessing and survey

9.1 Standard list of witness and survey

9.1.1 *(1/7/2024)*

Tab 6 summarises the activities that are to be witnessed or surveyed by the Society. The responsible role is to facilitate the activity.

Table 6 : Summary of test witnessing and survey *(1/7/2024)*

Item		Responsible role	System Category		
Paragraph reference	Activity		I	II	III
[4.2.7]	FAT witnessing	System supplier	- **(2)**	x **(1)**	x
[4.3.6]	SAT witnessing	System integrator	-	x	x
[4.3.7]	SOST witnessing	System integrator	-	x	x
[6.12]	Verification of changes	System integrator	-	x	x

Note 1:

(1) Witnessing required

(2) "-" means: No requirement

SECTION 4 CYBER RESILIENCE OF SHIPS

1 Introduction

1.1 General

1.1.1 *(1/7/2024)*

Interconnection of computer systems on ships, together with the widespread use onboard of commercial-off-the-shelf (COTS) products, open the possibility for attacks to affect personnel data, human safety, the safety of the ship, and threaten the marine environment.

Attackers may target any combination of people and technology to achieve their aim, wherever there is a network connection or any other interface between onboard systems and the external world. Safeguarding ships, and shipping in general, from current and emerging threats involves a range of measures that are continually evolving.

This Section establish a set of minimum functional and performance criteria to deliver a ship that can indeed be described as cyber resilient.

The minimum requirements in this Section applied consistently to the full threat surface using a goal-based approach are considered necessary to make cyber resilient ships.

1.2 Structure of this Section

1.2.1 *(1/7/2024)*

Tab 1 illustrate the structure of this Section

Table 1 : Structure of this Section *(1/7/2024)*

Introductory Part	1 Introduction 2 Definitions 3 Goals and Organization of Requirements
Main Part	4 Requirements 4.1 General 4.2 Identify 4.3 Protect 4.4 Detect 4.5 Respond 4.6 Recover
	5 Demonstration of compliance 5.1 General 5.2 During design and construction phases 5.3 Upon ship commissioning 5.4 During the operational life of the ship
Supplementary Part	6 Risk assessment for exclusion of CBS from the application of requirements (required only when systems are excluded from application of this Section)
	7: Summary of actions and documents 8: Summary of requirements and documents

1.3 Aim and purpose

1.3.1 *(1/7/2024)*

The aim of this Section is to provide a minimum set of requirements for cyber resilience of ships, with the purpose of providing technical means to stakeholders which would lead to cyber resilient ships.

This Section targets the ship as a collective entity for cyber resilience and is intended as a base for the complementary application of other industry standards addressing cyber resilience of onboard systems, equipment and components.

Minimum requirements for cyber resilience of on-board systems and equipment are given in Sec 5.

1.4 Scope of applicability

1.4.1 Vessels in scope *(1/7/2024)*

This Section is applicable to the following vessels:

- Passenger ships (including passenger high-speed craft) engaged in international voyages
- Cargo ships of 500 GT and upwards engaged in international voyages
- High speed craft of 500 GT and upwards engaged in international voyages
- Mobile offshore drilling units of 500 GT and upwards
- Self-propelled mobile offshore units engaged in construction (i.e. wind turbine installation maintenance and repair, crane units, drilling tenders, accommodation, etc)

This Section may be used as non-mandatory guidance to the following.

- Ships of war and troopships
- Cargo ships less than 500 GT
- Vessels not propelled by mechanical means
- Wooden ships of primitive build
- Passenger yachts (passengers not more than 12)
- Pleasure yachts not engaged in trade
- Fishing vessels
- Site specific offshore installations (i.e. FPSOs, FSUs, etc.)

1.4.2 Systems in scope *(1/7/2024)*

This Section applies to:

a) Operational Technology (OT) systems onboard ships, i.e. those CBSs using data to control or monitor physical processes that can be vulnerable to cyber incidents and, if compromised, could lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.

   In particular, the CBSs used for the operation of the following ship functions and systems, if present onboard, are to be considered:

   - Propulsion
   - Steering
   - Anchoring and mooring
   - Electrical power generation and distribution
   - Fire detection and extinguishing systems
   - Bilge and ballast systems, loading computer
   - Watertight integrity and flooding detection
   - Lighting (e.g. emergency lighting, low locations, navigation lights, etc.)
   - Any required safety system whose disruption or functional impairing may pose risks to ship operations (e.g. emergency shutdown system, cargo safety system, pressure vessel safety system, gas detection system, etc.).

   In addition, the following systems are to be included in the scope of applicability of this Section:

   - Navigational systems required by statutory regulations
   - Internal and external communication systems required by class rules and statutory regulations.

   For navigation and radiocommunication systems, the application of IEC 61162-460 or other equivalent standards in lieu of the required security capabilities in Sec 5, [4] may be accepted by the Society, on the condition that requirements in this Section are complied with.

b) Any Internet Protocol (IP)-based communication interface from CBSs in scope of this Section to other systems. Examples of such systems are, but not limited to, the following:

   - passenger or visitor servicing and management systems
   - passenger-facing networks
   - administrative networks
   - crew welfare systems
   - any other systems connected to OT systems, either permanently or temporarily (e.g. during maintenance).

The cyber incidents considered in this Section are events resulting from any offensive manoeuvre that targets OT systems onboard ships as defined in [2].

1.4.3 System Category *(1/7/2024)*

System categories are defined in Sec 3 on the basis of the consequences of a system failure to human safety, safety of the vessel and/or threat to the environment.

1.4.4 IACS Documents on Computer Based Systems and Cyber Resilience *(1/7/2024)*

Attention is made to additional IACS documents on CBSs and Cyber Resilience as follows: Sec 3 Computer Based Systems includes requirements for design, construction, commissioning and maintenance of computer-based systems where they depend on software for the proper achievement of their functions. The requirements in Sec 3 focus on the functionality of the software and on the hardware supporting the software which provide control, alarm, monitoring, safety or internal communication functions subject to classification requirements. Sec 5 Cyber resilience of on-board systems and equipment includes requirements for cyber resilience for on-board systems and equipment.

IACS Recommendation 166 Recommendation on Cyber Resilience: non-mandatory recommended technical requirements that stakeholders may reference and apply to assist with the delivery of cyber resilient ships, whose resilience can be maintained throughout their service life. IACS Recommendation 166 on Cyber Resilience is intended for ships contracted for construction after its publication and may be used as a reference for ships already in service prior to its publication. For ships to which this Section applies as mandatory instrument, when both this Section and Recommendation 166 are used, should any difference in requirements addressing the same topic be found between the two instruments, the requirements in this Section are to prevail.

2 Definitions

2.1 General

2.1.1 *(1/7/2024)*

In the purview of this Section, the following definitions apply:

Annual survey: see Pt A, Ch 2, Sec 2, [5.1.1]

Attack surface: the set of all possible points where an unauthorized user can access a system, cause an effect on or extract data from. The attack surface comprises two categories: digital and physical. The digital attack surface encompasses all the hardware and software that connect to an organization’s network. These include applications, code, ports, servers and websites. The physical attack surface comprises all endpoint devices that an attacker can gain physical access to, such as desktop computers, hard drives, laptops, mobile phones, removable drives and carelessly discarded hardware.

Authentication: provision of assurance that a claimed characteristic of an identity is correct.

Compensating countermeasure: an alternate solution to a countermeasure employed in lieu of or in addition to inherent security capabilities to satisfy one or more security requirements.

Computer Based System (CBS): A programmable electronic device, or interoperable set of programmable electronic devices, organized to achieve one or more specified purposes such as collection, processing, maintenance, use, sharing, dissemination, or disposition of information. CBS on-board include IT and OT systems. A CBS may be a combination of subsystems connected via network. On-board CBS may be connected directly or via public means of communications (e.g. Internet) to ashore CBSs, other vessels’ CBS and/or other facilities.

Cyber incident: an event resulting from any offensive cyber manoeuvre, either intentional or unintentional, that targets or affects one or more CBS onboard, which actually or potentially results in adverse consequences to an onboard system, network and computer or the information that they process, store or transmit, and which may require a response action to mitigate the consequences. Cyber incidents include unauthorized access, misuse, modification, destruction or improper disclosure of the information generated, archived or used in onboard CBS or transported in the networks connecting such systems. Cyber incidents do not include system failures.

Cyber resilience: the capability to reduce the occurrence and mitigating the effects of incidents arising from the disruption or impairment of operational technology (OT) used for the safe operation of a ship, which potentially lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.

Essential services: Services for propulsion and steering, and safety of the ship. Essential services comprise "Primary Essential Services" and "Secondary Essential Services": Primary Essential Services are those services which need to be in continuous operation to maintain propulsion and steering; Secondary Essential Services are those services which need not necessarily be in continuous operation to maintain propulsion and steering but which are necessary for maintaining the vessel’s safety.

Information Technology (IT): devices, software and associated networking focusing on the use of data as information, as opposed to Operational Technology (OT).

Integrated system: a system combining a number of interacting sub-systems and/or equipment organized to achieve one or more specified purposes.

Logical network segment: The same as “Network segment”, but where two or more logical network segments share the same physical components.

Network: A connection between two or more computers for the purpose of communicating data electronically by means of agreed communication protocols.

Network segment: In the context of this Section, a network segment is an OSI layer-2 Ethernet segment (a broadcast domain).

Note 1: Note on TCP/IP: Network address plan is prefixed by their IP addresses and the network mask. Communication between network segments is only possible by the use of routing service at network layer (OSI Layer 3).

Operational technology (OT): devices, sensors, software and associated networking that monitor and control onboard systems. Operational technology systems may be thought of as focusing on the use of data to control or monitor physical processes.

Physical network segment: The same as “Network segment”, but where physical components are not shared by other network segments.

Protocols: a common set of rules and signals that computers on the network use to communicate. Protocols allow to perform data communication, network management and security. Onboard networks usually implement protocols based on TCP/IP stacks or various field buses.

Security zone: A collection of CBSs in the scope of applicability of this Section that meet the same security requirements. Each zone consists of a single interface or a group of interfaces, to which an access control policy is applied.

Shipowner/Company: The owner of the ship or any other organization or person, such as the manager, agent or bareboat charterer, who has assumed the responsibility for operation of the ship from the shipowner and who on assuming such responsibilities has agreed to take over all the attendant duties and responsibilities. The shipowner could be the Shipyard or systems integrator during initial construction. After vessel delivery, the shipowner may delegate some responsibilities to the vessel management company.

Special survey: Pt A, Ch 2, Sec 2, [4.1.1]

Supplier: a manufacturer or provider of hardware and/or software products, system components or equipment (hardware or software) comprising of the application, embedded devices, network devices, host devices etc. working together as system or a subsystem. The Supplier is responsible for providing programmable devices, sub-systems or systems to the System Integrator.

System Integrator: the specific person or organization responsible for the integration of systems and products provided by suppliers into the system invoked by the requirements in the ship specifications and for providing the integrated system. The system integrator may also be responsible for integration of systems in the ship. Until vessel delivery, this role is to be taken by the Shipyard unless an alternative organization is specifically contracted/assigned this responsibility.

Untrusted network: any network outside the scope of applicability of this Section.

3 Goals and organization of requirements

3.1 Primary goal

3.1.1 *(1/7/2024)*

The primary goal is to support safe and secure shipping, which is operationally resilient to cyber risks.

Safe and secure shipping can be achieved through effective cyber risk management system. To support safe and secure shipping resilient to cyber risk, the following sub-goals for the management of cyber risk are defined in the five functional elements listed in [3.2].

3.2 Sub-goals per functional element

3.2.1 *(1/7/2024)*

a) Identify: Develop an organizational understanding to manage cybersecurity risk to onboard systems, people, assets, data, and capabilities.

b) Protect: Develop and implement appropriate safeguards to protect the ship against cyber incidents and maximize continuity of shipping operations.

c) Detect: Develop and implement appropriate measures to detect and identify the occurrence of a cyber incident onboard.

d) Respond: Develop and implement appropriate measures and activities to take action regarding a detected cyber incident onboard.

e) Recover: Develop and implement appropriate measures and activities to restore any capabilities or services necessary for shipping operations that were impaired due to a cyber incident.

These sub-goals and relevant functional elements should be concurrent and considered as parts of a single comprehensive risk management framework.

3.3 Organization of requirements

3.3.1 *(1/7/2024)*

The requirements are organized according to a goal-based approach. Functional/technical requirements are given for the achievement of specific sub-goals of each functional element.

The requirements are intended to allow a uniform implementation by stakeholders and to make them applicable to all types of vessels, in such a way as to enable an acceptable level of resilience and apply to all classed vessels/units regardless of operational risks and complexity of OT systems.

For each requirement, a rationale is given.

A summary of actions to be carried out and documentation to be made available is also given for each phase of the ship's life and relevant stakeholders participating to such phase.

4 Requirements

4.1 General

4.1.1 *(1/7/2024)*

This Article contains the requirements to be satisfied in order to achieve the primary goal defined in [3.1], organized according to the five functional elements identified in [3.2].

The requirements are to be fulfilled by the stakeholders involved in the design, building and operation of the ship. Among them, the following stakeholders can be identified (see also [2] for definitions):

- Shipowner/Company
- Systems integrator
- Supplier
- Classification Society

Whilst the above requirements may be fulfilled by these stakeholders, for the purposes of this Section, responsibility to fulfil them will lie with the stakeholder who has contracted with the Society.

4.2 Identify

4.2.1 *(1/7/2024)*

The requirements for the 'Identify' functional element are aimed at identifying: on one side, the CBSs onboard, their interdependencies and the relevant information flows; on the other side, the key resources involved in their management, operation and governance, their roles and responsibilities.

4.2.2 Vessel asset inventory *(1/1/2026)*

a) Requirement

An inventory of hardware and software (including application programs, operating systems, if any, firmware and other software components) of the CBSs in the scope of applicability of this Section and of the networks connecting such systems to each other and to other CBSs onboard or ashore is to be provided and kept up to date during the entire life of the ship.

b) Rationale

The inventory of CBSs onboard and relevant software used in OT systems, is essential for an effective management of cyber resilience of the ship, the main reason being that every CBS becomes a potential point of vulnerability.

Cybercriminals can exploit unaccounted and out-of-date hardware and software to hack systems. Moreover, managing CBS assets enables Companies understand the criticality of each system to ship safety objectives.

c) Requirement details

The vessel asset inventory is to include at least the CBSs indicated in [1.4.2], if present onboard.

The inventory is to be kept updated during the entire life of the ship. Software and hardware modifications potentially introducing new vulnerabilities or modifying functional dependencies or connections among systems is to be recorded in the inventory.

If confidential information is included in the inventory (e.g. IP addresses, protocols, port numbers), special measures are to be adopted to limit the access to such information only to authorized people.

1) Hardware

For all hardware devices in the scope of applicability of this Section, the vessel asset inventory is to include at least the information in Sec 5, [3.1.2].

In addition, the vessel asset inventory may specify system category and security zone associated with the CBS.

2) Software

For all software in the scope of applicability of this Section (e.g., application program, operating system, firmware), the vessel asset inventory is to include at least the information in Sec 5, [3.1.2].

The software of the CBSs in the scope of applicability of this Section is to be maintained and updated in accordance with the shipowner's process for management of software maintenance and update policy in the Ship cyber security and resilience program, see [5.4.2].

d) Demonstration of compliance

1) Design phase

The systems integrator is to submit vessel asset inventory to the Society (ref. [5.2.4]).

The vessel asset inventory is to incorporate the asset inventories of all individual CBSs falling under the scope of this Section. Any equipment in the scope of this Section delivered by the systems integrator is also to be included in the vessel asset inventory.

2) Construction phase

The systems integrator is to keep the vessel asset inventory updated.

3) Commissioning phase

The systems integrator is to submit Ship cyber resilience test procedure (ref. [5.3.2]) and demonstrate to the Society that:

- Vessel asset inventory is updated and completed at delivery
- CBSs in the scope of applicability of this Section are correctly represented by the vessel asset inventory
- Software of the CBSs in the scope of applicability of this Section has been kept updated, e.g. by vulnerability scanning or by checking the software versions of CBSs while switched on.

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

The shipowner is in the Ship cyber security and resilience program to describe the process of management of change (MoC) for the CBSs in the scope of applicability of this Section, addressing at least the following requirements in this Section:

- Management of change (see [5.4])
- Hardware and software modifications (see [4.2.2] c))

The shipowner is in the Ship cyber security and resilience program also to describe the management of software updates, addressing at least the following requirements in this Section:

- Vulnerabilities and cyber risks (see [4.2.2] b) and c))
- Security patching (see [4.3.7] c) 2))

First annual survey

The shipowner is to present to the Society records or other documented evidence demonstrating implementation of the Ship cyber security and resilience program, i.e., that:

- The approved management of change process has been adhered to.
- Known vulnerabilities and functional dependencies have been considered for the software in the CBSs.
- The Vessel asset inventory has been kept updated.

Subsequent annual surveys

The shipowner is upon request by the Society to demonstrate implementation of the Ship cyber security and resilience program by presenting records or other documented evidence as specified for the first annual survey.

Special Survey

The shipowner is to demonstrate to the Society the activities in section [4.2.2] d), 3) as per the Ship cyber resilience test procedure.

An example of the "Vessel Asset Inventory Template" form to be filled in and submitted by the shipyard/integrator during vessel construction and maintained through the vessel's operational life by the Shipowner, is available in IACS Rec.190 and published on the Society website.

4.3 Protect

4.3.1 General *(1/7/2024)*

The requirements for the Protect functional element are aimed at the development and implementation of appropriate safeguards supporting the ability to limit or contain the impact of a potential incident.

4.3.2 Security Zones and Network Segmentation *(1/7/2024)*

a) Requirement

All CBSs in the scope of applicability of this Section are to be grouped into security zones with well-defined security policies and security capabilities. Security zones are either to be isolated (i.e. air gapped) or connected to other security zones or networks by means providing control of data communicated between the zones (e.g. firewalls/routers, simplex serial links, TCP/IP diodes, dry contacts, etc.)

Only explicitly allowed traffic is to traverse a security zone boundary.

b) Rationale

While networks may be protected by firewall perimeter and include Intrusion Detection Systems (IDS) or Intrusion Prevention Systems (IPS) to monitor traffic coming in, breaching that perimeter is always possible. Network segmentation makes it more difficult for an attacker to perpetrate an attack throughout the entire network.

The main benefits of security zones and network segmentation are to reduce the extent of the attack surface, prevent attackers from achieving lateral movement through systems, and improve network performance. The concept of allocating the CBSs into security zones allows grouping the CBSs in accordance with their risk profile.

c) Requirement details

A security zone may contain multiple CBSs and networks, all of which are to comply with applicable security requirements given in this Section and Sec 5.

The network(s) of a security zone is to be logically or physically segmented from other zones or networks. See also [4.3.7] c)).

CBSs providing required safety functions are to be grouped into separate security zones and are to be physically segmented from other security zones.

Navigational and communication systems are not to be in same security zone as machinery or cargo systems. If navigation and/or radiocommunication systems are approved in accordance with other equivalent standard(s) (see [1.4.2]), these systems should be in a dedicated security zone.

Wireless devices are to be in dedicated security zones. See also [4.3.6].

Systems, networks or CBSs outside the scope of applicability of this Section are considered untrusted networks and are to be physically segmented from security zones required by this Section. Alternatively, it is accepted that such systems are part of a security zone if these OT-systems meet the same requirements as demanded by the zone.

It is to be possible to isolate a security zone without affecting the primary functionality of the CBSs in the zone, see also [4.5.4].

d) Demonstration of compliance

1) Design phase

The systems integrator is to submit Zones and conduit diagram and the Cyber security design description (see [5.2.2] and [5.2.3]).

The Zones and conduit diagram are to illustrate the CBSs in the scope of applicability of this Section, how they are grouped into security zones, and include the following information:

- Clear indication of the security zones
- Simplified illustration of each CBS in scope of applicability of this Section, and indication of the security zone in which the CBS is allocated, and indication of physical location of the CBS/equipment

- Reference to the approved version of the CBS system topology diagrams provided by the suppliers (see Sec 5, [3.1.3])
- Illustration of network communication between systems in a security zone
- Illustration of any network communication between systems in different security zones (conduits)
- Illustration of any communication between systems in a security zone and untrusted networks (conduits).

The systems integrator is to include the following information in the Cyber security design description:

- A short description of the CBSs allocated to the security zone. It is to be possible to identify each CBS in the Zones and conduit diagram
- Network communication between CBSs in the same security zone. The description is to include purpose and characteristics (i.e. protocols and data flows) of the communication
- Network communication between CBSs in different security zones. The description is to include purpose and characteristics (i.e. protocols and data flows) of the communication. The description is also to include zone boundary devices and specify the traffic that is permitted to traverse the zone boundary (e.g. firewall rules)
- Any communication between CBSs in security zones and untrusted networks. The description is to include discrete signals, serial communication, and the purpose and characteristics (i.e. protocols and data flows) of IP-based network communication. The description is also to include zone boundary devices and specify the traffic that is permitted to traverse the zone boundary (e.g. firewall rules).

2) Construction phase

The systems integrator is to keep the Zones and conduit diagram updated.

3) Commissioning phase

The systems integrator is to submit Ship cyber resilience test procedure (ref. [5.3.2]) and demonstrate to the Society that:

- the security zones on board are implemented in accordance with the approved documents (i.e. zones and conduit diagram, cyber security design description, asset inventory, and relevant documents provided by the supplier). This may be done by e.g., inspection of the physical installation, network scanning and/or other methods providing the Surveyor assurance that the installed equipment is grouped in security zones according to the approved design
- security zone boundaries allow only the traffic that has been documented in the approved Cyber security description. This may be done by e.g., evaluation of firewall rules or port scanning.

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

The shipowner is in the Ship cyber security and resilience program to describe the management of security zone boundary devices (e.g., firewalls), addressing at least the following requirements in this Section:

- Principle of Least Functionality (see [4.3.3] a))
- Explicitly allowed traffic (see [4.3.2] a))
- Protection against denial of service (DoS) events (see [4.3.3] a))
- Inspection of security audit records (see [4.4.2], a))

First annual survey

The shipowner is to demonstrate to the Society that the Zones and conduit diagram has been kept updated and present records or other documented evidence demonstrating implementation of the Ship cyber security and resilience program, i.e., that security zone boundaries are managed in accordance with the above requirements.

Subsequent annual surveys

The shipowner is upon request by the Society to demonstrate implementation of the Ship cyber security and resilience program by presenting records or other documented evidence as specified for the first annual survey.

Special survey

The shipowner is to demonstrate to the Society the activities in [4.3.2] d), 3) as per the Ship cyber resilience test procedure.

4.3.3 Network protection safeguards *(1/7/2024)*

a) Requirement

Security zones are to be protected by firewalls or equivalent means as specified in [4.3.2].

The networks are also to be protected against the occurrence of excessive data flow rate and other events which could impair the quality of service of network resources.

The CBSs in scope of this Section are to be implemented in accordance with the principle of Least Functionality, i.e. configured to provide only essential capabilities and to prohibit or restrict the use of non-essential functions, where unnecessary functions, ports, protocols and services are disabled or otherwise prohibited.

b) Rationale

Network protection covers a multitude of technologies, rules and configurations designed to protect the integrity, confidentiality and availability of networks. The threat environment is always changing, and attackers are always trying to find and exploit vulnerabilities.

There are many layers to consider when addressing network protection. Attacks can happen at any layer in the network layers model, so network hardware, software and policies are to be designed to address each area.

While physical and technical security controls are designed to prevent unauthorized personnel from gaining physical access to network components and protect data stored on or in transit across the network, procedural security controls consist of security policies and processes that control user behaviour.

c) Requirement details

The design of network is to include means to meet the intended data flow through the network and minimize the risk of denial of service (DoS) and network storm/high rate of traffic. Estimation of data flow rate is at least to consider the capacity of network, data speed requirement for intended application and data format.

d) Demonstration of compliance

1) Design phase

No requirements.

2) Construction phase

No requirements.

3) Commissioning phase

The systems integrator is to submit Ship cyber resilience test procedure (ref. [5.3.2]) and demonstrate the following to the Society:

- Test denial of service (DoS) attacks targeting zone boundary protection devices, as applicable
- Test denial of service (DoS) to ensure protection against excessive data flow rate, originating from inside each network segment. Such denial of service (DoS) tests is to cover flooding of network (i.e., attempt to consume the available capacity on the network segment), and application layer attack (i.e., attempt to consume the processing capacity of selected endpoints in the network)
- Test e.g. by analytic evaluation and port scanning that unnecessary functions, ports, protocols and services in the CBSs have been removed or prohibited in accordance with hardening guidelines provided by the suppliers. See Sec 5, [5.1.8] and Sec 5, [6.3.5] g).

The second and third tests may be omitted if performed during the certification of CBSs as per [5.3.2].

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

Special survey

Subject to modifications of the CBSs, the shipowner is to demonstrate to the Society the activities in [4.3.3] d), 3) as per the Ship cyber resilience test procedure.

4.3.4 Antivirus, antimalware, antispam and other protections from malicious code *(1/7/2024)*

a) Requirement

CBSs in the scope of applicability of this Section are to be protected against malicious code such as viruses, worms, trojan horses, spyware, etc.

b) Rationale

A virus or any unwanted program that enters a user's system without his/her knowledge can self-replicate and spread, perform unwanted and malicious actions that end up affecting the system's performance, user's data/files, and/or circumvent data security measures.

Antivirus, antimalware, antispam software will act as a closed door with a security guard fending off the malicious intruding viruses performing a prophylactic function. It detects potential virus and then works to remove it, mostly before the virus gets to harm the system.

Common means for malicious code to enter CBSs are electronic mail, electronic mail attachments, websites, removable media (for example, universal serial bus (USB) devices, diskettes or compact disks), PDF documents, web services, network connections and infected laptops.

c) Requirement details

Malware protection is to be implemented on CBSs in the scope of applicability of this Section. On CBSs having an operating system for which industrial-standard anti-virus and anti-malware software is available and maintained up-to-date, anti-virus and/or anti-malware software are to be installed, maintained and regularly updated, unless the installation of such software impairs the ability of CBS to provide the functionality and level of service required (e.g. for Cat.II and Cat.III CBSs performing real-time tasks).

On CBSs where anti-virus and anti-malware software cannot be installed, malware protection is to be implemented in the form of operational procedures, physical safeguards, or according to manufacturer's recommendations.

d) Demonstration of compliance

1) Design phase

The systems integrator is to include the following information in the Cyber security design description:

- For each CBS, summary of the approved mechanisms provided by the supplier for protection against malicious code or unauthorized software
- For CBSs with anti-malware software, information about how to keep the software updated
- Any operational conditions or necessary physical safeguards to be implemented in the shipowner's management system.

2) Construction phase

The systems integrator is to ensure that malware protection is kept updated during the construction phase.

3) Commissioning phase

The systems integrator is to submit Ship cyber resilience test procedure (ref. [5.3.2]) and demonstrate the following to the Society:

- Approved anti-malware software or other compensating countermeasures is effective (test e.g., with a trustworthy anti-malware test file).

The above tests may be omitted if performed during the certification of CBSs as per [5.3.2].

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

The shipowner is in the Ship cyber security and resilience program to describe the management of malware protection, addressing at least the following requirements in this Section:

- Maintenance/update (see [4.3.4] c))
- Operational procedures, physical safeguards (see [4.3.4] c))
- Use of mobile, portable, removable media (see [4.3.5] c), 4) and [4.3.8] c))
- Access control (see [4.3.5]).

First annual survey

The shipowner is to present to the Society records or other documented evidence demonstrating implementation of the Ship cyber security and resilience program, i.e., that:

- Any anti-malware software has been maintained and updated
- Procedures for use of portable, mobile or removable devices have been followed
- Policies and procedures for access control have been followed
- Physical safeguards are maintained.

Subsequent annual surveys

The shipowner is upon request by the Society to demonstrate implementation of the Ship cyber security and resilience program by presenting records or other documented evidence as specified for the first annual survey.

Special survey

The shipowner is to demonstrate to the Society the activities in [4.3.4] d), 3) as per the Ship cyber resilience test procedure.

4.3.5 Access control *(1/7/2024)*

a) Requirement

CBSs and networks in the scope of applicability of this Section are to provide physical and/or logical/digital measures to selectively limit the ability and means to communicate with or otherwise interact with the system itself, to use system resources to handle information, to gain knowledge of the information the system contains or to control system components and functions. Such measures are to be such as not to hamper the ability of authorized personnel to access CBS for their level of access according to the least privilege principle.

b) Rationale

Attackers may attempt to access the ship's systems and data from either onboard the ship, within the company, or remotely through connectivity with the internet. Physical and logical access controls to cyber assets, networks etc. should then be implemented to ensure safety of the ship and its cargo.

Physical threats and relevant countermeasures are also considered in the ISPS Code. Similarly, the ISM Code contains guidelines to ensure safe operation of ships and protection of the environment. Implementation of ISPS and ISM Codes may imply inclusion in the Ship Security Plan (SSP) and Safety Management System (SMS) of instructions and procedures for access control to safety critical assets.

c) Requirement details

Access to CBSs and networks in the scope of applicability of this Section and all information stored on such systems are only to be allowed to authorized personnel, based on their need to access the information as a part of their responsibilities or their intended functionality.

1) Physical access control

CBSs of Cat.II and Cat.III are generally to be located in rooms that can normally be locked or in controlled space to prevent unauthorized access, or are to be installed in lockable cabinets or consoles. Such locations or lockable cabinets/consoles are to be however easy to access to the crew and various stakeholders who need to access to CBSs for installation, integration, operation, maintenance, repair, replacement, disposal etc. so as not to hamper effective and efficient operation of the ship.

2) Physical access control for visitors

Visitors such as authorities, technicians, agents, port and terminal officials, and shipowner representatives are to be restricted regarding access to CBSs onboard whilst on board, e.g. by allowing access under supervision.

3) Physical access control of network access points

Access points to onboard networks connecting Cat.II and/or Cat.III CBSs are to be physically and/or logically blocked except when connection occurs under supervision or according to documented procedures, e.g. for maintenance.

Independent computers isolated from all onboard networks, or other networks, such as dedicated guest access networks, or networks dedicated to passenger recreational activities, are to be used in case of occasional connection requested by a visitor (e.g. for printing documents).

4) Removable media controls

A policy for the use of removable media devices is to be established, with procedures to check removable media for malware and/or validate legitimate software by digital signatures and watermarks and scan prior to permitting the uploading of files onto a ship's system or downloading data from the ship's system. See also [4.3.8].

5) Management of credentials

CBSs and relevant information are to be protected with file system, network, application, or database specific Access Control Lists (ACL). Accounts for onboard and onshore personnel are to be left active only for a limited period according to the role and responsibility of the account holder and are to be removed when no longer needed.

Note 1: CBSs are to identify and authenticate human users as per item No.1 in Sec 5, Tab 1. In other words, it is not necessary to "uniquely" identify and authenticate all human users

Onboard CBSs are to be provided with appropriate access control that fits to the policy of their Security Zone but does not adversely affect their primary purpose. CBSs which require strong access control may need to be secured using a strong encryption key or multi-factor authentication.

Administrator privileges are to be managed in accordance with the policy for access control, allowing only authorized and appropriately trained personnel full access to the CBS, who as part of their role in the company or onboard need to log on to systems using these privileges.

6) Least privilege principle

Any human user allowed to access CBS and networks in the scope of applicability of this Section is to have only the bare minimum privileges necessary to perform its function.

The default configuration for all new account privileges is to be set as low as possible. Wherever possible, raised privileges are to be restricted only to moments when they are needed, e.g. using only expiring privileges and one-time-use credentials. Accumulation of privileges over time is to be avoided, e.g. by regular auditing of user accounts.

d) Demonstration of compliance

1) Design phase

The systems integrator is to include the following information in the Cyber security design description:

- Location and physical access controls for the CBSs. Devices providing Human Machine Interface (HMI) for operators needing immediate access need not enforce user identification and authentication provided they are located in an area with physical access control. Such devices are to be specified.

2) Construction phase

The systems integrator is to prevent unauthorised access to the CBSs during the construction phase.

3) Commissioning phase

The systems integrator is to submit Ship cyber resilience test procedure (ref. [5.3.2]) and demonstrate the following to the Society:

- Components of the CBSs are located in areas or enclosures where physical access can be controlled to authorised personnel
- User accounts are configured according to the principles of segregation of duties and least privilege and that temporary accounts have been removed (may be omitted based on certification of CBSs as per [5.3.2]).

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

The shipowner is in the Ship cyber security and resilience program to describe the management of logical and physical access, addressing at least the following requirements in this Section:

- Physical access control (see [4.3.5] c), 1))
- Physical access control for visitors (see [4.3.4] d), 2))
- Physical access control of network access points (see [4.3.5] c), 3))
- Management of credentials (see [4.3.5] c), 5))
- Least privilege policy (see [4.3.5] c), 6))

The shipowner is in the Ship cyber security and resilience program to describe the management of confidential information, addressing at least the following requirements in this Section:

- Confidential information (see [4.2.2] c))
- Information allowed to authorized personnel (see [4.3.5] c))
- Information transmitted on the wireless network (see [4.3.6] c))

First annual survey

The shipowner is to present to the Society records or other documented evidence demonstrating implementation of the Ship cyber security and resilience program, i.e., that:

- Personnel are authorized to access the CBSs in accordance with their responsibilities
- Only authorised devices are connected to the CBSs
- Visitors are given access to the CBSs according to relevant policies and procedures
- Physical access controls are maintained and applied
- Credentials, keys, secrets, certificates, relevant CBS documentation, and other sensitive information is managed and kept confidential according to relevant policies and procedures.

Subsequent annual surveys

The shipowner is upon request by the Society to demonstrate implementation of the Ship cyber security and resilience program by presenting records or other documented evidence as specified for the first annual survey.

4.3.6 Wireless communication *(1/7/2024)*

a) Requirement

Wireless communication networks in the scope of this Section are to be designed, implemented and maintained to ensure that:

- Cyber incidents will not propagate to other control systems
- Only authorised human users will gain access to the wireless network
- Only authorised processes and devices will be allowed to communicate on the wireless network
- Information in transit on the wireless network cannot be manipulated or disclosed.

b) Rationale

Wireless networks give rise to additional or different cybersecurity risks than wired networks. This is mainly due to less physical protection of the devices and the use of the radio frequency communication.

Inadequate physical access control may lead to unauthorised personnel gaining access to the physical devices, which in turn could lead to circumventing logical access restrictions or deployment of rogue devices on the network.

Signal transmission by radio frequency introduces risks related to jamming as well as eavesdropping which in turn could cater for attacks such as Piggybacking or Evil twin attacks (see https://us-cert.cisa.gov/ncas/tips/ST05-003).

c) Requirement details

Cryptographic mechanisms such as encryption algorithms and key lengths in accordance with industry standards and best practices are to be applied to ensure integrity and confidentiality of the information transmitted on the wireless network.

Devices on the wireless network are only to communicate on the wireless network (i.e. they are not to be "dual-homed").

Wireless networks are to be designed as separate segments in accordance with [4.3.2] and protected as per [4.3.3].

Wireless access points and other devices in the network are to be installed and configured such that access to the network can be controlled.

The network device or system utilizing wireless communication is to provide the capability to identify and authenticate all users (humans, software processes or devices) engaged in that communication.

d) Demonstration of compliance

1) Design phase

The systems integrator is to include the following information in the Cyber security design description:

- Description of wireless networks in the scope of applicability of this Section and how these are implemented as separate security zones. The description is to include zone boundary devices and specify the traffic that is permitted to traverse the zone boundary (e.g. firewall rules).

2) Construction phase

The systems integrator is to prevent unauthorised access to the wireless networks during the construction phase.

3) Commissioning phase

The systems integrator is to submit Ship cyber resilience test procedure (ref. [5.3.2]) and demonstrate the following to the Society:

- Only authorised devices can access the wireless network.
- Secure wireless communication protocol is used as per approved documentation by the respective supplier (demonstrate e.g. by use of a network protocol analyser tool).

The above tests may be omitted if performed during the certification of CBSs as per [5.3.2].

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

Special survey

Subject to modifications of the wireless networks in the scope of applicability of this Section, the shipowner is to demonstrate to the Society the activities in [4.3.6] d), 3) as per the Ship cyber resilience test procedure.

4.3.7 Remote access control and communication with untrusted networks *(1/7/2024)*

a) Requirement

CBSs in scope of this Section are to be protected against unauthorized access and other cyber threats from untrusted networks.

b) Rationale

Onboard CBSs have become increasingly digitalized and connected to the internet to perform a wide variety of legitimate functions. The use of digital systems to monitor and control onboard CBSs makes them vulnerable to cyber incidents. Attackers may attempt to access onboard CBSs through connectivity with the internet and may be able to make changes that affect a CBS's operation or even achieve full control of the CBS, or attempt to download information from the ship's CBS. In addition, since use of legacy IT and OT systems that are no longer supported and/or rely on obsolete operating systems affects cyber resilience, special care should be put to relevant hardware and software installations on board to help maintain a sufficient level of cyber resilience when such systems can be remotely accessed, also keeping in mind that not all cyber incidents are a result of a deliberate attack.

c) Requirement details

User's manual is to be delivered for control of remote access to onboard IT and OT systems. Clear guidelines are to identify roles and permissions with functions.

For CBSs in the scope of applicability of this Section, no IP address is to be exposed to untrusted networks.

Communication with or via untrusted networks requires secure connections (e.g. tunnels) with endpoint authentication, protection of integrity and authentication and encryption at network or transport layer. Confidentiality is to be ensured for information that is subject to read authorization.

1) Design

CBSs in the scope of applicability of this Section are to:

- have the capability to terminate a connection from the onboard connection endpoint. Any remote access is not to be possible until explicitly accepted by a responsible role on board
- be capable of managing interruptions during remote sessions so as not to compromise the safe functionality of OT systems or the integrity and availability of data used by OT systems
- provide a logging function to record all remote access events and retain for a period of time sufficient for offline review of remote connections, e.g. after detection of a cyber incident.

2) Additional requirements for remote maintenance

When remote access is used for maintenance, the following requirements are to be complied with in addition to those in [4.3.7] c), 1):

- Documentation is to be provided to show how they connect and integrate with the shore side
- Security patches and software updates are to be tested and evaluated before they are installed to ensure they are effective and do not result in side effects or cyber events that cannot be tolerated. A confirmation report from the software supplier towards above is to be obtained, prior to undertaking remote update
- Suppliers are to provide plans for and make security updates available to the shipowner, see Sec 5, [5.1.3], [5.1.4] and [5.1.5]
- At any time, during remote maintenance activities, authorized personnel is to have the possibility to interrupt and abort the activity and roll back to a previous safe configuration of the CBS and systems involved
- Multi-factor authentication is required for any access by human users to CBS's in scope from an untrusted network
- After a configurable number of failed remote access attempts, the next attempt is to be blocked for a predetermined length of time
- If the connection to the remote maintenance location is disrupted for some reason, access to the system is to be terminated by an automatic logout function.

d) Demonstration of compliance

1) Design phase

The systems integrator is to include the following information in the Cyber security design description:

- Identification of each CBS in the scope of applicability of this Section that can be remotely accessed or that otherwise communicates through the security zone boundary with untrusted networks
- For each CBS, a description of compliance with requirements in [4.3.7], c), as applicable.

2) Construction phase

The systems integrator is to ensure that any communication with untrusted networks is only temporarily enabled and used in accordance with the requirements of this Section.

3) Commissioning phase

The systems integrator is to submit Ship cyber resilience test procedure (ref. [5.3.2]) and demonstrate the following to the Society:

- Communication with untrusted networks is secured in accordance with Sec 5, [4.3] and that the communication protocols cannot be negotiated to a less secure version (demonstrate e.g., by use of a network protocol analyzer tool).
- Remote access requires multifactor authentication of the remote user
- A limit of unsuccessful login attempts is implemented, and that a notification message is provided for the remote user before session is established
- Remote connections are to be explicitly accepted by responsible personnel on board
- Remote sessions can be manually terminated by personnel on board or that the session will automatically terminate after a period of inactivity
- Remote sessions are logged (see Sec 5, Tab 1, item 13)
- Instructions or procedures are provided by the respective product suppliers (see Sec 5, [3.1.4]).

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

The shipowner is in the Ship cyber security and resilience program to describe the management of remote access and communication with/via untrusted networks, addressing at least the following requirements in this Section:

- User's manual (see [4.3.7] c))
- Roles and permissions (see [4.3.7] c))
- Patches and updates (see [4.3.7] c), 2))
- Confirmation prior to undertaking remote software update (see [4.3.7] c), 2))
- Interrupt, abort, roll back (see [4.3.7] c), 2))

First annual survey

The shipowner is to present to the Society records or other documented evidence demonstrating implementation of the Ship cyber security and resilience program, i.e., that:

- Remote access sessions have been recorded or logged and carried out as per relevant policies and user manuals
- Installation of security patches and other software updates have been carried out in accordance with Management of change procedures and in cooperation with the supplier.

Annual survey

The shipowner is upon request by the Society to demonstrate implementation of the Ship cyber security and resilience program by presenting records or other documented evidence as specified for the first annual survey.

Special survey

The shipowner is to demonstrate to the Society the activities in [4.3.7] d), 3) as per the Ship cyber resilience test procedure.

4.3.8 Use of Mobile and Portable Devices *(1/7/2024)*

a) Requirement

The use of mobile and portable devices in CBSs in the scope of applicability of this Section is to be limited to only necessary activities and be controlled in accordance with Sec 5, Tab 1, item 10. For any CBS that cannot fully meet these requirements, the interface ports are to be physically blocked.

b) Rationale

It is generally known that CBSs can be impaired due to malware infection via a mobile or a portable device. Therefore, connection of mobile and portable devices should be carefully considered. In addition, mobile equipment that is required to be used for the operation and maintenance of the ship should be under the control of the shipowner.

c) Requirement details

Mobile and portable devices are only to be used by authorised personnel. Only authorised devices may be connected to the CBSs. All use of such devices is to be in accordance with the shipowner's policy for use of mobile and portable devices, taking into account the risk of introducing malware in the CBS.

d) Demonstration of compliance

1) Design phase

The systems integrator is to include the following information in the Cyber security design description:

- Any CBSs in the scope of applicability that do not meet the requirements in Sec 5, Tab 1, item 10, i.e., that are to have protection of interface ports by physical means such as port blockers.

2) Construction phase

The systems integrator is to ensure that use of physical interface ports in the CBSs is controlled in accordance with Sec 5, Tab 1, item 10, and that any use of such devices follows procedures to prevent malware from being introduced in the CBS.

3) Commissioning phase

The systems integrator is to submit Ship cyber resilience test procedure (ref. [5.3.2]) and demonstrate to the Society that capabilities to control use of mobile and portable devices are implemented correctly, the following countermeasures are to be demonstrated as relevant:

- Use of mobile and portable devices is restricted to authorised users
- Interface ports can only be used by specific device types
- Files cannot be transferred to the system from such devices
- Files on such devices will not be automatically executed (by disabling autorun)

- Network access is limited to specific MAC or IP addresses
- Unused interface ports are disabled
- Unused interface ports are physically blocked

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

The shipowner is in the Ship cyber security and resilience program to describe the management of mobile and portable devices, addressing at least the following requirements in this Section:

- Policy and procedures (see [4.3.5] c), 4))
- Physical block of interface ports (see [4.3.8] a))
- Use by authorized personnel (see [4.3.8] c))
- Connect only authorized devices (see [4.3.8] c))
- Consider risk of introducing malware (see [4.3.8] c))

First annual survey

The shipowner is to present to the Society records or other documented evidence demonstrating implementation of the Ship cyber security and resilience program, i.e., that:

- The use of mobile, portable or removable media is restricted to authorised personnel and follows relevant policies and procedures
- Only authorised devices are connected to the CBSs
- Means to restrict use of physical interface ports are implemented as per approved design documentation.

Subsequent annual survey

The shipowner is upon request by the Society to demonstrate implementation of the Ship cyber security and resilience program by presenting records or other documented evidence as specified for the first annual survey.

Special survey

The shipowner is to demonstrate to the Society the activities in [4.3.8] d), 3) as per the Ship cyber resilience test procedure.

4.4 Detect

4.4.1 General *(1/7/2024)*

The requirements for the Detect functional element are aimed at the development and implementation of appropriate means supporting the ability to reveal and recognize anomalous activity on CBSs and networks onboard and identify cyber incidents.

4.4.2 Network operation monitoring *(1/7/2024)*

a) Requirement

Networks in scope of this Section are to be continuously monitored, and alarms are to be generated if malfunctions or reduced/degraded capacity occurs.

b) Rationale

Cyber-attacks are becoming increasingly sophisticated, and attacks that target vulnerabilities that were unknown at the time of construction could result in incidents where the vessel is ill-prepared for the threat. To enable an early response to attacks targeting these types of unknown vulnerabilities, technology capable of detecting unusual events is required. A monitoring system that can detect anomalies in networks and that can use post-incident analysis provides the ability to appropriately respond and further recover from a cyber event.

c) Requirement details

Measures to monitor networks in the scope of applicability of this Section are to have the following capabilities:

- Monitoring and protection against excessive traffic
- Monitoring of network connections
- Monitoring and recording of device management activities
- Protection against connection of unauthorized devices
- Generate alarm if utilization of the network's bandwidth exceeds a threshold specified as abnormal by the supplier. See Sec 3, [7.3.1].

Intrusion detection systems (IDS) may be implemented, subject to the following:

- The IDS is to be qualified by the supplier of the respective CBS
- The IDS is to be passive and not activate protection functions that may affect the performance of the CBS

- Relevant personnel should be trained and qualified for using the IDS.

d) Demonstration of compliance

1) Design phase

No requirements.

2) Construction phase

No requirements.

3) Commissioning phase

The systems integrator is to specify in the Ship cyber resilience test procedure and demonstrate to the Society the network monitoring and protection mechanisms in the CBSs.

- Test that disconnected network connections will activate alarm and that the event is recorded.
- Test that abnormally high network traffic is detected, and that alarm and audit record is generated. This test may be carried on together with the test in [4.5.5] d), 3).
- Demonstrate that the CBS will respond in a safe manner to network storm scenarios, considering both unicast and broadcast messages (see also [4.3.3] d), 3))
- Demonstrate generation of audit records (logging of security-related events)
- If Intrusion detection systems are implemented, demonstrate that this is passive and will not activate protection functions that may affect intended operation of the CBSs.

The above tests may be omitted if performed during the certification of CBSs as per [5.3.2].

Any Intrusion detection systems in the CBSs in scope of applicability to be implemented is to be subject to verification by the Society. Relevant documentation is to be submitted for approval, and survey/tests are to be carried out on board.

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

The shipowner is in the Ship cyber security and resilience program to describe the management activities to detect anomalies in the CBSs and networks, addressing at least the following requirements in this Section:

- Reveal and recognize anomalous activity (see [4.4])
- Inspection of security audit records (see [4.4.2] c))
- Instructions or procedures to detect incidents (see [4.5.2] a))

The above activities may be addressed together with incident response in [4.5.2].

First annual survey

The shipowner is to present to the Society records or other documented evidence demonstrating implementation of the Ship cyber security and resilience program, i.e., that:

- The CBSs are routinely monitored for anomalies by inspection of security audit records and investigation of alerts in the CBSs.

Subsequent annual surveys

The shipowner is upon request by the Society to demonstrate implementation of the Ship cyber security and resilience program by presenting records or other documented evidence as specified for the first annual survey.

Special survey

Subject to modifications of the CBSs, the shipowner is to demonstrate to the Society the activities in [4.4.2] d), 3) as per the Ship cyber resilience test procedure.

4.4.3 Verification and diagnostic functions of CBS and networks *(1/7/2024)*

a) Requirement

CBSs and networks in the scope of applicability of this Section are to be capable to check performance and functionality of security functions required by this Section. Diagnostic functions are to provide adequate information on CBSs integrity and status for the use of the intended user and means for maintaining their functionality for a safe operation of the ship.

b) Rationale

The ability to verify intended operation of the security functions is important to support management of cyber resilience in the lifetime of the ship. Tools for diagnostic functions may comprise automatic or manual functions such as self-diagnostics capabilities of each device, or tools for network monitoring (such as ping, traceroute, ipconfig, netstat, nslookup, Wireshark, nmap, etc.).

It should be noted however that execution of diagnostic functions may sometimes impact the operational performance of the CBS.

c) Requirement details

CBSs and networks' diagnostics functionality is to be available to verify the intended operation of all required security functions during test and maintenance phases of the ship.

d) Demonstration of compliance

1) Design phase

No requirements.

2) Construction phase

No requirements.

3) Commissioning phase

The systems integrator is to submit Ship cyber resilience test procedure (ref. [5.3.2]) and demonstrate to the Society the effectiveness of the procedures for verification of security functions provided by the suppliers.

The above tests may be omitted if performed during the certification of CBSs as per [5.3.2].

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

The shipowner is in the Ship cyber security and resilience program to describe the management activities to verify correct operation of the security functions in the CBSs and networks, addressing at least the following requirements in this Section:

- Test and maintenance periods (see [4.4.3] c))
- Periodic maintenance (see [5.4.4]).

First annual survey

The shipowner is to present to the Society records or other documented evidence demonstrating implementation of the Ship cyber security and resilience program, i.e., that:

- The security functions in the CBSs are periodically tested or verified.

Subsequent annual surveys

The shipowner is upon request by the Society to demonstrate implementation of the Ship cyber security and resilience program by presenting records or other documented evidence as specified for the first annual survey.

4.5 Respond

4.5.1 General *(1/7/2024)*

The requirements for the Respond functional element are aimed at the development and implementation of appropriate means supporting the ability to minimize the impact of cyber incidents, containing the extension of possible impairment of CBSs and networks onboard.

4.5.2 Incident response plan *(1/7/2024)*

a) Requirement

An incident response plan is to be developed by the shipowner covering relevant contingencies and specifying how to react to cyber security incidents. The Incident response plan is to contain documentation of a predetermined set of instructions or procedures to detect, respond to, and limit consequences of incidents against CBSs in the scope of applicability of this Section.

b) Rationale

An incident response plan is an instrument aimed to help responsible persons respond to cyber incidents. As such, the Incident response plan is as effective as it is simple and carefully designed. When developing the Incident response plan, it is important to understand the significance of any cyber incident and prioritize response actions accordingly.

Means for maintaining as much as possible the functionality and a level of service for a safe operation of the ship, e.g. transfer active execution to a standby redundant unit, should also be indicated. Designated personnel ashore should be integrated with the ship in the event of a cyber incident.

c) Requirement details

The various stakeholders involved in the design and construction phases of the ship are to provide information to the shipowner for the preparation of the Incident Response Plan to be placed onboard at the first annual Survey. The Incident Response Plan is to be kept up-to-date (e.g. upon maintenance) during the operational life of the ship.

The Incident response plan is to provide procedures to respond to detected cyber incidents on networks by notifying the proper authority, reporting needed evidence of the incidents and taking timely corrective actions, to limit the cyber incident impact to the network segment of origin.

The incident response plan is, as a minimum, to include the following information:

- Breakpoints for the isolation of compromised systems
- A description of alarms and indicators signalling detected ongoing cyber events or abnormal symptoms caused by cyber events
- A description of expected major consequences related to cyber incidents
- Response options, prioritizing those which do not rely on either shut down or transfer to independent or local control, if any
- Independent and local control information for operating independently from the system that failed due to the cyber incident, as applicable

The Incident response plan is to be kept in hard copy in the event of complete loss of electronic devices enabling access to it.

d) Demonstration of compliance

1) Design phase

The systems integrator is to include the following information in the Cyber security design description:

- References to information provided by the suppliers (see Sec 5, [3.1.9]) that may be applied by the shipowner to establish plans for incident response.

2) Construction phase

No requirements.

3) Commissioning phase

No requirements.

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

The shipowner is in the Ship cyber security and resilience program to describe incident response plans. The plans are to cover the CBSs in scope of applicability of this Section and are to address at least the following requirements in this Section:

- Description of who, when and how to respond to cyber incidents in accordance with requirements of [4.5.2]
- Procedures or instructions for local/manual control in accordance with requirements in [4.5.3]
- Procedures or instructions for isolation of security zones in accordance with requirements in [4.5.4]
- Description of expected behaviour of the CBSs in the event of cyber incidents in accordance with requirements in [4.5.5].

First annual survey

The shipowner is to present to the Society records or other documented evidence demonstrating implementation of the Ship cyber security and resilience program, i.e., that:

- The incident response plans are available for the responsible personnel onboard
- Procedures or instructions for local/manual controls are available for responsible personnel onboard
- Procedures or instructions for disconnection/isolation of security zones are available for responsible personnel onboard
- Any cyber incidents have been responded to in accordance with the incident response plans.

Subsequent annual surveys

The shipowner is upon request by the Society to demonstrate implementation of the Ship cyber security and resilience program by presenting records or other documented evidence as specified for the first annual survey.

4.5.3 Local, independent and/or manual operation *(1/7/2024)*

a) Requirement

Any CBS needed for local backup control as required by SOLAS II-1 Regulation 31 is to be independent of the primary control system. This includes also necessary Human Machine Interface (HMI) for effective local operation.

b) Rationale

Independent local controls of machinery and equipment needed to maintain safe operation is a fundamental principle for manned vessels. The objective of this requirement has traditionally been to ensure that personnel can cope with failures and other incidents by performing manual operations in close vicinity of the machinery. Since

incidents caused by malicious cyber events should also be considered, this principle of independent local control is no less important.

c) Requirement details

The CBS for local control and monitoring is to be self-contained and not depend on communication with other CBS for its intended operation.

If communication to the remote control system or other CBS's is arranged by networks, segmentation and protection safeguards as described in [4.3.2] and [4.3.3] are to be implemented. This implies that the local control and monitoring system is to be considered a separate security zone. Notwithstanding the above, special considerations can be given to CBSs with different concepts on case by case basis

The CBS for local control and monitoring is otherwise to comply with requirements in this Section.

d) Demonstration of compliance

1) Design phase

The systems integrator is to include the following information in the Cyber security design description:

- Description of how the local controls specified in SOLAS II-1 Reg.31 are protected from cyber incidents in any connected remote or automatic control systems.

2) Construction phase

No requirements.

3) Commissioning phase

The systems integrator is to submit Ship cyber resilience test procedure (ref. [5.3.2]) and demonstrate to the Society that the required local controls in the scope of applicability of this Section needed for safety of the ship can be operated independently of any remote or automatic control systems. The tests are to be carried out by disconnecting all networks from the local control system to other systems/devices.

The above tests may be omitted if performed during the certification of CBSs as per [5.3.2].

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

Special survey

Subject to modifications of the CBSs, the shipowner is to demonstrate to the Society the activities in [4.5.3] d), 3) as per the Ship cyber resilience test procedure.

4.5.4 Network isolation *(1/7/2024)*

a) Requirement

It is to be possible to terminate network-based communication to or from a security zone.

b) Rationale

In the event that a security breach has occurred and is detected, it is likely that the incident response plan includes actions to prevent further propagation and effects of the incident. Such actions could be to isolate network segments and control systems supporting essential functions.

c) Requirement details

Where the Incident Response Plan indicates network isolation as an action to be done, it is to be possible to isolate security zones according to the indicated procedure, e.g. by operating a physical ON/OFF switch on the network device or similar actions such as disconnecting a cable to the router/firewall. There are to be available instructions and clear marking on the device that allows the personnel to isolate the network in an efficient manner.

Individual system's data dependencies that may affect function and correct operation, including safety, are to be identified, clearly showing where systems are to have compensations for data or functional inputs if isolated during a contingency.

d) Demonstration of compliance

1) Design phase

The systems integrator is to include the following information in the Cyber security design description:

- specification of how to isolate each security zone from other zones or networks. The effects of such isolation are also to be described, demonstrating that the CBSs in a security zone do not rely on data transmitted by IP-networks from other zones or networks.

2) Construction phase

No requirements.

3) Commissioning phase

The systems integrator is to submit Ship cyber resilience test procedure (ref. [5.3.2]) and demonstrate to the Society by disconnecting all networks traversing security zone boundaries, that the CBSs in the security zone will maintain adequate operational functionality without network communication with other security zones or networks.

The above tests may be omitted if performed during the certification of CBSs as per [5.3.2].

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

Special survey

Subject to modifications of the CBSs, the shipowner is to demonstrate to the Society the activities in [4.5.4] d), 3) as per the Ship cyber resilience test procedure.

4.5.5 Fallback to a minimal risk condition *(1/7/2024)*

a) Requirement

In the event of a cyber incident impairing the ability of a CBS or network in the scope of applicability of this Section to provide its intended service, the affected system or network is to fall back to a minimal risk condition, i.e. bring itself in a stable, stopped condition to reduce the risk of possible safety issues.

b) Rationale

The ability of a CBS and integrated systems to fallback to one or more minimal risk conditions to be reached in case of unexpected or unmanageable failures or events is a safety measure aimed to keep the system in a consistent, known and safe state.

Fallback to a minimal risk condition usually implies the capability of a system to abort the current operation and signal the need for assistance, and may be different depending on the environmental conditions, the voyage phase of the ship (e.g. port depart/arrival vs. open sea passage) and the events occurred.

c) Requirement details

As soon as a cyber incident affecting the CBS or network is detected, compromising the system's ability to provide the intended service as required, the system is to fall back to a condition in which a reasonably safe state can be achieved. Fall-back actions may include:

- bringing the system to a complete stop or other safe state
- disengaging the system
- transferring control to another system or human operator
- other compensating actions.

Fall-back to minimum risk conditions is to occur in a time frame adequate to keep the ship in a safe condition.

The ability of a system to fall back to a minimal risk condition is to be considered from the design phase by the supplier and the systems integrator.

d) Demonstration of compliance

1) Design phase

The systems integrator is to include the following information in the Cyber security design description:

- Specification of safe state for the control functions in the CBSs in the scope of applicability of this Section.

2) Construction phase

No requirements.

3) Commissioning phase

The systems integrator is to submit Ship cyber resilience test procedure (ref. [5.3.2]) and demonstrate to the Society that CBSs in the scope of applicability of this Section respond to cyber incidents in a safe manner (as per [4.5.5] d), 1)), e.g. by maintaining its outputs to essential services and allowing operators to carry out control and monitoring functions by alternative means. The tests are at least to include denial of service (DoS) attacks and may be done together with related test in [4.4.2] d), 3).

The above tests may be omitted if performed during the certification of CBSs as per [5.3.2].

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

Special survey

Subject to modifications of the CBSs, the shipowner is to demonstrate to the Society the activities in [4.5.5] d), 3) as per the Ship cyber resilience test procedure.

4.6 Recover

4.6.1 General *(1/7/2024)*

The requirements for the Recover functional element are aimed at the development and implementation of appropriate means supporting the ability to restore CBSs and networks onboard affected by cyber incidents.

4.6.2 Recovery plan *(1/7/2024)*

a) Requirement

A recovery plan is to be made by the shipowner to support restoring CBSs under the scope of applicability of this Section to an operational state after a disruption or failure caused by a cyber incident. Details of where assistance is available and by whom are to be part of the recovery plan.

b) Rationale

Incident response procedures are an essential part of system recovery. Responsible personnel should consider carefully and be aware of the implications of recovery actions (such as wiping of drives) and execute them carefully.

It should be noted, however, that some recovery actions may result in the destruction of evidence that could provide valuable information on the causes of an incident.

Where appropriate, external cyber incident response support should be obtained to assist in preservation of evidence whilst restoring operational capability.

c) Requirement details

The various stakeholders involved in the design and construction phases of the ship are to provide information to the shipowner for the preparation of the recovery plan to be placed onboard at the first annual Survey. The recovery plan is to be kept up-to-date (e.g. upon maintenance) during the operational life of the ship.

Recovery plans are to be easily understandable by the crew and external personnel and include essential instructions and procedures to ensure the recovery of a failed system and how to get external assistance if the support from ashore is necessary. In addition, software recovery medium or tools essential for recovery on board are to be available.

When developing recovery plans, the various systems and subsystems involved are to be specified. The following recovery objectives are also to be specified:

- System recovery: methods and procedures to recover communication capabilities are to be specified in terms of Recovery Time Objective (RTO). This is defined as the time required to recover the required communication links and processing capabilities
- Data recovery: methods and procedures to recover data necessary to restore safe state of OT systems and safe ship operation are to be specified in terms of Recovery Point Objective (RPO). This is defined as the longest period of time for which an absence of data can be tolerated.

Once the recovery objectives are defined, a list of potential cyber incidents are to be created, and the recovery procedure developed and described. Recovery plans are to include, or refer to the following information

- Instructions and procedures for restoring the failed system without disrupting the operation from the redundant, independent or local operation
- Processes and procedures for the backup and secure storage of information
- Complete and up-to-date logical network diagram
- The list of personnel responsible for restoring the failed system
- Communication procedure and list of personnel to contact for external technical support including system support vendors, network administrators, etc
- Current configuration information for all components.

The operation and navigation of the ship is to be prioritized in the plan in order to help ensure the safety of onboard personnel.

Recovery plans in hard copy onboard and ashore are to be available to personnel responsible for cyber security and who are tasked with assisting in cyber incidents.

d) Demonstration of compliance

1) Design phase

The systems integrator is to include the following information in the Cyber security design description:

- references to information provided by the suppliers (see Sec 5, [3.1.9]) that may be applied by the shipowner to establish plans to recover from cyber incidents.

2) Construction phase

No requirements.

3) Commissioning phase

The systems integrator is to submit Ship cyber resilience test procedure (ref. [5.3.2]) and demonstrate to the Society the effectiveness of the procedures and instructions provided by the suppliers to respond to cyber incidents as specified in [4.6.3] and [4.6.4].

The above tests may be omitted if performed during the certification of CBSs as per [5.3.2].

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

The shipowner is in the Ship cyber security and resilience program to describe incident recovery plans. The plans are to cover the CBSs in scope of applicability of this Section and are to address at least the following requirements in this Section:

- Description of who, when and how to restore and recover from cyber incidents in accordance with requirements in [4.6.2]
- Policy for backup addressing frequency, maintenance and testing of the backups, considering acceptable downtime, availability of alternative means for control, vendor support arrangements and criticality of the CBSs in accordance with requirements in [4.6.3]
- Reference to user manuals or procedures for backup, shutdown, reset, restore and restart of the CBSs in accordance with requirements in [4.6.3] and [4.6.4].

First annual survey

The shipowner is to present to the Society records or other documented evidence demonstrating implementation of the Ship cyber security and resilience program, i.e., that:

- Instructions and/or procedures for incident recovery are available for the responsible personnel onboard
- Equipment, tools, documentation, and/or necessary software and data needed for recovery is available for the responsible personnel onboard
- Backup of the CBSs have been taken in accordance with the policies and procedures
- Manuals and procedures for shutdown, reset, restore and restart are available for the responsible personnel onboard.

Subsequent annual survey

The shipowner is upon request by the Society to demonstrate implementation of the Ship cyber security and resilience program by presenting records or other documented evidence as specified for the first annual survey.

4.6.3 Backup and restore capability *(1/7/2024)*

a) Requirement

CBSs and networks in the scope of applicability of this Section are to have the capability to support back-up and restore in a timely, complete and safe manner. Backups are to be regularly maintained and tested.

b) Rationale

In general, the purpose of a backup and restore strategy should protect against data loss and reconstruct the database after data loss. Typically, backup administration tasks include the following: Planning and testing responses to different kinds of failures; Configuring the database environment for backup and recovery; Setting up a backup schedule; Monitoring the backup and recovery environment; Creating a database copy for long-term storage; Moving data from one database or one host to another, etc.

c) Requirement details

1) Restore capability

CBSs in the scope of applicability of this Section are to have backup and restore capabilities to enable the ship to safely regain navigational and operational state after a cyber incident.

Data are to be restorable from a secure copy or image.

Information and backup facilities are to be sufficient to recover from a cyber incident.

2) Backup

CBSs and networks in the scope of applicability of this Section are to provide backup for data. The use of offline backups is also to be considered to improve tolerance against ransomware and worms affecting online backup appliances.

Backup plans are to be developed, including scope, mode and frequency, storage medium and retention period.

d) Demonstration of compliance

1) Design phase

No requirements.

2) Construction phase

No requirements.

3) Commissioning phase

The systems integrator is to submit Ship cyber resilience test procedure (ref. [5.3.2]) and demonstrate to the Society the procedures and instructions for backup and restore provided by the suppliers for CBSs in the scope of applicability of this Section.

The above tests may be omitted if performed during the certification of CBSs as per [5.3.2].

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

Special survey

Subject to modifications of the CBSs, the shipowner is to demonstrate to the Society the activities in [4.6.3] d), 3) as per the Ship cyber resilience test procedure.

4.6.4 Controlled shutdown, reset, roll-back and restart *(1/7/2024)*

a) Requirement

CBS and networks in the scope of applicability of this Section are to be capable of controlled shutdown, reset to an initial state, roll-back to a safe state and restart from a power-off condition in such state, in order to allow fast and safe recovery from a possible impairment due to a cyber incident.

Suitable documentation on how to execute the above-mentioned operations is to be available to onboard personnel.

b) Rationale

Controlled shutdown consists in turning a CBS or network off by software function allowing other connected systems to commit/rollback pending transactions, terminating processes, closing connections, etc. leaving the entire integrated system in a safe and known state. Controlled shutdown is opposed to hard shutdown, which occurs for example when the computer is forcibly shut down by interruption of power.

While in the case of some cyber incidents hard shutdowns may be considered as a safety precaution, controlled shutdown is preferable in case of integrated systems to keep them in a consistent and known state with predictable behaviour. When standard shutdown procedures are not done, data or program and operating system files corruption may occur. In case of OT systems, the result of corruption can be instability, incorrect functioning or failure to provide the intended service.

The reset operation would typically kick off a soft boot, instructing the system to go through the process of shutting down, clear memory and reset devices to their initialized state. Depending on system considered, the reset operation might have different effects.

Rollback is an operation which returns the system to some previous state. Rollbacks are important for data and system integrity, because they mean that the system data and programs can be restored to a clean copy even after erroneous operations are performed. They are crucial for recovering from crashes ad cyber incidents, restoring the system to a consistent state.

Restarting a system and reloading a fresh image of all the software and data (e.g. after a rollback operation) from a read-only source appears to be an effective approach to recover from unexpected faults or cyber incidents. Restart operations should be however controlled in particular for integrated systems, where unexpected restart of a single component can result in inconsistent system state or unpredictable behaviour.

c) Requirement details

CBS and networks in the scope of applicability of this Section are to be capable of:

- controlled shutdown allowing other connected systems to commit/rollback pending transactions, terminating processes, closing connections, etc. leaving the entire integrated system in a safe, consistent and known state
- resetting themselves, instructing the system to go through the process of shutting down, clear memory and reset devices to their initialized state
- rolling back to a previous configuration and/or state, to restore system integrity and consistency
- restarting and reloading a fresh image of all the software and data (e.g. after a rollback operation) from a read-only source. Restart time is to be compatible with the system's intended service and is not to bring other connected systems, or the integrated system it is part of, to an inconsistent or unsafe state.

Documentation is to be available to onboard personnel on how to execute the above-mentioned operations in case of a system affected by a cyber incident.

d) Demonstration of compliance

1) Design phase

The systems integrator is to include the following information in the Cyber security design description:

- references to product manuals or procedures describing how to safely shut down, reset, restore and restart the CBSs in the scope of applicability of this Section.

2) Construction phase

No requirements.

3) Commissioning phase

The systems integrator is to submit Ship cyber resilience test procedure (ref. [5.3.2]) and demonstrate to the Society that manuals or procedures are established for shutdown, reset and restore of the CBSs in the scope of applicability of this Section. These manuals/procedures are to be provided to the shipowner.

The above tests may be omitted if performed during the certification of CBSs as per [5.3.2].

4) Operation phase

For general requirements to surveys in the operation phase, see [5.4].

Special survey

Subject to modifications of the CBSs, the shipowner is to demonstrate to the Society the activities in [4.6.4] d), 3) as per the Ship cyber resilience test procedure.

5 Demonstration of compliance

5.1 General

5.1.1 *(1/7/2024)*

Evaluation of compliance with requirements in this Section is to be carried out by the Society by assessment of documentation and survey in the relevant phases as specified in the following articles.

Documentation to be submitted by suppliers to the Society is specified in Sec 5. The approved versions of this documentation is also to be provided by the suppliers to the systems integrator as specified in Sec 5, [6.2].

Documents to be provided by the systems integrator are listed in [5.2] and [5.3].

Documents to be provided by the shipowner are listed in [5.4].

Upon delivery of the ship, the systems integrator is to provide below documentation to the shipowner:

- Documentation of the CBSs provided by the suppliers (see Sec 5, [6.2])
- Documentation produced by the systems integrator (see [5.1] and [5.2]).

See also [7] and [8] for a summary of the documents.

5.2 During design and construction phases

5.2.1 *(1/7/2024)*

The supplier is to demonstrate compliance to the Society by following the certification process specified in Sec 5, [6].

The systems integrator is to demonstrate compliance by submitting documents in the following articles to the Society for assessment.

During the design and construction phases, modifications to the design is to be carried out in accordance with the management of change (MoC) requirements in Sec 3.

5.2.2 Zones and conduit diagram *(1/7/2024)*

The content of this document is specified in [4.3.2] d), 1).

5.2.3 Cyber security design description (CSDD) *(1/7/2024)*

The content of this document is specified in articles “Design phase” for each requirement in [4].

5.2.4 Vessel asset inventory *(1/7/2024)*

The content of this document is specified in [4.2.2].

5.2.5 Risk assessment for the exclusion of CBSs *(1/7/2024)*

The content of this document is specified in [6].

5.2.6 Description of compensating countermeasures *(1/7/2024)*

If any CBS in the scope of applicability of this Section has been approved with compensating countermeasures in lieu of a requirement in Sec 5, this document is to specify the respective CBS, the lacking security capability, as well as provide a detailed description of the compensating countermeasures. See also Sec 5, [3.1.4] requiring that the supplier describes such compensating countermeasures in the system documentation.

5.3 Upon ship commissioning

5.3.1 *(1/7/2024)*

Before final commissioning of the ship, the systems integrator is to:

a) Submit updated design documentation to the Society (as-built versions of the documents in [5.2])

b) Submit Ship cyber resilience test procedure to the Society describing how to demonstrate compliance with this Section by testing and/or analytic evaluation

c) Carry out testing, witnessed by the Society, in accordance with the approved Ship cyber resilience test procedure.

5.3.2 Ship cyber resilience test procedure *(1/7/2024)*

The content of this document is specified for the Commissioning phase in each article “Demonstration of compliance” in [4].

For each CBS, the required inherent security capabilities and configuration thereof are verified and tested in the certification process of each CBS (see Sec 5). Testing of such security functions may be omitted if specified in the respective article "Commissioning phase", on the condition that these security functions have been successfully tested during the certification of the CBS as per Sec 5. Nevertheless, all tests are to be included in the Ship cyber resilience test procedure and the decision to omit tests will be taken by the Society. Tests may generally not be omitted if findings/comments are carried over from the certification process to the commissioning phase, if the respective requirements have been met by compensating countermeasures, or due to other reasons such as modifications of the CBS after the certification process.

The Ship cyber resilience test procedure is also to specify how to test any compensating countermeasures described in [5.2.3].

The Ship cyber resilience test procedure is to include means to update status and record findings during the testing, and specify the following information:

- Necessary test setup (i.e. to ensure the test can be repeated with the same expected result)
- Test equipment
- Initial condition(s)
- Test methodology, detailed test steps
- Expected results and acceptance criteria.

Before submitting the Ship cyber resilience test procedure to the Society, the systems integrator is to verify that the information is updated and placed under change management; that it is aligned with the latest configurations of CBSs and networks connecting such systems together onboard the ship and to other CBSs not onboard (e.g., ashore); and that the tests documented are sufficiently detailed as to allow verification of the installation and operation of measures adopted for the fulfilment of relevant requirements on the final configuration of CBSs and networks onboard.

The systems integrator is to document verification tests or assessments of security controls and measures in the fully integrated ship, maintaining change management for configurations, and noting in the documented test results where safety conditions may be affected by specific circumstances or failures addressed in the Ship cyber resilience test procedure.

The testing is to be carried out on board in accordance with the approved Ship cyber resilience test procedure after other commissioning activities for the CBSs are completed. The Society may request execution of additional tests.

5.4 During the operational life of the ship

5.4.1 *(1/7/2024)*

After the ship has been delivered to the shipowner, the shipowner is to manage technical and organisational security countermeasures by establishing and implementing processes as specified in this Section.

Modifications to the CBSs in scope of applicability of this Section are to be carried out in accordance with the management of change (MoC) requirements in Sec 3. This includes keeping documentation of the CBSs up to date.

The shipowner, with the support of suppliers, is to keep the Ship cyber resilience test procedure up to date and aligned with the CBSs onboard the ship and the networks connecting such systems to each other and to other CBSs not

onboard (e.g. ashore). The shipowner is to update the Ship cyber resilience test procedure considering the changes occurred on CBSs and networks onboard, possible emerging risks related to such changes, new threats, new vulnerabilities and other possible changes in the ship's operational environment.

The shipowner is to prepare and implement operational procedures, provide periodic training and carry out drills for the onboard personnel and other concerned personnel ashore to familiarize them with the CBSs onboard the ship and the networks connecting such systems to each other and to other CBSs not onboard (e.g. ashore), and to properly manage the measures adopted for the fulfilment of requirements.

The shipowner, with the support of supplier, is to keep the measures adopted for the fulfilment of requirements up to date, e.g. by periodic maintenance of hardware and software of CBSs onboard the ship and the networks connecting such systems.

The shipowner is to retain onboard a copy of results of execution of tests and an updated Ship cyber resilience test procedure and make them available to the Society.

5.4.2 **First annual survey** *(1/7/2024)*

In due time before the first annual survey of the ship, the shipowner is to submit to the Society a Ship cyber security and resilience program documenting management of cyber security and cyber resilience of the CBSs in the scope of applicability of this Section.

The Ship cyber security and resilience program is to include policies, procedures, plans and/or other information documenting the processes/activities specified in articles "Demonstration of compliance" in [4] of this Section.

After the Society has approved the Ship cyber security and resilience program, the shipowner is in the first annual survey to demonstrate compliance by presenting records or other documented evidence of implementation of the processes described in the approved Ship cyber security and resilience program.

Change of vessel management company will require a new verification of the Ship cyber security and resilience program.

5.4.3 **Subsequent annual surveys** *(1/7/2024)*

In the subsequent annual surveys of the ship, the shipowner is upon request by the Society to demonstrate implementation of the Ship cyber security and resilience program.

5.4.4 **Special survey** *(1/7/2024)*

Upon renewal of the ship's classification certificate, the shipowner is to carry out testing witnessed by the Society in accordance with the Ship cyber resilience test procedure. Certain security safeguards are to be demonstrated at Special survey whereas other need only be carried out upon request by the Society based on modifications to the CBSs as specified in articles "Operation phase" in [4].

6 Risk assessment for exclusion of CBS from the application of requirements

6.1 Requirement

6.1.1 *(1/7/2024)*

A risk assessment is to be carried out in case any of the CBSs falling under the scope of applicability of this Section is excluded from the application of relevant requirements. The risk assessment is to provide evidence of the acceptable risk level associated to the excluded CBSs.

6.2 Rationale

6.2.1 *(1/7/2024)*

Exclusion of a CBS falling under the scope of applicability of this Section from the application of relevant requirements needs to be duly justified and documented. Such exclusion can be accepted by the Society only if evidence is given that the risk level associated to the operation of the CBS is under an acceptable threshold by means of specific risk assessment.

The risk assessment is to be based on available knowledge bases and experience on similar designs, if any, considering the CBS category, connectivity and the functional requirements and specifications of the ship and of the CBS. Cyber threat information from internal and external sources may be used to gain a better understanding of the likelihood and impact of cybersecurity events.

6.3 Requirement details

6.3.1 *(1/7/2024)*

Risk assessment is to be made and kept up to date by the System integrator during the design and building phase considering possible variations of the original design and newly discovered threats and/or vulnerabilities not known from the beginning.

During the operational life of the ship, the shipowner is to update the risk assessment considering the constant changes in the cyber scenario and new weaknesses identified in CBS onboard in a process of continuous improvement. Should new risks be identified, the shipowner is to update existing, or implement new risk mitigation measures.

Should the changes in the cyber scenario be such as to elevate the risk level associated to the CBS under examination above the acceptable risk threshold, the shipowner is to inform the Society and submit the updated risk assessment for evaluation.

The envisaged operational environments for the CBS under examination are to be analyzed in the risk assessment to discern the likelihood of cyber incidents and the impact they could have on the human safety, the safety of the vessel or the marine environment, taking into account the category of the CBS. The attack surface is to be analyzed, taking into account the connectivity of the CBS, possible interfaces for portable devices, logical access restrictions, etc.

Emerging risks related to the specific configuration of the CBS under examination are to be also identified. In the risk assessment, the following elements are to be considered:

- Asset vulnerabilities
- Threats, both internal and external
- Potential impacts of cyber incidents affecting the asset on human safety, safety of the vessel and/or threat to the environment
- Possible effects related to integration of systems, or interfaces among systems, including systems not onboard (e.g. if remote access to onboard systems is provided).

6.4 Acceptance criteria

6.4.1 *(1/7/2024)*

Exclusion of a CBS falling under the scope of applicability of this Section from the application of relevant requirements can be accepted by the Society only if assurance is given that the operation of the CBS has no impact on the safety of operations regarding cyber risk. The said exclusion may be accepted for a CBS which does not fully meet the additional criteria listed below but is provided with a rational explanation together with evidence and is found satisfactory by the Society. The Society may also require submittal of additional documents to consider the said exclusion.

The following criteria are to be met to exclude a system from the scope of applicability of this Section:

a) The CBS is to be isolated (i.e, have no IP-network connections to other systems or networks)

b) The CBS is to have no accessible physical interface ports. Unused interfaces are to be logically disabled. It is not to be possible to connect unauthorised devices to the CBS

c) The CBS is to be located in areas to which physical access is controlled

d) The CBS is not to be an integrated control system serving multiple ship functions as specified in the scope of applicability of this Section (see [1.4]).

The following additional criteria should be considered for the evaluation of risk level acceptability:

a) The CBS should not serve ship functions of category III

b) Known vulnerabilities, threats, potential impacts deriving from a cyber incident affecting the CBS have been duly considered in the risk assessment

c) The attack surface for the CBS is minimized, having considered its complexity, connectivity, physical and logical access points, including wireless access points.

7 Summary of actions and documents

7.1 General

7.1.1 *(1/7/2024)*

Tab 2 provide a summary of actions and documents.

Table 2 *(1/7/2024)*

Document	Systems integrator			Shipowner			
	Design	**Construction**	**Commissioning**	**Operation**	**1st AS (5)**	**AS (6)**	**SS (7)**
Approved supplier documentation [5]		Maintain **(3)**	Maintain	Maintain			
Zones and conduit diagram [5.2.2]	Submit **(2)**	Maintain	Maintain	Maintain			
Cyber security design description [5.2.3]	Submit	Maintain	Maintain	Maintain			
Vessel asset inventory [5.2.4]	Submit	Maintain	Maintain	Maintain			
Risk assessment for the exclusion of CBSs [5.2.5] (1)	Submit	Maintain	Maintain	Maintain			
Description of compensating countermeasures [5.2.6] (1)	Submit	Maintain	Maintain	Maintain			
Ship cyber resilience test procedure [5.3.2]		Submit	Demonstrate **(4)**	Maintain			Demonstrate
Ship cyber security and resilience program [5.4.2] • Management of change (MoC) [4.2.2] d), 4) • Management of software updates [4.2.2] d), 4) • Management of firewalls [4.3.2] d), 4) • Management of malware protection [4.3.4] d), 4) • Management of access control [4.3.5] d), 4) • Management of confidential information [4.3.5] d), 4) • Management of remote access [4.3.7] d), 4) • Management of mobile and portable devices [4.3.8] d), 4) • Detection of security anomalies [4.4.2] d), 4) • Verification of security functions [4.4.3] d), 4) • Incident response plans [4.5.2] d), 4) • Recovery plans [4.6.2] d), 4)				Maintain	Submit	Demonstrate	

Notes:

(1) if applicable

(2) The stakeholder is to submit the document to the Society for verification and approval of compliance with requirements in this Section

(3) The stakeholder is to keep the document updated in accordance with procedure for management of change (MoC). Updated document and change management records are to be submitted to the Society as per Sec 3

(4) The stakeholder is to demonstrate compliance to the Society in accordance with the approved document

(5) First annual survey

(6) Annual survey

(7) Special survey

8 Summary of requirements and documents

8.1 General

8.1.1 *(1/7/2024)*

Tab 3 to Tab 20 provides a summary of requirements and documents.

Table 3 *(1/7/2024)*

Vessel asset inventory (see [4.2.2])		
CBS security capabilities	Provide documentation of product security updates	Sec 5, [5.1.3]
	Provide documentation of dependent component security updates	Sec 5, [5.1.4]
CBS documentation	Provide security updates	Sec 5, [5.1.5]
	CBS asset inventory	Sec 5, [3.1.2]
	Management of change plan	Sec 5, [3.1.10]
Vessel design documentation	Vessel asset inventory	[4.2.2] d), 1)
Ship cyber security and resilience program	Management of change	[4.2.2] d), 4)
	Management of software updates	[4.2.2] d), 4)

Table 4 *(1/7/2024)*

Security zones and network segmentation (see [4.3.2])		
CBS security capabilities		
CBS documentation	Topology diagrams	Sec 5, [3.1.3]
Vessel design documentation	Zones and conduit diagram	[4.3.2] d), 1)
	Design description	[4.3.2] d), 1)
	Ship cyber resilience test procedure	[4.3.2] d), 3)
Ship cyber security and resilience program	Management of security zone boundary devices [e.g., firewalls)	[4.3.2] d), 4)

Table 5 *(1/7/2024)*

Network protection safeguards (see [4.3.3])		
CBS security capabilities	Denial of service (DoS) protection (item 24) Deterministic output (item 20)	Sec 5, [4.2]
CBS documentation	Description of security capabilities	Sec 5, [3.1.4]
	Test procedure for security capabilities	Sec 5, [3.1.5]
Vessel design documentation	Ship cyber resilience test procedure	[4.3.3] d), 3)
Ship cyber security and resilience program		

Table 6 *(1/7/2024)*

Antivirus, antimalware, antispam and other protections from malicious code (see [4.3.4])		
CBS security capabilities	Malicious code protection (#18)	Sec 5, [4.2]
CBS documentation	Description of security capabilities Test procedure for security capabilities	Sec 5, [3.1.4] Sec 5, [3.1.5]
Vessel design documentation	Design description Ship cyber resilience test procedure	[4.3.4] d), 1) [4.3.4]d), 3)
Ship cyber security and resilience program	Management of malware protection	[4.3.4] d), 4)

Table 7 *(1/7/2024)*

Access control (see [4.3.5])		
CBS security capabilities	Human user id. and auth. (#1) Account management (#2) Identifier management (#3) Authenticator management (#4) Authorisation enforcement (#8)	Sec 5, [4.2]
CBS documentation	Description of security capabilities Test procedure for security capabilities	Sec 5, [3.1.4] Sec 5, [3.1.5]
Vessel design documentation	Design description Ship cyber resilience test procedure	[4.3.5] d), 1) [4.3.5] d), 3)
Ship cyber security and resilience program	Management of confidential information	[4.3.5] d), 4)
	Management of logical and physical access	[4.3.5] d), 4)

Table 8 *(1/7/2024)*

Wireless communication (see [4.3.6])		
CBS security capabilities	Wireless access management (#5) Wireless use control (#9)	Sec 5, [4.2]
CBS documentation	Description of security capabilities Test procedure for security capabilities	Sec 5, [3.1.4] Sec 5, [3.1.5]
Vessel design documentation	Design description Ship cyber resilience test procedure	[4.3.6] d), 1) [4.3.6] d), 3)
Ship cyber security and resilience program		

Table 9 *(1/7/2024)*

Remote access control and communication with untrusted networks (see [4.3.7])		
CBS security capabilities	Multifactor authentication (#31) Process / device id. and auth. (#32) Unsuccessful login attempts (#33) System use notification (#34) Access via untrusted networks (#35) Explicit access request approval (#36) Remote session termination (#37) Cryptographic integrity protection (#38) Input validation (#39) Session integrity (#40) Invalidation of session ID (#41)	Sec 5, [4.3]
CBS documentation	Description of security capabilities Test procedure for security capabilities	Sec 5, [3.1.4] Sec 5, [3.1.5]
Vessel design documentation	Design description Ship cyber resilience test procedure	[4.3.7] d), 1) [4.3.7] d), 3)
Ship cyber security and resilience program	Management of remote access and communication with/via untrusted networks	[4.3.7] d), 4)

Table 10 *(1/7/2024)*

U**se of mobile and portable devices (see [4.3.8])**		
CBS security capabilities	Use control for portable devices (#10)	Sec 5, [4.2]
CBS documentation	Description of security capabilities Test procedure for security capabilities	Sec 5, [3.1.4] Sec 5, [3.1.5]
Vessel design documentation	Design description Ship cyber resilience test procedure	[4.3.8] d), 1) [4.3.8] d), 3)
Ship cyber security and resilience program	Management of mobile and portable devices	[4.3.8] d), 4)

Table 11 *(1/7/2024)*

Network operation monitoring (see [4.4.2])		
CBS security capabilities	Use control for portable devices (#10) Auditable events (#13) Denial of service (DoS) protection (#24)	Sec 5, [4.2]
	Alarm excessive bandwidth use	Sec 3, [7.3.1]
CBS documentation	Description of security capabilities Test procedure for security capabilities	Sec 5, [3.1.4] Sec 5, [3.1.5]
Vessel design documentation	Ship cyber resilience test procedure	[4.4.2] d), 3)
Ship cyber security and resilience program	Incident response plans	[4.4.2] d), 4)

Table 12 *(1/7/2024)*

Verification and diagnostic functions of CBS and networks (see [4.4.3])		
CBS security capabilities	Security function verification (#19)	Sec 5, [4.2]
CBS documentation	Description of security capabilities Test procedure for security capabilities Plans for maintenance and verification	Sec 5, [3.1.4] Sec 5, [3.1.5] Sec 5, [3.1.8]
Vessel design documentation	Ship cyber resilience test procedure	[4.4.3] d), 3)
Ship cyber security and resilience program	Verification of security functions	[4.4.3] d), 4)

Table 13 *(1/7/2024)*

Incident response plan (see [4.5.2])		
CBS security capabilities		
CBS documentation	Description of security capabilities Test procedure for security capabilities Information supporting incident response and recovery plans	Sec 5, [3.1.4] Sec 5, [3.1.5] Sec 5, [3.1.9]
Vessel design documentation	Design description Ship cyber resilience test procedure	[4.5.2] d), 1) [4.5.2] d), 3)
Ship cyber security and resilience program	Incident response plans	[4.5.2] d), 4)

Table 14 *(1/7/2024)*

Local, independent and/or manual operation (see [4.5.3])		
CBS security capabilities		
CBS documentation	Description of security capabilities Test procedure for security capabilities Information supporting incident response and recovery plans	Sec 5, [3.1.4] Sec 5, [3.1.5] Sec 5, [3.1.9]
Vessel design documentation	Design description Ship cyber resilience test procedure	[4.5.3] d), 1) [4.5.3] d), 3)
Ship cyber security and resilience program	Incident response plans	[4.5.2] d), 4)

Table 15 *(1/7/2024)*

Network isolation (see [4.5.4])		
CBS security capabilities		
CBS documentation	Description of security capabilities Test procedure for security capabilities Information supporting incident response and recovery plans	Sec 5, [3.1.4] Sec 5, [3.1.5] Sec 5, [3.1.9]
Vessel design documentation	Design description Ship cyber resilience test procedure	[4.5.4] d), 1) [4.5.4] d), 3)
Ship cyber security and resilience program	Incident response plans	[4.5.2] d), 4)

Table 16 *(1/7/2024)*

Fallback to a minimal risk condition (see [4.5.5])		
CBS security capabilities	Deterministic output (#20)	Sec 5, [4.2]
CBS documentation	Description of security capabilities Test procedure for security capabilities Information supporting incident response and recovery plans	Sec 5, [3.1.4] Sec 5, [3.1.5] Sec 5, [3.1.9]
Vessel design documentation	Design description Ship cyber resilience test procedure	[4.5.5] d), 1) [4.5.5] d), 3)
Ship cyber security and resilience program	Incident response plans	[4.5.2] d), 4)

Table 17 *(1/7/2024)*

Recovery plan (see [4.6.2])		
CBS security capabilities		
CBS documentation	Description of security capabilities Test procedure for security capabilities Information supporting incident response and recovery plans	Sec 5, [3.1.4] Sec 5, [3.1.5] Sec 5, [3.1.9]
Vessel design documentation	Design description Ship cyber resilience test procedure	[4.6.2] d), 1) [4.6.2] d), 3)
Ship cyber security and resilience program	Recovery plans	[4.6.2] d), 4)

Table 18 *(1/7/2024)*

Backup and restore capability (see [4.6.3])		
CBS security capabilities	System backup (#26) System recovery and reconstitution (#27)	Sec 5, [4.2]
CBS documentation	Description of security capabilities Test procedure for security capabilities Information supporting incident response and recovery plans	Sec 5, [3.1.4] Sec 5, [3.1.5] Sec 5, [3.1.9]
Vessel design documentation	Ship cyber resilience test procedure	[4.6.3] d), 3)
Ship cyber security and resilience program	Recovery plan	[4.6.2] d), 4)

Table 19 *(1/7/2024)*

Controlled shutdown, reset, restore and restart (see [4.6.4])		
CBS security capabilities	System recovery and reconstitution (#27)	Sec 5, [4.2]
CBS documentation	Description of security capabilities Test procedure for security capabilities Information supporting incident response and recovery plans	Sec 5, [3.1.4] Sec 5, [3.1.5] Sec 5, [3.1.9]
Vessel design documentation	Design description Ship cyber resilience test procedure	[4.6.4] d), 1) [4.6.4] d), 3)
Ship cyber security and resilience program	Recovery plans	[4.6.2] d), 4)

Table 20 *(1/7/2024)*

Risk assessment for exclusion of CBS from the application of requirements (see [6])		
CBS security capabilities		
CBS documentation		
Vessel design documentation	Risk assessment for the exclusion of CBSs	[5.2.5]
Ship cyber security and resilience program		

SECTION 5 CYBER RESILIENCE OF ON-BOARD SYSTEMS AND EQUIPMENT

1 General

1.1 Introduction

1.1.1 *(1/7/2024)*

This Section specifies requirements for cyber resilience of on-board systems and equipment.

1.2 Limitations

1.2.1 *(1/7/2024)*

This Section does not cover environmental performance for the system hardware and the functionality of the software.

1.3 Scope of applicability

1.3.1 *(1/7/2024)*

The requirements specified in this Section are applicable to computer based systems specified in Sec 4 for the following types of vessels:

- **Mandatory requirements for**:
  - Passenger ships (including passenger high-speed craft) engaged in international voyages
  - Cargo ships of 500 GT and upwards engaged in international voyages
  - High speed craft of 500 GT and upwards engaged in international voyage
  - Mobile offshore drilling units of 500 GT and upwards
  - Self-propelled mobile offshore units engaged in construction (i.e. wind turbine installation maintenance and repair, crane units, drilling tenders, accommodation, etc).
- **Non-mandatory guidance to**:
  - Ships of war and troopships
  - Cargo ships less than 500 gross tonnage
  - Vessels not propelled by mechanical means
  - Wooden ships of primitive build
  - Passenger yachts (passengers not more than 12)
  - Pleasure yachts not engaged in trade
  - Fishing vessels
  - Site specific offshore installations (i.e. FPSOs, FSUs, etc).

For navigation and radiocommunication systems, the application of IEC 61162-460 or other equivalent standards in lieu of the required security capabilities in [4] may be accepted by the Society, on the condition that requirements in Sec 4 are complied with.

1.3.2 Information and Communication Technology (ICT) *(1/7/2024)*

Attention is made to the following requirements on Computer Based Systems and Cyber Resilience:

- Sec 3 “Computer based systems” which includes requirements for design, construction, commissioning and maintenance of computer-based systems where they depend on software for the proper achievement of their functions. The requirements in Sec 3 focus on the functionality of the software and on the hardware supporting the software which provide control, alarm, monitoring, safety or internal communication functions
- Sec 4 “Cyber resilience of Ships” which includes requirements for cyber resilience of ships, with the purpose of providing technical means to stakeholders which would lead to cyber resilient ships
- IACS Recommendation 166 on Cyber Resilience: non-mandatory recommended technical requirements that stakeholders may reference and apply to assist with the delivery of cyber resilient ships, whose resilience can be maintained throughout their service life.

1.4 Definitions & Abbreviations

1.4.1 *(1/7/2024)*

Attack surface: the set of all possible points where an unauthorized user can access a system, cause an effect on or extract data from. The attack surface comprises two categories: digital and physical. The digital attack surface encompasses all the hardware and software that connect to an organization's network. These include applications, code, ports, servers and websites. The physical attack surface comprises all endpoint devices that an attacker can gain physical access to, such as desktop computers, hard drives, laptops, mobile phones, removable drives and carelessly discarded hardware.

Authentication: provision of assurance that a claimed characteristic of an identity is correct.

Compensating countermeasure: an alternate solution to a countermeasure employed in lieu of or in addition to inherent security capabilities to satisfy one or more security requirements.

Computer Based System (CBS): A programmable electronic device, or interoperable set of programmable electronic devices, organized to achieve one or more specified purposes such as collection, processing, maintenance, use, sharing, dissemination, or disposition of information. CBS on-board include IT and OT systems. A CBS may be a combination of subsystems connected via network. On-board CBS may be connected directly or via public means of communications (e.g. Internet) to ashore CBSs, other vessels' CBS and/or other facilities.

Computer Network : a connection between two or more computers for the purpose of communicating data electronically by means of agreed communication protocols.

Control: means of managing risk, including policies, procedures, guidelines, practices or organizational structures, which can be administrative, technical, management, or legal in nature.

Cyber incident: an event resulting from any offensive cyber manoeuvre, either intentional or unintentional, that targets or affects one or more CBS onboard, which actually or potentially results in adverse consequences to an onboard system, network and computer or the information that they process, store or transmit, and which may require a response action to mitigate the consequences. Cyber incidents include unauthorized access, misuse, modification, destruction or improper disclosure of the information generated, archived or used in onboard CBS or transported in the networks connecting such systems. Cyber incidents do not include system failures.

Cyber resilience: the capability to reduce the occurrence and mitigating the effects of incidents arising from the disruption or impairment of operational technology (OT) used for the safe operation of a ship, which potentially lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.

Defence in depth: information Security strategy integrating people, technology, and operations capabilities to establish variable barriers across multiple layers and missions of the organization.

Essential Systems: Computer Based System contributing to the provision of services essential for propulsion and steering, and safety of the ship. Essential services comprise "Primary Essential Services" and "Secondary Essential Services": Primary Essential Services are those services which need to be in continuous operation to maintain propulsion and steering; Secondary Essential Services are those services which need not necessarily be in continuous operation to maintain propulsion and steering but which are necessary for maintaining the vessel's safety.

Firewall: a logical or physical barrier that monitors and controls incoming and outgoing network traffic controlled via predefined rules.

Firmware: software embedded in electronic devices that provide control, monitoring and data manipulation of engineered products and systems. These are normally self-contained and not accessible to user manipulation.

Hardening: hardening is the practice of reducing a system's vulnerability by reducing its attack surface.

Information Technology (IT): devices, software and associated networking focusing on the use of data as information, as opposed to Operational Technology (OT).

Integrated system: a system combining a number of interacting sub-systems and/or equipment organized to achieve one or more specified purposes.

Network switch (Switch): a device that connects devices together on a computer network, by using packet switching to receive, process and forward data to the destination device.

Offensive cyber manoeuvre: actions that result in denial, degradation, disruption, destruction, or manipulation of OT or IT systems.

Operational technology (OT): devices, sensors, software and associated networking that monitor and control onboard systems. Operational technology systems may be thought of as focusing on the use of data to control or monitor physical processes.

OT system: computer based systems, which provide control, alarm, monitoring, safety or internal communication functions.

Patches: software designed to update installed software or supporting data to address security vulnerabilities and other bugs or improve operating systems or applications.

Protocols: a common set of rules and signals that computers on the network use to communicate. Protocols allow to perform data communication, network management and security. Onboard networks usually implement protocols based on TCP/IP stacks or various field buses.

Recovery: develop and implement the appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a cyber security event. The Recovery function supports timely return to normal operations to reduce the impact from a cyber security event.

Supplier: a manufacturer or provider of hardware and/or software products, system components or equipment (hardware or software) comprising of the application, embedded devices, network devices, host devices etc. working together as system or a subsystem. The Supplier is responsible for providing programmable devices, sub-systems or systems to the System Integrator.

System: combination of interacting programmable devices and/or sub-systems organized to achieve one or more specified purposes.

System Categories (I, II, III): system categories based on their effects on system functionality, which are defined in Sec 3.

System Integrator: the specific person or organization responsible for the integration of systems and products provided by suppliers into the system invoked by the requirements in the ship specifications and for providing the integrated system. The system integrator may also be responsible for integration of systems in the ship. Until vessel delivery, this role is to be taken by the Shipyard unless an alternative organization is specifically contracted/assigned this responsibility.

Untrusted network: any network outside the scope of applicability of this Section.

1.5 Requirements and Credits

1.5.1 *(1/7/2024)*

The requirements in this Section are to be applied in conjunction with the applicable ones in Sec 3, Sec 4 and Sec 8.

The following credits may also be considered:

- IACS Rec 166 (Corr.1 2020): Recommendation on Cyber Resilience
- IEC 62443-3-3 (2013): Industrial communication networks – Network and system security. Part 3-3: System security requirements and security levels
- IEC 62443-4-1 (2018): Security for industrial automation and control systems Part 4-1: Secure product development lifecycle requirements.

2 Security Philosophy

2.1 Systems and Equipment

2.1.1 *(1/7/2024)*

A System can consist of group of hardware and software enabling safe, secure and reliable operation of a process. Typical example could be Engine control system, DP system, etc.

2.1.2 *(1/7/2024)*

Equipment may be one of the following:

- Network devices (i.e. routers, managed switches)
- Security devices (i.e. firewall, Intrusion Detection System)
- Computers (i.e. workstation, servers)
- Automation devices (i.e. Programmable Logic Controllers)
- Virtual machine cloud-hosted.

2.2 Cyber Resilience

2.2.1 *(1/7/2024)*
The cyber resilience requirements in [4] will be applicable for all systems in scope of Sec 4 as applicable. Additional requirements related to interface with untrusted networks will only apply for systems where such connectivity is designed.

2.3 Essential Systems Availability

2.3.1 *(1/7/2024)*
Security measures for Essential system are not to adversely affect the systems availability.

2.3.2 *(1/7/2024)*
Implementation of security measures is not to cause loss of safety functions, loss of control functions, loss of monitoring functions or loss of other functions which could result in health, safety and environmental consequences.

2.3.3 *(1/7/2024)*
The system is to be adequately designed to allow the ship to continue its mission critical operations in a manner that ensures the confidentiality, integrity, and availability of the data necessary for safety of the vessel, its systems, personnel and cargo.

2.4 Compensating Countermeasures

2.4.1 *(1/7/2024)*
Compensating countermeasure may be employed in lieu of or in addition to inherent security capabilities to satisfy one or more security requirements.

Compensating countermeasure(s) is(are) to meet the intent and rigor of the original stated requirement considering the referenced standards as well as the differences between each requirement and the related items in the standards, and follow the principles specified in [3.1.4].

3 Documentation

3.1 CBS Documentation

3.1.1 *(1/7/2024)*
The following documents are to be submitted to the Society for review and approval in accordance with the requirements in this Section; see also [6.2].

3.1.2 **CBS asset inventory** *(1/1/2026)*
The CBS asset inventory is to include the information below:

- List of hardware components (e.g., host devices, embedded devices, network devices) Name
- Brand/manufacturer
- Model/type
- Short description of functionality/purpose
- Physical interfaces (e.g., network, serial)
- Name/type of system software (e.g., operating system, firmware)
- Version and patch level of system software
- Supported communication protocols

List of software components (e.g., application software, utility software)

- The hardware component where it is installed
- Brand/manufacturer
- Model/type
- Short description of functionality/purpose
- Version of software

An example of the "Vessel Asset Inventory Template" form to be filled in and submitted by the shipyard/integrator during vessel construction and maintained through the vessel's operational life by the Shipowner, is available in IACS Rec.190 and published on the Society website.

3.1.3 Topology diagrams *(1/7/2024)*

The physical topology diagram is to illustrate the physical architecture of the system. It is to be possible to identify the hardware components in the CBS asset inventory. The diagram is to illustrate the following:

- All endpoints and network devices, including identification of redundant units
- Communication cables (networks, serial links), including communication with I/O units
- Communication cables to other networks or systems

The logical topology diagram is to illustrate the data flow between components in the system. The diagram is to illustrate the following:

- Communication endpoints (e.g. workstations, controllers, servers)
- Network devices (switches, routers, firewalls)
- Physical and virtual computers
- Physical and virtual communication paths
- Communication protocols

One combined topology diagram may be acceptable if all requested information can be clearly illustrated.

3.1.4 Description of security capabilities *(1/7/2024)*

This document is to describe how the CBS with its hardware and software components meets the required security capabilities in [4.2].

Any network interfaces to other CBSs in the scope of applicability of Sec 4 is to be described. The description is to include destination CBS, data flows, and communication protocols. If the System integrator has allocated the destination CBS to another security zone, components providing protection of the security zone boundary (see Sec 4, [4.3.3] a)) are to be described in detail if delivered as part of the CBS.

Any network interfaces to other systems or networks outside the scope of applicability of Sec 4 (untrusted networks) are to be described. The description is to specify compliance with the additional security capabilities in [4.3], and include relevant procedures or instructions for the crew. Components providing protection of the security zone boundary (see Sec 4, [4.3.3] a)) are to be described in detail if delivered as part of the CBS.

A separate chapter is to be designated for each requirement. All hardware and software components in the system are to be addressed in the description, as relevant.

If any requirement is not fully met, this is to be specified in the description, and compensating countermeasures are to be proposed. The compensating countermeasures should:

- Protect against the same threats as the original requirement
- Provide an equal level of protection as the original requirement
- Not be a security control that is required by other requirements in this Section
- Not introduce higher security risk.

Any supporting documents (e.g. OEM information) necessary to verify compliance with the requirements are to be referenced in the description and submitted.

3.1.5 Test procedure of security capabilities *(1/7/2024)*

This document is to describe how to demonstrate by testing that the system complies with the requirements in [4.2] and [4.3], including any compensating countermeasures. Demonstration of compliance by analytic evaluation may be specially considered. The procedure is to include a separate chapter for each applicable requirement and describe:

- Necessary test setup (i.e. to ensure the test can be repeated with the same expected result)
- Test equipment
- Initial condition(s)
- Test methodology, detailed test steps
- Expected results and acceptance criteria

The procedure is to also include means to update test results and record findings during the testing.

3.1.6 Security configuration guidelines *(1/7/2024)*

This document is to describe recommended configuration settings of the security capabilities and specify default values. The objective is to ensure the security capabilities are implemented in accordance with Sec 4 and any specifications by the System integrator (e.g. user accounts, authorisation, password policies, safe state of machinery, firewall rules, etc.)

The document is to serve as basis for verification of item no. 29 in Tab 1.

3.1.7 Secure development lifecycle documents *(1/7/2024)*

This documentation is to be submitted to the Society upon request and is to describe the supplier's processes and controls in accordance with requirements for secure development lifecycle in [5]. Software updates and patching are to be described. The document is to prepare the Society for survey as per [6.3.5].

3.1.8 Plans for maintenance and verification of the CBS *(1/7/2024)*

This documentation is to be submitted to the Society upon request and is to include procedures for security-related maintenance and testing of the system. The document is to include instructions for how the user can verify correct operation of the system's security functions as required by item no.19 in Tab 1.

3.1.9 Information supporting the owner's incident response and recovery plan *(1/7/2024)*

This documentation is to be submitted to the Society upon request and is to include procedures or instructions allowing the user to accomplish the following:

- Local independent control (see Sec 4, [4.5.3])
- Network isolation (see Sec 4, [4.5.4])
- Forensics by use of audit records (see Tab 1, item no.13)
- Deterministic output (see Sec 4, [4.5.5] and Tab 1, item no. 20)
- Backup (see Tab 1, item no. 26)
- Restore (see Tab 1, item no. 27)
- Controlled shutdown, reset, roll-back and restart (see Sec 4, [4.6.4]).

3.1.10 Management of change plan *(1/7/2024)*

This documentation is to be submitted to the Society upon request. It is expected that this procedure is not specific for cyber security and is also required by Sec 3.

3.1.11 Test reports *(1/7/2024)*

CBSs with Type approval certificate covering the security capabilities of this Section may be exempted from survey by the Society. However, test reports signed by the supplier are to be submitted to the Society, demonstrating that the supplier has completed design, construction, testing, configuration, and hardening as would otherwise be verified by the Society in survey (see [6.3]).

4 System Requirements

4.1 General

4.1.1 *(1/7/2024)*

This Article specifies the required security capabilities for CBSs in the scope specified in [1.3].

The requirements in this Article are based on the selected requirements in IEC 62443-3-3. To determine the full content, rationale and relevant guidance for each requirement, the reader should consult the referenced standard.

4.2 Required security capabilities

4.2.1 *(1/7/2024)*

The following security capabilities are required for all CBSs in the scope specified in [1.3].

Table 1 *(1/7/2024)*

Item No	Objective	Requirements
Protect against casual or coincidental access by unauthenticated entities		
1	Human user identification and authentication	The CBS is to identify and authenticate all human users who can access the system directly or through interfaces (IEC 62443-3-3/SR 1.1)
2	Account management	The CBS is to provide the capability to support the management of all accounts by authorized users, including adding, activating, modifying, disabling and removing account (IEC 62443-3-3/SR 1.3)
3	Identifier management	The CBS is to provide the capability to support the management of identifiers by user, group and role. (IEC 62443-3-3/SR 1.4)

Item No	Objective	Requirements
4	Authenticator management	The CBS is to provide the capability to: - Initialize authenticator content - Change all default authenticators upon control system installation - Change/refresh all authenticators - Protect all authenticators from unauthorized disclosure and modification when stored and transmitted. (IEC 62443-3-3/SR 1.5)
5	Wireless access management	The CBS is to provide the capability to identify and authenticate all users (humans, software processes or devices) engaged in wireless communication (IEC 62443-3-3/SR 1.6)
6	Strength of password-based authentication	The CBS is to provide the capability to enforce configurable password strength based on minimum length and variety of character types. (IEC 62443-3-3/SR 1.7)
7	Authenticator feedback	The CBS is to obscure feedback during the authentication process. (IEC 62443-3-3/SR 1.10)
Protect against casual or coincidental misuse		
8	Authorization enforcement	On all interfaces, human users are to be assigned authorizations in accordance with the principles of segregation of duties and least privilege. (IEC 62443-3-3/SR 2.1)
9	Wireless use control	The CBS is to provide the capability to authorize, monitor and enforce usage restrictions for wireless connectivity to the system according to commonly accepted security industry practices (IEC 62443-3-3/SR 2.2)
10	Use control for portable and mobile devices	When the CBS supports use of portable and mobile devices, the system is to include the capability to: (1) a) Limit the use of portable and mobile devices only to those permitted by design b) Restrict code and data transfer to/from portable and mobile devices (IEC 62443-3-3/SR 2.3)
11	Mobile code	The CBS is to control the use of mobile code such as java scripts, ActiveX and PDF. (IEC 62443-3-3/SR 2.4)
12	Session lock	The CBS is to be able to prevent further access after a configurable time of inactivity or following activation of manual session lock. (IEC 62443-3-3/SR 2.5)
13	Auditable events	The CBS is to generate audit records relevant to security for at least the following events: access control, operating system events, backup and restore events, configuration changes, loss of communication. (IEC 62443-3-3/SR 2.8)
14	Audit storage capacity	The CBS is to provide the capability to allocate audit record storage capacity according to commonly recognized recommendations for log management. Auditing mechanisms are to be implemented to reduce the likelihood of such capacity being exceeded. (IEC 62443-3-3/SR 2.9)
15	Response to audit processing failures	The CBS is to provide the capability to prevent loss of essential services and functions in the event of an audit processing failure. (IEC 62443-3-3/SR 2.10)
16	Timestamps	The CBS is to timestamp audit records. (IEC 62443-3-3/SR 2.11)
Protect the integrity of the CBS against casual or coincidental manipulation		
17	Communication integrity	The CBS is to protect the integrity of transmitted information. (2) (IEC 62443-3-3/SR 3.1)

Item No	Objective	Requirements
18	Malicious code protection	The CBS is to provide capability to implement suitable protection measures to prevent, detect and mitigate the effects due to malicious code or unauthorized software. It is to have the feature for updating the protection mechanisms (IEC 62443-3-3/SR 3.2)
19	Security functionality verification	The CBS is to provide the capability to support verification of the intended operation of security functions and report when anomalies occur during maintenance (IEC 62443-3-3/SR 3.3)
20	Deterministic output	The CBS is to provide the capability to set outputs to a predetermined state if normal operation cannot be maintained as a result of an attack. The predetermined state could be: - Unpowered state, - Last-known value, or - Fixed value (IEC 62443-3-3/SR 3.6)
Prevent the unauthorized disclosure of information via eavesdropping or casual exposure		
21	Information confidentiality	The CBS is to provide the capability to protect the confidentiality of information for which explicit read authorization is supported, whether at rest or in transit. (3) (IEC 62443-3-3/SR 4.1)
22	Use of cryptography	If cryptography is used, the CBS is to use cryptographic algorithms, key sizes and mechanisms according to commonly accepted security industry practices and recommendations. (IEC 62443-3-3/SR 4.3)
Monitor the operation of the CBS and respond to incidents		
23	Audit log accessibility	The CBS is to provide the capability for accessing audit logs on read only basis by authorized humans and/or tools. (IEC 62443-3-3/SR 6.1)
Ensure that the control system operates reliably under normal production conditions		
24	Denial of service protection	The CBS is to provide the minimum capability to maintain essential functions during DoS events. (4) (IEC 62443-3-3/SR 7.1)
25	Resource management	The CBS is to provide the capability to limit the use of resources by security functions to prevent resource exhaustion. (IEC 62443-3-3/SR 7.2)
26	System backup	The identity and location of critical files and the ability to conduct backups of user-level and system-level information (including system state information) is to be supported by the CBS without affecting normal operations (IEC 62443-3-3/SR 7.3)
27	System recovery and reconstitution	The CBS is to provide the capability to be recovered and reconstituted to a known secure state after a disruption or failure. (IEC 62443-3-3/SR 7.4)
28	Alternative power source	The CBS is to provide the capability to switch to and from an alternative power source without affecting the existing security state or a documented degraded mode. (IEC 62443-3-3/SR 7.5)
29	Network and security configuration settings	The CBS traffic is to provide the capability to be configured according to recommended network and security configurations as described in guidelines provided by the supplier. The CBS is to provide an interface to the currently deployed network and security configuration settings. (IEC 62443-3-3/SR 7.6)

Item No	Objective	Requirements
30	Least Functionality	The installation, the availability and the access rights of the following are to be limited to the strict needs of the functions provided by the CBS: - operating systems software components, processes and services - network services, ports, protocols, routes and hosts accesses and any software (IEC 62443-3-3/SR 7.7)
Notes: **(1)** Port limits / blockers (and silicone) could be accepted for a specific system **(2)** Cryptographic mechanisms are to be employed for wireless networks **(3)** For wireless network, cryptographic mechanisms are to be employed to protect confidentiality of all information in transit **(4)** It is acceptable that the CBS may operate in a degraded mode upon DoS events, but it is not to fail in a manner which may cause hazardous situations. Overload-based DoS events should be considered, i.e. where the networks capacity is attempted flooded, and where the resources of a computer is attempted consumed.		

4.3 Additional security capabilities

4.3.1 *(1/7/2024)*

The following additional security capabilities are required for CBSs with network communication to untrusted networks (i.e. interface to any networks outside the scope of Sec 4).

CBSs with communication traversing the boundaries of security zones are to also meet requirements for network segmentation and zone boundary protection in Sec 4, [4.3.2] and Sec 4, [4.3.3].

Table 2 *(1/7/2024)*

Item No	Objective	Requirements
31	Multifactor authentication for human users	Multifactor authentication is required for human users when accessing the CBS from or via an untrusted network. (IEC 62443-3-3/SR 1.1, RE 2)
32	Software process and device identification and authentication	The CBS is to identify and authenticate software processes and devices (IEC 62443-3-3/SR 1.2)
33	Unsuccessful login attempts	The CBS is to enforce a limit of consecutive invalid login attempts from untrusted networks during a specified time period. (IEC 62443-3-3/SR 1.11)
34	System use notification	The CBS is to provide the capability to display a system use notification message before authenticating. The system use notification message is to be configurable by authorized personnel. (IEC 62443-3-3/SR 1.12)
35	Access via Untrusted Networks	Any access to the CBS from or via untrusted networks is to be monitored and controlled. (IEC 62443-3-3/SR 1.13)
36	Explicit access request approval	The CBS is to deny access from or via untrusted networks unless explicitly approved by authorized personnel on board. (IEC 62443-3-3/SR 1.13, RE1)
37	Remote session termination	The CBS is to provide the capability to terminate a remote session either automatically after a configurable time period of inactivity or manually by the user who initiated the session. (IEC 62443-3-3/SR 2.6)
38	Cryptographic integrity protection	The CBS is to employ cryptographic mechanisms to recognize changes to information during communication with or via untrusted networks. (IEC 62443-3-3/SR 3.1, RE1)
39	Input validation	The CBS is to validate the syntax, length and content of any input data via untrusted networks that is used as process control input or input that directly impacts the action of the CBS. (IEC 62443-3-3/SR 3.5)

Item No	Objective	Requirements
40	Session integrity	The CBS is to protect the integrity of sessions. Invalid session IDs are to be rejected. (IEC 62443-3-3/SR 3.8)
41	Invalidation of session IDs after session termination	The system is to invalidate session IDs upon user logout or other session termination (including browser sessions). (IEC 62443-3-3/SR 3.8, RE1)

5 Secure Development Lifecycle Requirements

5.1 General

5.1.1 *(1/7/2024)*

A Secure Development Lifecycle (SDLC) broadly addressing security aspects in following stages is to be followed for the development of systems or equipment

- Requirement analysis phase
- Design phase
- Implementation phase
- Verification phase
- Release phase
- Maintenance Phase
- End of life phase

A document, is to be produced that records how the security aspects have been addressed in above phases and is to at minimum integrate controlled processes as set out in below [5.1.2] to [5.1.8]. The said document is required to be submitted to the Society for review and approval.

5.1.2 IEC 62443-4-1/SM-8 *(1/7/2024)*

The manufacturer is to have procedural and technical controls in place to protect private keys used for code signing, if applicable, from unauthorized access or modification.

5.1.3 IEC 62443-4-1/SUM-2 *(1/7/2024)*

A process is to be employed to ensure that documentation about product security updates is made available to users (which could be through establishing a cyber security point of contact or periodic publication which can be accessed by the user) that includes but is not limited to:

a) The product version number(s) to which the security patch applies

b) Instructions on how to apply approved patches manually and via an automated process

c) Description of any impacts that applying the patch to the product can have, including reboot

d) Instructions on how to verify that an approved patch has been applied

e) Risks of not applying the patch and mediations that can be used for patches that are not approved or deployed by the asset owner.

5.1.4 IEC 62443-4-1/SUM-3 *(1/7/2024)*

A process is to be employed to ensure that documentation about dependent component or operating system security updates is available to users that includes but is not limited to:

a) Stating whether the product is compatible with the dependent component or operating system security update

5.1.5 IEC 62443-4-1/SUM-4 *(1/7/2024)*

A process is to be employed to ensure that security updates for all supported products and product versions are made available to product users in a manner that facilitates verification that the security patch is authentic.

IACS supplement: The manufacturer is to have QA process to test the updates before releasing.

5.1.6 IEC 62443-4-1/SG-1 *(1/7/2024)*

A process is to exist to create product documentation that describes the security defence in depth strategy for the product to support installation, operation and maintenance that includes:

a) Security capabilities implemented by the product and their role in the defence in depth strategy

b) Threats addressed by the defence in depth strategy

c) Product user mitigation strategies for known security risks associated with the product, including risks associated with legacy code.

5.1.7 IEC 62443-4-1/SG-2 *(1/7/2024)*

A process is to be employed to create product user documentation that describes the security defence in depth measures expected to be provided by the external environment in which the product is to be used.

5.1.8 IEC 62443-4-1/SG-3 *(1/7/2024)*

A process is to be employed to create product user documentation that includes guidelines for hardening the product when installing and maintaining the product. The guidelines are to include, but are not limited to, instructions, rationale and recommendations for the following:

a) Integration of the product, including third-party components, with its product security context

b) Integration of the product's application programming interfaces/protocols with user applications

c) Applying and maintaining the product's defence in depth strategy

d) Configuration and use of security options/capabilities in support of local security policies, and for each security option/capability:

   1) its contribution to the product's defence in depth strategy

   2) descriptions of configurable and default values that include how each affects security along with any potential impact each has on work practices

   3) setting/changing/deleting its value.

e) Instructions and recommendations for the use of all security-related tools and utilities that support administration, monitoring, incident handling and evaluation of the security of the product

f) Instructions and recommendations for periodic security maintenance activities

g) Instructions for reporting security incidents for the product to the supplier

h) Description of the security best practices for maintenance and administration of the product.

6 Demonstration of compliance

6.1 General

6.1.1 *(1/7/2024)*

Suppliers are to in cooperation with the System integrator determine if this Section is mandatory for the CBS, see Fig 1.

Compliance with security requirements is to be demonstrated as indicated in Fig 2. This classification process is ship-specific and is to result in a System certificate.

Type approval is voluntary and applies for CBSs that are standard and routinely manufactured. See Sec 3 for definition of System certification and Type approval.

The process in Fig 1 and Fig 2 applies also if other equivalent standards are applied for navigation and radiocommunication equipment (see [1.3]). In such case:

- the process in Fig 1 illustrates if the equivalent standard is mandatory (in lieu of this Section)
- the process in Fig 2 illustrates that the certification process is lessened if the CBS has been type approved in accordance with the equivalent standard.

Figure 1 *(1/7/2024)*

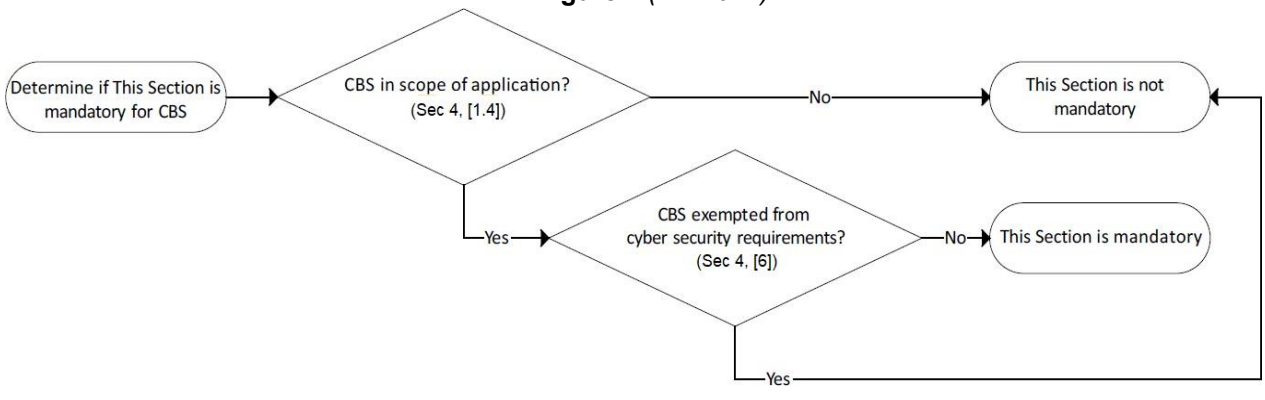
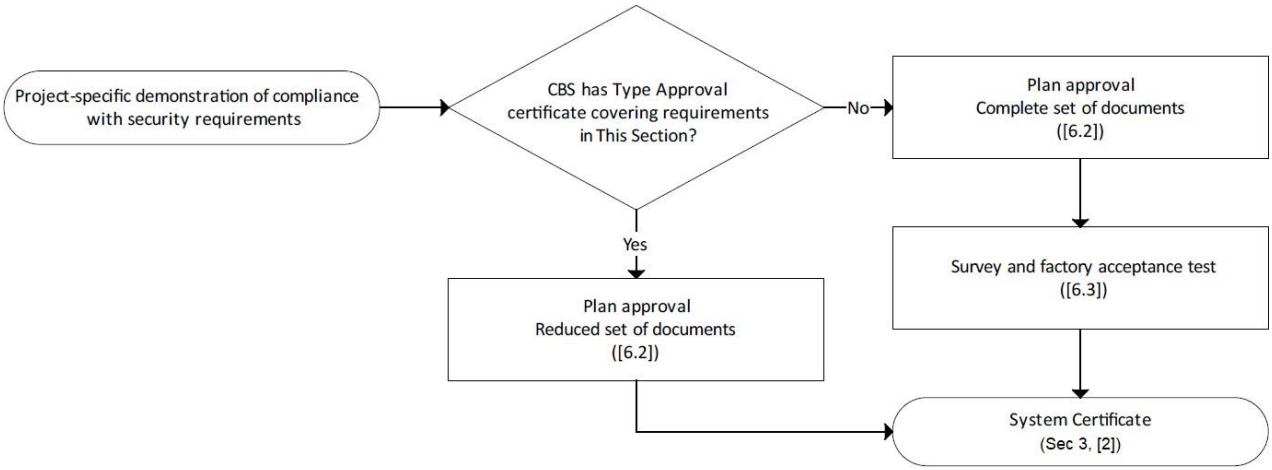


Figure 2 *(1/7/2024)*



6.2 Plan approval

6.2.1 *(1/7/2024)*

Plan approval is assessment of documents of a CBS intended for a specific vessel. The documents in [5] are required to be submitted by the supplier. The documents are to enable the Society to verify compliance with requirements in this Section.

If the CBS holds a valid Type approval certificate covering the requirements of this Section, subject to approval by the Society, the supplier may submit a reduced set of vessel-specific documents to the Society (see Tab 3).

The approved version of the documents is to be included in the delivery of the CBS to the system integrator.

6.3 Survey and factory acceptance test

6.3.1 *(1/7/2024)*

Survey and factory acceptance testing (FAT) is a vessel-specific verification activity required for CBSs that do not hold a valid Type approval certificate covering the requirements of this Section.

The objective of the survey and FAT is to demonstrate by testing and/or analytic evaluation that the CBS complies with applicable requirements in this Section. The survey and FAT are to be carried out at the supplier's premises or at other works having the adequate apparatus for testing and inspection.

After completed plan approval and survey/FAT, the Society will issue a System certificate that is to accompany the CBS upon delivery to the system integrator.

The following subsections specify the survey and FAT activities.

6.3.2 General survey items *(1/7/2024)*

The supplier is to demonstrate that design, construction, and internal testing has been completed.

It is to also be demonstrated that the system to be delivered is correctly represented by the approved documentation. This is to be done by inspecting the system and comparing the components and arrangement/architecture with the asset inventory (see [3.1.2]) and the topology diagrams (see [3.1.3]).

6.3.3 Test of security capabilities *(1/7/2024)*

The supplier is to test the required security capabilities on the system to be delivered. The tests are to be carried out in accordance with the approved test procedure in [3.1.5] and be witnessed/accepted by the Surveyor.

The tests is to provide the Surveyor with reasonable assurance that all requirements are met. This implies that testing of identical components is normally not required.

6.3.4 Correct configuration of security capabilities *(1/7/2024)*

The supplier is to test/demonstrate for the class surveyor that security settings in the system's components have been configured in accordance with the configuration guidelines in [3.1.6]. This demonstration may be carried out in conjunction with testing of the security capabilities.

The security settings are to be documented in a report, e.g. a ship-specific instance of the configuration guidelines.

6.3.5 Secure development lifecycle *(1/7/2024)*

The supplier is to, in accordance with documentation in [3.1.7], demonstrate compliance with requirements for secure development lifecycle in [5].

a) Controls for private keys (IEC 62443-4-1/SM-8)

This requirement applies if the system includes software that is digitally signed for the purpose of enabling the user to verify its authenticity.

The supplier is to present management system documentation substantiating that policies, procedures and technical controls are in place to protect generation, storage and use of private keys used for code signing from unauthorized access.

The policies and procedures are to address roles, responsibilities and work processes. The technical controls are to include e.g. physical access restrictions and cryptographic hardware (e.g. Hardware security module) for storage of the private key.

b) Security update documentation (IEC 62443-4-1/SUM-2)

The supplier is to present management system documentation substantiating that a process is established in the organization to ensure security updates are informed to the users. The information to the users are to include the items listed in [5.1.3].

c) Dependent component security update documentation (IEC 62443-4-1/SUM-3)

The supplier is to present management system documentation, as required by [5.1.4], substantiating that a process is established in the organization to ensure users are informed whether the system is compatible with updated versions of acquired software in the system (new versions/patches of operating system or firmware). The information are to address how to manage risks related to not applying the updated acquired software.

d) Security update delivery (IEC 62443-4-1/SUM-4)

The supplier is to present management system documentation, as required by [5.1.5], substantiating that a process is established in the organization ensuring that system security updates are made available to users, and describing how the user may verify the authenticity of the updated software.

e) Product defence in depth (IEC 62443-4-1/SG-1)

The supplier is to present management system documentation, as required by [5.1.6], substantiating that a process is established in the organization to document a strategy for defence-in-depth measures to mitigate security threats to software in the CBS during installation, maintenance and operation.

Examples of threats could be installation of unauthorised software, weaknesses in the patching process, tampering with software in the operational phase of the ship.

f) Defence in depth measures expected in the environment (IEC 62443-4-1/SG-2)

The supplier is to present management system documentation, as required by [5.1.7], substantiating that a process is established in the organization to document defence-in-depth measures expected to be provided by the external environment, such as physical arrangement, policies and procedures.

g) Security hardening guidelines (IEC 62443-4-1/SG-3)

The supplier is to present management system documentation, as required by [5.1.8], substantiating that a process is established in the organization to ensure that hardening guidelines are produced for the system.

The guidelines are to specify how to reduce vulnerabilities in the system by removal/prohibiting/disabling of unnecessary software, accounts, services, etc.

Table 3 : Documents to be submitted *(1/7/2024)*

No.	I/A **(1)**	Document	Requirements
1	A **(2)**, **(3)**	CBS asset inventory (see [3.1.2])	To be incorporated in Vessel asset inventory (see Sec 4, [4.2.2])
2	A **(2)**, **(3)**	Topology diagrams (see [3.1.3])	Enabling System integrator to design security zones and conduits (see Sec 4, [4.3.2])
(1) A = to be submitted for approval; I = to be submitted for information. **(2)** Required for CBS without type approved security capabilities **(3)** Required for CBS with type approved security capabilities			

No.	I/A **(1)**	Document	Requirements
3	A **(2)**	Description of security capabilities (see [3.1.4])	Required security capabilities (see [4.2])
4			Additional security capabilities, if applicable (see [4.3])
5	A **(2)**	Test procedure for security capabilities (see [3.1.5])	Required security capabilities (see [4.2])
6			Additional security capabilities, if applicable (see [4.3])
7	I **(2)**	Security configuration guidelines (see [3.1.6])	Network and security configuration settings (see Tab 1, item 29)
8	A **(2)**	Secure development lifecycle (see [3.1.7])	SDLC requirements (see [5])
9	I **(2)**	Plans for maintenance and verification (see [3.1.8])	Security functionality verification (see Tab 1, item 19)
10	I **(2)**	Information supporting incident response and recovery plans (see [3.1.9])	Auditable events (see Tab 1, item 13)
11	I **(2)**		Deterministic output (see Tab 1, item 20)
12	I **(2)**		System backup (see Tab 1, item 26)
13	I **(2)**		System recovery and reconstitution (see Tab 1, item 27)
14	I **(2)**	Management of change plan (see [3.1.10])	Management of change process (see Sec 3)
15	I **(3)**	Test reports (see [3.1.11])	Configuration of security capabilities and hardening (see [3.1.6] and [5.1.8])

(1) A = to be submitted for approval;
I = to be submitted for information.

(2) Required for CBS without type approved security capabilities

(3) Required for CBS with type approved security capabilities

SECTION 6 CONSTRUCTIONAL REQUIREMENTS

1 General

1.1 Construction

1.1.1 Automation systems are to be so constructed as:

- to withstand the environmental conditions, as defined in Ch 2, 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 Sec 8.

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 access to replaceable parts
- 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 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 Chapter 2 and Chapter 3.

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 2, 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 Chapter 2.

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 Chapter 2.

3 Pneumatic systems

3.1 General requirements

3.1.1 Pneumatic automation systems are to comply with Ch 1, Sec 10, [14].

3.1.2 Pneumatic circuits of automation systems are to be independent of any other pneumatic circuit on board.

4 Hydraulic systems

4.1 General requirements

4.1.1 Hydraulic automation systems are to comply with Ch 1, Sec 10, [14].

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 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 wheelhouse, all lighted instruments of consoles are to be dimmable, where necessary.

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 7 INSTALLATION REQUIREMENTS

1 General

1.1 General requirements

1.1.1 Automation systems are to be installed taking into account:

- the maintenance requirements (test and replacement of systems or components)
- the influence of EMI. The IEC 60533 standard is to be taken as guidance
- the environmental conditions corresponding to the location in accordance with Ch 2, Sec 1 and Ch 2, 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 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 Pressure elements

2.3.1 Three-way valves or other suitable arrangements are to be installed to permit functional testing of pressure elements, such as pressure sensors, pressure switches or pressure gauges, without stopping the installation.

2.3.2 In specific applications, where high pulsations of pressure are likely to occur, a damping element, such as a capillary tube or equivalent, is to be installed.

2.4 Level switches

2.4.1 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 2, 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 2, 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 Chapter 2. 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 Installation and marking

4.1.1 For installation of piping circuits used for automation purposes, see the requirements in Ch 1, Sec 10.

4.1.2 As far as practicable, piping containing liquids is not to be installed in or adjacent to electrical enclosures (see Sec 6, [2.1.2]).

4.1.3 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.

SECTION 8 TESTING

1 General

1.1 Commissioning

1.1.1 Automation systems are to be tested for type approval, acceptance or commissioning, 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 [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 commissioned when installed on board and prior to sea trials, to verify their performance and adaptation on site, according to [4].

2 Type approval

2.1 General

2.1.1 *(1/1/2016)*

This test specification for type approval is applicable, but not confined, to electrical, electronic and programmable equipment intended for (see Note 1a)):

- control, monitoring, alarm and protection systems for use in ships
- internal communication.

Note 1:

a) These test requirements are harmonised with IEC 60092-504 “Electrical Installations in Ships -Part 504: Special features - Control and Instrumentation” and IEC 60533 “Electrical and electronic installations in ships - Electromagnetic compatibility”. Electrical and electronic equipment on board ships, required neither by the Rules nor by International Conventions, liable to cause electromagnetic disturbance are to be of type which fulfill the test requirements of test specification items 19 and 20 of Tab 1.

b) Functional test, as used in Tab 1, is a simplified test sufficient to verify that the equipment under test (EUT) has not suffered any deterioration caused by the individual environmental tests and not a complete performance test as required in item 2 of Tab 1.

2.1.2 The necessary documents to be submitted, prior to type testing, are listed in 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 *(1/1/2002)*

These tests are to demonstrate the ability of the equipment to function as intended under the specified testing conditions.

The extent of the testing, i.e. the selection and sequence of tests and the number of pieces to be tested is to be determined upon examination and evaluation of the equipment or component subject to testing giving due regard to its intended use.

Equipment is to be tested in its normal position unless otherwise specified in the test specification.

The relevant tests are listed in Tab 1.

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.

Table 1 : Type tests *(1/1/2026)*

No.	Test	Procedure **(1)**	Test parameters	Other information
1	Visual inspection			• conformance to drawings, design data.
2	Performance test	Manufacturer performance test programme based upon specification and relevant Rule requirements. When the EUT is required to comply with an international performance standard, e.g. protection relays, verification of requirements in the standard are to be part of the performance testing required in this initial test and subsequent performance tests after environmental testing where required in this Tab 1.	• standard atmosphere condition • 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 system or equipment • checking of self-monitoring features • checking of specified protection against an access to the memory • checking against effect an erroneous use of control elements in the case of computer systems
3	External power supply failure		• 3 interruptions during 5 minutes • switching- off time 30 s each case	• The time of 5 minutes may be exceeded if the equipment under test needs a longer time for start up, e.g. booting sequence • For equipment which requires booting, one additional power supply interruption during booting to be performed Verification of: • equipment behaviour upon loss and restoration of supply; • possible corruption of programme or data held in programmable electronic systems, where applicable.

No.	Test	Procedure **(1)**	Test parameters	Other information
4	Power supply variations a) Electric		AC SUPPLY Combination 1: Voltage variation permanent; Frequency variation permanent 2: + 6%; + 5% 3: + 6%; – 5% 4: – 10%; – 5% – 10%; + 5% voltage transient 1,5 s frequency transient 5 s 5: %; % 6: + 20%; + 10% – 20%; – 10%	
			DC SUPPLY Voltage tolerance continuous: ± 10% Voltage cyclic variation: 5% Voltage ripple: 10% Electric battery supply: • +30% to –25% for equipment connected to charging battery or as determined by the charging/discharging characteristics, including ripple voltage from the charging device; • +20% to –25% for equipment not connected to the battery during charging	
	b) Pneumatic and hydraulic		Pressure: ± 20% Duration: 15 minutes	
5	Dry heat (see **(2)**)	IEC 60068-2-2 Test Bb for non-heat dissipating equipment	• Temperature: 55°C ± 2°C Duration: 16 hours, or • Temperature: 70°C ± 2°C Duration: 16 hours	• equipment operating during conditioning and testing • functional test (see [2.1.1] Note 1b)) during the last hour at the test temperature • for equipment specified for increased temperature the dry heat test is to be conducted at the agreed test temperature and duration.
		IEC 60068-2-2 Test Be for heat dissipating equipment	• Temperature: 55°C ± 2°C Duration: 16 hours, or • Temperature: 70°C ± 2°C Duration: 16 hours	• equipment operating during conditioning and testing with cooling system on if provided • functional test (see [2.1.1] Note 1b)) during the last hour at the test temperature • for equipment specified for increased temperature the dry heat test is to be conducted at the agreed test temperature and duration

No.	Test	Procedure **(1)**	Test parameters	Other information
6	Damp heat	IEC 60068-2-30 Test D_b	Temperature: 55°C Humidity: 95% Duration: 2 cycles 2 x (12 + 12 hours)	• measurement of insulation resistance before test • the test is to start with 25°C ± 3°C and at least 95% humidity • 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; duration of the second cycle can be extended due to more convenient management of the functional test • recovery at standard atmosphere conditions • insulation resistance measurements and performance test

7	Vibration	IEC 60068-2-6 Test F_c	• 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: More severe conditions may exist for example on exhaust manifolds or fuel oil injection systems of diesel engines. For equipment specified for increased vibration levels the vibration test is to be conducted at the agreed vibration level, frequency range and duration. Values may be required to be in these cases 40 Hz to 2000 Hz - acceleration: ± 10,0 g at 600°C,duration 90 min.
				• duration in case of no resonance condition 90 minutes at 30 Hz;
				• duration at each resonance frequency at which $Q \geq 2$ is recorded - 90 minutes;
				• during the vibration test, functional tests are to be carried out;
				• tests to be carried out in three mutually perpendicular planes;
				• it is recommended as a guidance that Q does not exceed 5.
				• where sweep test is to be carried out instead of the discrete frequency test and a number of resonant frequencies are detected close to each other, duration of the test is to be 120 min. Sweep over a restricted frequency range between 0,8 and 1,2 times the critical frequencies can be used where appropriate.
				Note: Critical frequency is a frequency at which the equipment being tested may exhibit:
				  • malfunction and/or performance deterioration
				  • mechanical resonances and/or other response effects occur, e.g. chatter

No.	Test	Procedure **(1)**	Test parameters	Other information
8	Inclination	IEC 60092-504	Static 22,5° Dynamic 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. 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. On ships for the carriage of liquified gases and chemicals, the emergency power supply is to remain operational with the ship flooded up to a maximum final athwart ship inclination of 30°. (see 1983 IGC Code, clause 2.9.2.2, 2014 IGC Code, clause 2.7.2.2, IBC Code, clause 2.9.3.2). Note: These inclination tests are normally not required for equipment with no moving parts
9	Insulation resistance	Rated supply voltage voltage U_n(V) (V) $U_n \leq 65$ $U_n > 65$ Test voltage D.C. 2 x U_n min. 24 500	Minimum insulation resistance before test: 10 MΩ after test: 1,0 MΩ 100 MΩ 10 MΩ	For high voltage equipment, reference is made to Ch 2, Sec 13. • insulation resistance test is to be carried out before and after: damp heat test, cold test and salt mist test, high voltage test; • between all circuits and earth; and where appropriate • between the phases. Note: Certain components e.g. for EMC protection may be required to be disconnected for this test.

No.	Test	Procedure **(1)**	Test parameters	Other information
10	High voltage	Rated voltage U_n (V) Up to 65 66 to 250 251 to 500 501 to 690	Test voltage (V) (A.C. voltage 50 or 60Hz) 2 x U_n + 500 1500 2000 2500	For high voltage equipment, reference is made to Ch 2, Sec 13. • 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
11	Cold	IEC 60068-2-1	• Temperature: +5°C ± 3°C Duration: 2 hours, or • Temperature: –25°C ± 3°C Duration: 2 hours (see **(3)**)	• 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 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 performance test 4 to 6h after recovery (see **(4)**) • on completion of exposure, the equipment shall be examined to verify that deterioration or corrosion (if any) is superficial in nature
13	Electrostatic discharge	IEC 61000-4-2	Contact discharge: 6 kV Air discharge: 2kV, 4kV, 8 kV Interval between single discharges: 1 s. No. of pulses: 10 per polarity According to test level 3	• 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 **(5)**)

No.	Test	Procedure **(1)**	Test parameters	Other information
14	Electromagnetic field	IEC 61000-4-3 or IEC 61000-4-3+ AMD1+AMD2	Frequency range: 80 MHz 6 GHz Modulation**: 80% AM at 1000Hz Field strength: 10V/m Frequency sweep rate: $\leq 1{,}5.10^{-3}$ decades/s (or 1% / 3 s) According to test level 3	• 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 **(6)**). ** If, for tests of equipment, an input signal with a modulation frequency of 1000 Hz is necessary, a modulation frequency of 400 Hz may be chosen • If an equipment is intended to receive radio signals for the purpose of radio communication (e.g. wi-fi router, remote radio controller), then the immunity limits at its communication frequency do not apply, subject to the provisions “Specific requirements for wireless data links” in Sec 3.
15	Conducted low frequency		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, min 3 V rms Max 2 W D.C.: • Frequency range: 50 Hz - 10 kHz • Test voltage (rms) :10% of supply max. 2 W	• to simulate distortions in the power supply system generated for instance, by electronic consumers and coupled in as harmonics • performance criterion A (see **(6)**) • See Figure in Notes in this Table • to keep max. 2W, the voltage of the test signal may be lower.
16	Conducted Radio Frequency	IEC 61000-4-6	AC, DC, I/O ports and signal/control lines: 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 test level 2	• Equipment design and the choice of materials is to simulate electromagnetic fields coupled as high frequency into the test specimen via the connecting lines • performance criterion A (see **(6)**). *** If, for tests of equipment, an input signal with a modulation frequency of 1000 Hz is necessary, a modulation frequency of 400 Hz may be chosen

No.	Test	Procedure **(1)**	Test parameters	Other information
17	Electrical Fast Transients / Burst	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 on I/O data control and communication ports (coupling clamp) Pulse period: 300 ms Burst duration: 15 ms Duration/polarity: 5 min According to test level 3	• 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 **(5)**)
18	Surge	IEC 61000-4-5+AMD1	Test applicable to AC and DC power ports Open-circuit voltage: Pulse rise time: 1,2 µs ((front time) Pulse width: 50 µs (time to half value) Amplitude (peak) : 1 kV line/earth; 0,5 kV line/line Short-circuit current: Pulse rise time: 8 µs (front time) Pulse width: 20 µs (time to half value) Repetition rate: ≥ 1 pulse/min No of pulses: 5 per polarity Application: continuous According to test level 2	• 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 **(5)**)
19	Radiated Emission	CISPR 16-2-3+AMD1+AMD2 IEC 60945 for 156-165 MHz	Limits below 1000 MHz For equipment installed in the bridge and deck zone: Frequency range: — Quasi peak limits: 0,15 - 0,30 MHz — 80 - 52 dBµV/m 0,30 - 30 MHz — 52 - 34 dBµV/m 30 - 1000 MHz — 54 dBµV/m except for: 156 - 165 MHz — 24 dBµV/m For equipment installed in the general power distribution zone: Frequency range: — Quasi peak limits: 0,15 - 30 MHz — 80 - 50 dBµV/m 30 - 100 MHz — 60 - 54 dBµV/m 100 - 1000 MHz — 54 dBµV/m except for: 156 - 165 MHz — 24 dBµV/m Limits above 1000 MHz Frequency range: Average limit: 1000 - 6000 MHz 54 dBµV/m	• procedure in accordance with the standard but distance 3 m between equipment and antenna • for the frequency band 156 MHz to 165 MHz the measurement is to be repeated with a receiver bandwidth of 9 kHz (as per IEC 60945) • alternatively the radiation limit at a distance of 3 m from the enclosure port over the frequency 156 MHz to 165 MHz is to be 30 dB micro-V/m peak (as per IEC 60945). • procedure in accordance with the standard (distance 3 m between equipment and antenna) • equipment intended to transmit radio signals for the purpose of radio communication (e.g. wi-fi router, remote radio controller) may be exempted from limit, within its communication frequency range, subject to the provisions “Specific requirements for wireless data links” in Sec 3, [7.3.2].

No.	Test	Procedure **(1)**	Test parameters	Other information
20	Conducted Emission	CISPR 16-2-1+AMD1	Test applicable to AC and DC power ports For equipment installed in the bridge and deck zone: Frequency range: Limits: 10 - 150 kHz 96 - 50 dBµV 150 - 350 kHz 60 - 50 dBµV 0,35 - 30 MHz 50 dBµV For equipment installed in the general power distribution zone: Frequency range: Limits: 10 - 150 kHz 120 - 69 dBµV 150 - 500 kHz 79 dBµV 0,5 - 30 MHz 73 dBµV	

No.	Test	Procedure **(1)**	Test parameters	Other information
21	Flame retardant	IEC 60092-101 or IEC 60695-11-5	Flame application: 5 times 15 s each Interval between each application: 15 s or one time 30 s. Test criteria based upon application. The test is performed with the EUT or housing of the EUT applying needle-flame test method.	• the burnt out or damaged part of the specimen by not more than 60mm long • no flame, no incandescence or in the event of a flame or incandescence being present, it is to extinguish itself within 30 s of the removal of the needle flame without full combustion of the test specimen • any dripping material is to extinguish itself in such a way as not to ignite a wrapping tissue. The drip height is 200 mm ± 5 mm.

(1) 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 required in the other columns is fulfilled. Later versions (including revisions) of the international standards specified in this Section are acceptable for use provided the Society determines them to be equivalent to the technical specifications of this Section.

(2) Dry heat at 70 °C is to be carried out to automation, control and instrumentation equipment subject to high degree of heat, for example mounted in consoles, housings, etc. together with other heat dissipating power equipment.

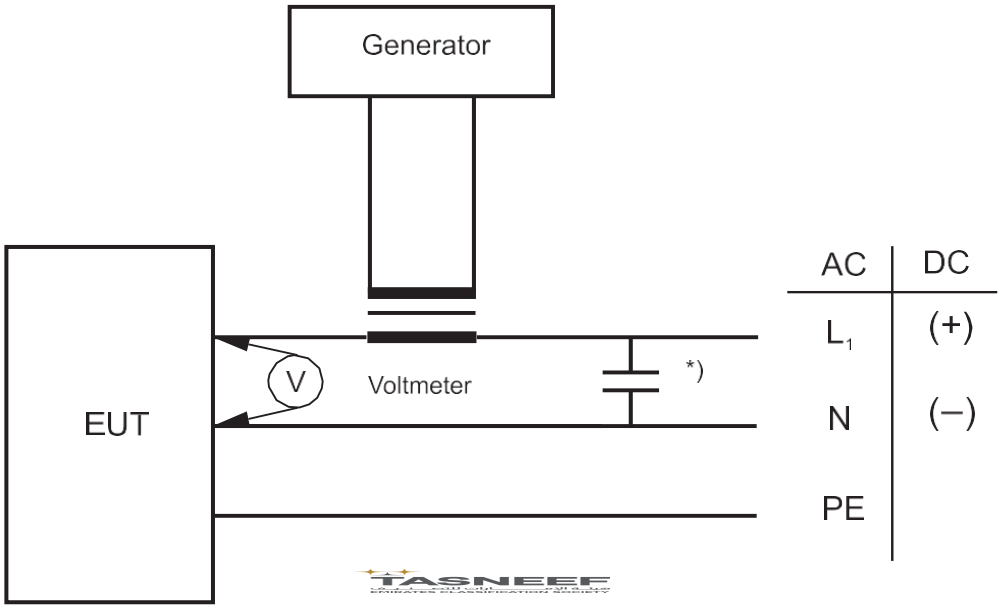
(3) For equipment installed in non-weather protected locations or cold locations test is to be carried out at –25°C.

(4) Salt mist test is to be carried out for equipment installed in weather exposed areas.

(5) Performance Criterion B: (for transient phenomena): the EUT is to 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.

(6) Performance Criterion A (for continuous phenomena): the Equipment Under Test is to continue to operate as intended during and after the test. No degradation of performance or loss is allowed as defined in relevant equipment standard and the technical specification published by the Manufacturer.

(7) For equipment installed on the bridge and deck zone, the test levels are to 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.



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 Tab 2 are required to demonstrate the development quality.

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.

2.3.2 For programmable electronic systems, as a guidance, the documents to be submitted for information are listed in Tab 2.

2.3.3 The software type approval applies only to basic software of the programmable electronic system.

The basic software approval is carried out in the following phases:

- Examination of the documents as required in Sec 1, [2.3.2],
- Verification that all the development work has been carried out according to the quality procedure. The complementary documents required in Tab 2 prove the quality of the development work.

Note 1: Particular attention will be given to the test results collected on unit testing file, integration test file and validation test file

- Repetition of tests of the essential function of the software. Comparison with documentation containing the test results of previous tests is to be carried out.

2.3.4 The application software is to be approved on a case by case basis, according to [3.3.2].

2.4 Navigational and radio equipment

2.4.1 *(1/1/2002)*

The test conditions as specified in IEC 60945 (marine navigational and radiocommunication equipment and systems - general requirements, methods of testing and required test results) are to be applied for the above-mentioned equipment.

2.5 Loading instruments

2.5.1 *(1/1/2017)*

Loading instrument approval consists of:

- approval of hardware according to [2.2], unless two computers are available on board for loading calculations only
- for programmable loading instruments, approval of basic software according to [2.3]
- approval of application software, consisting in data verification which results in the Endorsed Test Condition according to Part B
- installation testing according to [4].

Table 2 : Basic software development documents

No.	I/A **(2)**	DOCUMENT
1	I	Follow-up of developed software: identification, safeguard, storage
2	I	Document showing the capability and training of the development team
3	I	Production of a specification file
4	I	Production of a preliminary design file
5	I	Production of a detailed design file
6	I	Production of a coding file
7	I	Production of a unit testing file **(1)**
8	I	Production of an integration test file **(1)**
9	I	Production of a validation test file **(1)**
10	I	Production of a maintenance facility file
11	I	Production of a quality plan
12	I	Follow-up of the quality plan: checks, audits, inspections, reviews

(1) Complementary test carried out, at random, at the request of the Surveyor

(2) A : to be submitted for approval;
I : to be submitted for information.

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.

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
- 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 programmable electronic 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 tests, 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 Commissioning

4.1 General

4.1.1 Commissioning 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 3.

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 commissioning tests, test reports are to be made available to the Surveyor.

Table 3 : Commissioning 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

Chapter 4

FIRE PROTECTION, DETECTION AND EXTINCTION

SECTION 1 REQUIREMENTS FOR FIRE PROTECTION, DETECTION AND EXTINCTION

1 General

1.1 Purpose and application

1.1.1 *(1/1/2007)*

This Section applies to cargo ships and passenger ships for which classification is requested.

Note 1: As from 1 January 2007, the statutory requirements of the SOLAS Convention and/or national safety regulations, as applicable, regarding fire protection, detection and extinction (hereinafter referred to as "fire protection statutory requirements") are no longer mandatory for the purpose of classification except where the Society carries out surveys relevant to fire protection statutory requirements on behalf of the flag Administration. In such cases, fire protection statutory requirements are considered a matter of class and therefore compliance with these requirements is also verified by the Society for classification purposes. In general, only IACS Unified Requirements in force related to fire protection, detection and extinction have been retained as Rule requirements within the scope of classification and are contained in this Chapter 4.

1.1.2 *(1/1/2007)*

[2]; [3]; [4]; [5.1]; [5.3]; [6]; [7]; [8] apply to all ships.

1.1.3 *(1/1/2007)*

[5.2]; [8]; [9] apply to cargo ships only.

1.1.4 *(1/1/2007)*

Requirements for tankers in this Section apply to tankers carrying oil having a flashpoint not exceeding 60°C (closed cup test).

1.1.5 *(1/1/2007)*

Unless otherwise stated, for materials and design criteria of piping and relevant accessories reference is to be made to Ch 1, Sec 10.

2 Documentation to be submitted

2.1 Standard list of documents

2.1.1 *(1/1/2007)*

The Interested Party is to submit to the Society the documents listed in Tab 1.

Table 1 : Documentation to be submitted *(1/7/2012)*

No.	I/A **(1)**	Document **(2)**
1	A	Ventilation systems in cargo area of tankers, excluding cargo tanks
2	A	Automatic fire detection systems in unattended machinery spaces

(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
- surface areas of protected zones for pressure water-spraying systems
- type, number and location of nozzles of extinguishing media for gas and pressure water-spraying 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.

No.	I/A **(1)**	Document **(2)**
3	A	Arrangement of local application fixed fire-extinguishing systems **(2)** and inert gas systems
4	A	Gas detection systems on tankers
5	A	Fixed fire-extinguishing system in scavenge spaces of two-stroke crosshead type engines, according to the requirements of Ch 1, Sec 2, [4.4.1]
6	A	Electrical diagram of local application fixed gas fire-extinguishing systems
7	I	General arrangement plan

(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
- surface areas of protected zones for pressure water-spraying systems
- type, number and location of nozzles of extinguishing media for gas and pressure water-spraying 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.

3 Definitions

3.1 Accommodation spaces

3.1.1 *(1/1/2007)*

Accommodation spaces are those spaces used for public spaces, corridors, stairs, lavatories, cabins, offices, hospitals, cinemas, games and hobby rooms, barber shops, pantries containing no cooking appliances and similar spaces.

3.2 Airlock

3.2.1 *(1/7/2022)*

An airlock is a space enclosed by gastight steel bulkheads with two gastight doors spaced not more than 2,5 m apart. The doors are to be self-closing without any holding back arrangements. Air locks are to have mechanical ventilation and are not to be used for other purposes. An audible and visual alarm system to give a warning on both sides of the air lock is to be provided to indicate if more than one door is moved from the closed position. The air lock space is to be monitored for dangerous gas as defined in Ch 1, App 8, [2.1.3].

3.3 Ballast Water Management System (BWMS)

3.3.1 *(1/7/2022)*

Ballast Water Management System means any system defined in Ch 1, App 8, [2.1.1].

3.4 Ballast Water Management Room (BWMR)

3.4.1 *(1/7/2022)*

Ballast Water Management Room is any space containing equipment belonging to the Ballast Water Management System. A space containing remote controls for the BWMS or a space dedicated to the storage of liquid or solid chemicals for BWMS need not be considered as a BWMR.

3.5 BWMS storing, introducing or generating chemicals

3.5.1 *(1/7/2022)*

In general, BWMS storing, introducing or generating chemicals refer to:

- In-line flocculation (cat.2 as per Ch 1, App 8, Tab 1)
- Chemical injection (cat.6 as per Ch 1, App 8, Tab 1), and
- BWM technologies using neutralizers injection (cat.4, 5, 6 and 7 as per Ch 1, App 8, Tab 1).

BWMS that do not store, introduce or generate toxic or flammable chemicals may be specially considered as detailed in Tab 2.

Table 2 : Requirements that may be reduced for BWMS storing, introducing or generating chemicals depending on the chemicals *(1/7/2022)*

Requirement	Conditions to be met before reducing the requirement
[10.2.3] d)	The stored chemicals are neither toxic nor flammable
[10.3.1]	The BWMS does not use any flammable or toxic chemical substances
[10.3.3]	No dangerous gas as defined in Ch 1, App 8, [2.1.3] will be generated by the BWMS
[10.6.1] a)	No toxic chemical is stored and no toxic gas will be generated by the BWMS
[10.7.1] a), c), f)	No toxic chemical is used or will be generated by the BWMS

The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guidelines) and ''safety hazard'' as listed in Ch.17 of IMO IBC code are to be considered for this purpose.

Note 1: Chemicals include additives for BWMS.

3.6 Cargo area

3.6.1 *(1/1/2007)*

The cargo area is that part of the ship that contains cargo holds, cargo tanks, slop tanks and cargo pump rooms including pump rooms, cofferdams, ballast and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the ship over the above-mentioned spaces.

3.6.2 *(1/1/2007)*

For the definition of the cargo area of chemical tankers (see [3.9]) and gas carriers (see [3.18]), refer to Part E, Chapter 8 and Part E, Chapter 9, respectively.

3.7 Cargo ship

3.7.1 *(1/1/2007)*

Cargo ship is any ship which is not a passenger ship.

3.8 Cargo spaces

3.8.1 *(1/1/2007)*

Cargo spaces are spaces used for cargo, cargo oil tanks, tanks for other liquid cargo and trunks to such spaces.

3.9 Chemical tanker

3.9.1 *(1/1/2007)*

Chemical tanker is a tanker constructed or adapted and used for the carriage in bulk of any liquid product of a flammable nature listed in Pt E, Ch 8, Sec 17.

3.10 Closed ro-ro spaces

3.10.1 *(1/1/2007)*

Closed ro-ro spaces are those ro-ro spaces which are neither open ro-ro spaces nor weather decks.

3.11 Closed vehicle spaces

3.11.1 *(1/1/2007)*

Closed vehicle spaces are vehicle spaces which are neither open vehicle spaces nor weather decks.

3.12 Combination carriers

3.12.1 *(1/1/2007)*

A combination carrier is a cargo ship designed to carry both oil and solid cargoes in bulk.

3.13 Continuously manned central control stations

3.13.1 *(1/1/2007)*

A continuously manned central control station is a central control station which is continuously manned by a responsible member of the crew.

3.14 Control stations

3.14.1 *(1/1/2007)*

Control stations are those spaces in which the ship's radio or main navigating equipment or the emergency source of power is located or where the fire recording or fire control equipment is centralized.

3.15 Crude oil

3.15.1 *(1/1/2007)*

Crude oil is any oil occurring naturally in the earth whether or not treated to render it suitable for transportation and includes crude oil where certain distillate fractions may have been removed from, or added to.

3.16 Deadweight

3.16.1 *(1/1/2007)*

The deadweight is the difference in tonnes between the displacement of a ship in water of a specific gravity of 1,025 t/m^3 at the load waterline corresponding to the assigned summer freeboard and the lightweight of the ship.

3.17 Flashpoint

3.17.1 *(1/1/2007)*

Flashpoint is the temperature in degrees Celsius (closed cup test) at which a product will give off enough flammable vapour to be ignited, as determined by an approved flashpoint apparatus.

3.18 Gas carrier

3.18.1 *(1/1/2007)*

A gas carrier is a cargo ship constructed or adapted and used for the carriage in bulk of any liquefied gas or other products of a flammable nature listed in Pt E, Ch 9, Sec 19.

3.19 Lightweight

3.19.1 *(1/1/2007)*

The lightweight is the displacement of a ship in tonnes without cargo, fuel, lubricating oil, ballast water, fresh water and feed water in tanks, consumable stores, and passengers and crew and their effects.

3.20 Machinery spaces

3.20.1 *(1/1/2007)*

Machinery spaces are machinery spaces of category A and other spaces containing propulsion machinery, boilers, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.

3.21 Machinery spaces of category A

3.21.1 *(1/1/2007)*

Machinery spaces of category A are those spaces and trunks to such spaces which contain either:

a) internal combustion machinery used for main propulsion,

b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW, or

c) any oil-fired boiler or oil fuel unit, or any oil-fired equipment other than boilers, such as inert gas generators, incinerators, etc.

3.22 Main vertical zones

3.22.1 *(1/7/2012)*

Main vertical zones are those sections into which the hull, superstructure and deckhouses are divided by "A" class divisions, the mean length and width of which on any deck does not in general exceed 40 m.

3.23 Oil fuel unit

3.23.1 *(1/1/2007)*

The oil fuel unit is the equipment used for the preparation of oil fuel for delivery to an oil fired boiler or equipment used for the preparation for delivery of heated oil to an internal combustion engine and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 0,18 MPa.

3.23.2 *(1/1/2007)*

"Oil fuel unit" includes any equipment used for the preparation and delivery of oil fuel, whether or not heated, to boilers (including inert gas generators) and engines (including gas turbines) at a pressure of more than 0,18 MPa.

Note 1: For the purpose of these Rules “oil fuel” has the same meaning of “fuel oil”.

3.24 Open decks (open deck spaces)

3.24.1 *(1/7/2023)*

Open decks (open deck spaces) are those *open deck spaces and enclosed promenades clear of lifeboat and liferaft embarkation and lowering stations. To be considered in this category, enclosed promenades shall have no significant fire risk, meaning that furnishings shall be restricted to deck furniture. In addition, such spaces shall be naturally ventilated by permanent openings.*

Air spaces (the space outside superstructures and deckhouses).

3.25 Open ro-ro spaces

3.25.1 *(1/1/2007)*

Open ro-ro spaces are those ro-ro spaces that are either open at both ends or have an opening at one end and are provided with adequate natural ventilation effective over their entire length through permanent openings distributed in the side plating or deckhead or from above, having a total area of at least 10% of the total area of the space's sides.

3.26 Open vehicle spaces

3.26.1 *(1/1/2007)*

Open vehicle spaces are those vehicle spaces that are either open at both ends or have an opening at one end and are provided with adequate natural ventilation effective over their entire length through permanent openings distributed in the side plating or deckhead or from above, having a total area of at least 10% of the total area of the space's sides.

3.27 Passenger ship

3.27.1 *(1/1/2007)*

A passenger ship is a ship which carries more than twelve passengers.

3.28 Public spaces

3.28.1 *(1/1/2007)*

Public spaces are those portions of the accommodation which are used for halls, dining rooms, lounges and similar permanently enclosed spaces.

3.29 Ro-ro spaces

3.29.1 *(1/1/2007)*

Ro-ro spaces are spaces not normally subdivided in any way and extending to either a substantial length or the entire length of the ship in which motor vehicles with fuel in their tanks for their own propulsion and/or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks or in or on similar stowage units or other receptacles) can be loaded and unloaded normally in a horizontal direction.

3.30 Ro-ro passenger ship

3.30.1 *(1/1/2007)*

Ro-ro passenger ship means a passenger ship with ro-ro spaces or special category spaces as defined in [3.32].

3.31 Service spaces

3.31.1 *(1/1/2007)*

Service spaces are those spaces used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, storerooms, workshops other than those forming part of the machinery spaces, and similar spaces and trunks to such spaces.

3.32 Special category spaces

3.32.1 *(1/1/2007)*

Special category spaces are those enclosed vehicle spaces above and below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.

3.33 Tanker

3.33.1 *(1/1/2007)*

A tanker is a cargo ship constructed or adapted for the carriage in bulk of liquid cargoes of an inflammable nature.

Note 1: For the purpose of this Chapter, the term tanker includes the following service notations (see Pt A, Ch 1, Sec 2, Tab 1):

- Chemical tanker
- Combination carrier/OBO
- Combination carrier/OOC
- Flammable liquid substances tanker
- Liquefied gas carrier
- Oil recovery ship
- Oil tanker.

3.34 Vehicle spaces

3.34.1 *(1/1/2007)*

Vehicle spaces are cargo spaces intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion.

3.35 Weather decks

3.35.1 *(1/1/2007)*

A weather deck is a deck which is completely exposed to the weather from above and from at least two sides.

4 Type approved products

4.1 Type approval and case by case approval

4.1.1 *(1/1/2007)*

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 acceptance may be given for individual ships on the basis of suitable documentation or ad hoc tests:

a) Flexible pipes and expansion bellows of non-conventional material for any type of fluid

b) Nozzles for fixed pressure water-spraying fire-extinguishing systems for machinery spaces and boiler rooms

c) Sensing heads for automatic fire alarm and fire detection systems.

d) Fixed fire detection and fire alarm systems

e) Explosive mixture detecting systems

f) Portable explosive mixture detecting apparatus

g) Fixed instruments for measuring the oxygen content for inert gas systems serving cargo tanks

h) Portable instruments for measuring the oxygen content for inert gas systems serving cargo tanks.

5 Probability of ignition

5.1 Arrangements for gaseous fuel for domestic purposes

5.1.1 *(1/1/2007)*

In general gaseous fuel systems may only be considered for cargo ships.

However, this does not preclude the use, on passenger ships, of movable cooking appliances - the so-called "flambé carts" - providing they meet the following requirements:

a) Constructional requirements:

   1) In addition to the main gas supply valve, the flambe carts are equipped with an emergency gas shut-off valve which can be activated:
      - manually by the operator, either by pulling on a metallic wire loop or using a rod pull type lever;
      - automatically with a mechanical (in general gravity type) tip over device which will shut off the gas flow from the gas cylinder should the cart accidentally tip over.
   2) The regulation system ensures a pressure of about 0,0001 MPa downstream from the regulator itself.
   3) A pressure gauge is fitted between the gas cylinder and the regulation system, to indicate the gas pressure inside the cylinder.
   4) Special materials are used for the low pressure hose (between the regulation system and the stove) so that, in case of fire, the hose melts and closes on itself acting as an automatic check valve.
   5) The gas cylinder is safely secured on its cradle inside the cart.
   6) A safely re-ignition system is provided to automatically relight the burner if the flame goes out when the gas valve is "on".
   7) At least two of the four swivel castors are equipped with brakes, to block the cart in position.

b) Operational requirements.

   Flambé carts complying with the constructional requirements listed under item a) above may be used in public spaces (restaurant, buffet, etc.) on passenger ships under the following conditions, the implementation of which is the Owner's responsibility:

   1) The carts are safely secured, specially when they are left unmanned in the space where they are used.
   2) The number of carts permitted in a public space is such that the free volume at ambient temperature and atmospheric pressure of the natural gas contained in the cylinders of all the carts is less than 2% of the gross volume of the public space.
   3) No spare full gas cylinders are permitted on board.

   Empty bottles are replaced only when the ship is in the harbour.

5.2 Cargo area of tankers

5.2.1 Restriction on boundary openings *(1/7/2014)*

Where driven shafts pass through pump room bulkhead or deck plating, gas-tight glands are to be fitted. The glands are to be efficiently lubricated from outside the pump room. The seal parts of the glands are to be of material that will not initiate sparks. The glands are to be constructed and fitted in accordance with the relevant Rules for fittings attached to watertight bulkheads and, if a bellows piece is incorporated in the design, it is to be pressure tested before fitting.

5.2.2 Ventilation systems in cargo pump rooms *(1/1/2007)*

Discharges and air inlets are to be located at a vertical distance of at least 2,4 m from the open deck. Air discharges are also to be arranged at a horizontal distance of not less than 3 m from any other opening leading to the served spaces.

The ventilation system capable of providing the required air changes per hour is to comply with the following as applicable:

a) in order to avoid air stagnation zones, air exhaust ports inside the pump room are to be adequately distributed and the various landings are to consist of open gratings or perforated flats;

b) inlet ducts are generally to end at the top of the room and outlet ducts are to extend below the floor plates, with suction ports at the level of the upper edge of ordinary floors or bottom longitudinals;

c) in addition, suction ducts are to be provided with an emergency intake at approximately 2 m above the pump room lower grating, with a shutter capable of being opened or closed both at lower grating level and from the weather deck level, so that suction normally occurs through the lower suction ports and, in the event of the pump room flooding, through those at the top branched from the emergency intake;

d) an arrangement involving a specific ratio of areas of upper emergency and lower main ventilator openings, which can be shown to result in at least the required 20 air changes per hour through the lower inlets, can be adopted without the use of shutters.

When the lower access inlets are closed then at least 15 air changes per hour are to be obtained through the upper inlets.

5.2.3 Ventilation systems in spaces other than the cargo pump room *(1/1/2007)*

Hose lockers and enclosed or partially enclosed spaces adjacent to cargo tanks are to be independently ventilated, in general by mechanical ventilation (exhaust) where such spaces are normally attended by the crew. In general, the arrangement of inlets and outlets serving these spaces is to comply with the provisions set out in [5.2.2] a).

5.2.4 Gas measurements *(1/7/2021)*

a) Portable instruments

Every oil tanker is to be provided with at least two portable gas detectors capable of measuring flammable vapour concentrations in air (%LEL) and at least two portable O_2 analysers. Alternatively, at least two gas detectors, each capable of measuring both oxygen and flammable vapour concentrations in air (%LEL), are to be provided.

In addition, for tankers fitted with inert gas systems, at least two portable gas detectors are to be capable of measuring concentrations of flammable vapours in inerted atmosphere (% gas by volume).

b) Arrangement for gas measurement in double hull and double bottom spaces.

Gas analysing units with non-explosion proof measuring equipment associated to the fixed gas sampling line system may be located in areas outside cargo areas, e.g. in the cargo control room, navigation bridge or engine room, when mounted on the forward bulkhead facing the cargo area provided the following requirements are observed:

- sampling lines are not to run through gas-safe spaces, except where permitted under the last bullet below;
- the gas sampling pipes are to be equipped with flame arresters. Sample gas is to be led to the atmosphere with outlets arranged in a safe location;
- bulkhead penetrations of sample pipes between safe and dangerous areas are to be approved by the Society and to have the same fire integrity as the division penetrated. A manual isolating valve is to be fitted in each of the sampling lines at the bulkhead on the gas-safe side;
- the gas detection equipment, including sample piping, sample pumps, solenoids, analysing units etc., is to be located in a reasonably gas-tight enclosure (e.g. a fully enclosed steel cabinet with a gasketed door), which is to be monitored by its own sampling point. At gas concentration above 30% of the lower flammable limit (LFL) inside the enclosure, the entire gas analysing unit is to be automatically shut down;

and

- where the enclosure cannot be arranged directly on the bulkhead facing the cargo area, sample pipes are to be of steel or other equivalent material and without detachable connections, except for the connection points for isolating valves at the bulkhead and analysing units, and are to be routed along the shortest path.

5.2.5 Safety aspects of double hull spaces, double bottoms and duct keels under cargo oil tanks *(1/1/2007)*

Pipe ducts in the double bottom are to comply with the following requirements:

a) In general, they are not to communicate with the engine room. When access is provided from a pump room, a watertight door is to be fitted complying with the requirements of Pt B, Ch 2, Sec 1, [6.2.1] and, in addition, with the following:

   1) in addition to operation from the bridge, the watertight door is to be capable of being manually closed from outside the main pump room entrance; and

   2) the watertight door is to be kept closed during normal operation of the ship except when access to the pipe tunnel is required.

b) For double bottoms and ducts keels, provision is to be made for at least two exits to the open deck arranged as far apart from each other as practicable. One of these exits fitted with a watertight closure may lead to the cargo pump room;

c) In the duct, provision is to be made for adequate mechanical ventilation.

5.3 Non-sparking fans

5.3.1 General *(1/1/2007)*

Where non-sparking fans are required by the Rules, the provisions of [5.3.2] and [5.3.3] are also to be complied with.

5.3.2 Design criteria *(1/1/2007)*

a) The air gap between the impeller and the casing is to be not less than 0,1 of the shaft diameter in way of the impeller bearing and in any case not less than 2 mm, but need not exceed 13 mm.

b) Protective screens with square mesh of not more than 13 mm are to be fitted to the inlet and outlet of ventilation openings on the open deck to prevent objects entering the fan housing.

5.3.3 Materials *(1/1/2007)*

a) Except as indicated in the fourth bullet of item c) below, the impeller and the housing in way of the impeller are to be made of spark-proof materials which are recognised as such by means of an appropriate test to the satisfaction of the Society.

b) Electrostatic charges, both in the rotating body and the casing, are to be prevented by the use of antistatic materials. Furthermore, the installation on board of ventilation units is to be such as to ensure their safe bonding to the hull.

c) Tests may not be required for fans having the following material combinations:

   - impellers and/or housings of non-metallic material, due regard being paid to the elimination of static electricity
   - impellers and housings of non-ferrous materials
   - impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous material is fitted in way of the impeller
   - any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm design tip clearance.

d) The following impeller and housing combinations are considered as sparking and therefore are not permitted:

   - impellers of an aluminium alloy or a magnesium alloy and a ferrous housing, regardless of tip clearance
   - housings made of an aluminium alloy or a magnesium alloy and a ferrous impeller, regardless of tip clearance
   - any combination of ferrous impeller and housing with less than 13 mm design tip clearance.

e) Complete fans are to be tested in accordance either with the Society's requirements or national or international standards accepted by the Society.

6 Suppression of fire - detection and alarm

6.1 Protection of machinery spaces

6.1.1 Installation *(1/1/2007)*

Fire detecting systems to be fitted in unattended machinery spaces are also to comply with the following:

a) the system is to be designed with self-monitoring properties. Power or system failures are to initiate an audible alarm distinguishable from the fire alarm.

b) The fire detection indicating panel is to be located on the navigating bridge, fire control station, or other accessible place where a fire in the machinery space will not render it inoperative.

c) The fire detection indicating panel is to indicate the place of the detected fire in accordance with the arranged fire zones by means of a visual signal. Audible signals clearly distinguishable in character from any other audible signals are to be audible throughout the navigating bridge and the accommodation area of the personnel responsible for the operation of the machinery space.

d) Fire detectors are to be of types, and so located, that they will rapidly detect the onset of fire in conditions normally present in the machinery space. Consideration is to be given to avoiding false alarms. The type and location of detectors are to be approved by the Society and a combination of detector types is recommended in order to enable the system to react to more than one type of fire symptom.

e) Fire detector zones are to be arranged in a manner that will enable the operating staff to locate the seat of the fire. The arrangement and the number of loops and the location of detector heads are to be approved in each case. Air currents created by the machinery are not to render the detection system ineffective.

f) When fire detectors are provided with the means to adjust their sensitivity, necessary arrangements are to be ensured to fix and identify the set point.

g) When it is intended that a particular loop or detector is to be temporarily switched off, this state is to be clearly indicated. Reactivation of the loop or detector is to be performed automatically after a preset time.

h) The fire detection indicating panel is to be provided with facilities for functional testing.

i) The fire detecting system is to be fed automatically from the emergency source of power by a separate feeder if the main source of power fails.

j) Facilities are to be provided in the fire detecting system to manually release the fire alarm from the following places:
   - passageways having entrances to the engine and boiler rooms,
   - the navigating bridge and control station in the engine room.

k) The testing of the fire detecting system on board is to be carried out to the satisfaction of the Society.

For the fire detecting system for unattended machinery spaces, see also Pt F, Ch 3, Sec 2.

7 Suppression of fire: fire - fighting

7.1 Fire-extinguishing arrangements in machinery spaces

7.1.1 General *(1/1/2007)*

a) Air pipes from oil fuel tanks are to be led to a safe position on the open deck. Air pipes from lubricating oil storage tanks may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.

   Any overflow pipe is to have a sectional area of at least 1,25 times that of the filling pipe and is to be led to an overflow tank of adequate capacity or to a storage tank having space reserved for overflow purposes.

   An alarm device is to be provided to give warning when the oil reaches a predetermined level in the tank, or alternatively, a sight glass is to be provided in the overflow pipe to indicate when any tank is overflowing. Such sight glasses are to be placed on vertical pipes only and in readily visible positions.

b) Short sounding pipes may be used for tanks other than double bottom tanks without the additional closed level gauge provided an overflow system is fitted.

c) Level switches may be used below the tank top provided they are contained in a steel enclosure or other enclosures not capable of being destroyed by fire.

d) Controls required by this regulation are to be also provided from the compartment itself.

e) Hose clamps and similar types of attachments for flexible pipes are permitted.

f) Oil fuel in storage tanks is not to be heated to temperatures within 10°C below the flashpoint of the oil fuel, except that where oil fuel in service tanks, settling tanks and any other tanks in the supply system is heated the following arrangements are to be provided:

- the length of the vent pipes from such tanks and/or a cooling device is sufficient for cooling the vapours to below 60°C, or the outlet of the vent pipes is located 3 m away from a source of ignition;
- the vent pipes are fitted with flame screens;
- there are no openings from the vapour space of the fuel tanks into machinery spaces (bolted manholes are acceptable);
- enclosed spaces are not located directly over such fuel tanks, except for vented cofferdams;
- electrical equipment is not fitted in the vapour space of the tanks, unless it is certified to be intrinsically safe.

g) In the proximity of any electrical switchboard or section board having a power of 20 kW and upwards at least one CO_2 or powder extinguisher is to be fitted.

7.1.2 Fixed local application fire-fighting systems *(1/7/2010)*

This item applies to the installation of electrical and electronic equipment in engine rooms protected by fixed water-based local application fire-fighting systems (FWBLAFFS).

a) The following definitions apply (see also Fig 1):

1) Protected space: a machinery space where a FWBLAFFS is installed.

2) Protected areas: areas within a protected space which are required to be protected by FWBLAFFS.

3) Adjacent areas:

- areas, other than protected areas, exposed to direct spray
- areas, other than those defined above, where water may extend.

b) The electrical and electronic equipment enclosures located within areas protected by FWBLAFFS and those within adjacent areas exposed to direct spray is to have a degree of protection not less than IP44, except where evidence of suitability is submitted to and approved by the Society.

c) The electrical and electronic equipment within adjacent areas not exposed to direct spray may have a lower degree of protection provided evidence of suitability for use in these areas is submitted taking into account the design and equipment layout, e.g. position of inlet ventilation openings, and that cooling airflow for the equipment is assured.

Note 1: Additional precautions may be required to be taken in respect of:

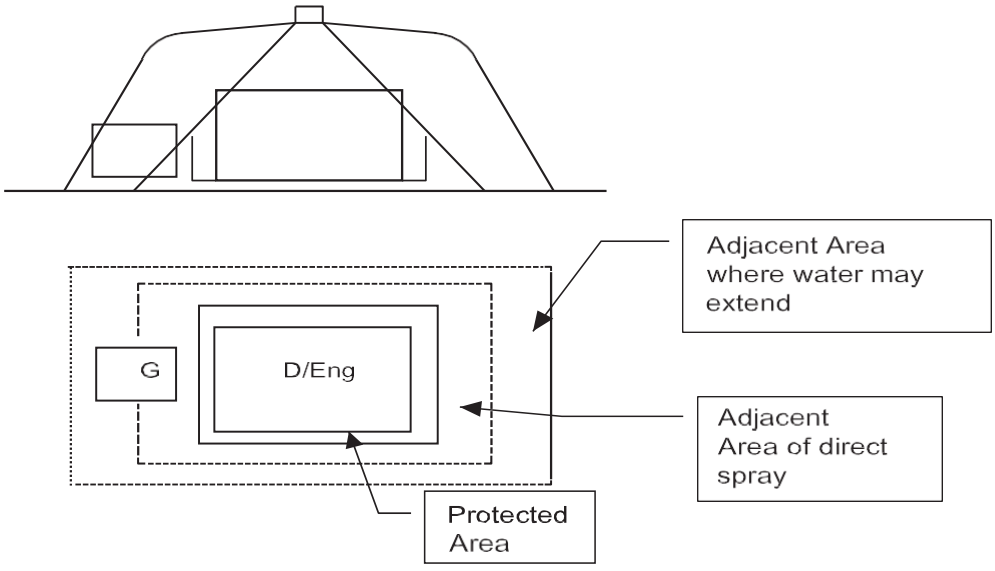
a) tracking as a result of water entering the equipment

b) potential damage as a result of residual salts from sea water systems

c) high voltage installations

d) personnel protection against electric shock.

Figure 1 *(1/7/2010)*



7.2 Low pressure CO_2 piping system

7.2.1 General *(1/7/2022)*

Where a low-pressure CO_2 system is fitted, the piping system is to be designed in such a way that the CO_2 pressure at the nozzles is not be less than 1 N/mm^2.

8 Fire safety systems: General requirements and application for inert gas systems

8.1 General requirements

8.1.1 *(1/1/2007)*

The inert gas system is to be capable of inerting, purging and gas-freeing empty cargo tanks and maintaining the atmosphere in cargo tanks with the required oxygen content.

8.1.2 *(1/1/2007)*

The inert gas system referred to in [8.2.1] is to be designed, constructed and tested in accordance with the requirements of [9]. Unless otherwise stated, for materials and design criteria of piping and relevant accessories reference is to be made to Ch 1, Sec 10.

8.1.3 *(1/1/2007)*

Tankers fitted with a fixed inert gas system are to be provided with a closed ullage system.

8.2 Application

8.2.1 *(1/1/2016)*

For tankers (including chemical carriers and gas carriers) of 8,000 tonnes deadweight and upwards, cargo tanks are to be protected by a fixed inert gas system in accordance with the requirements of [9], except that, for tankers of less than 20,000 tonnes deadweight in lieu of the fixed installations required in [9] the Society, after having given consideration to the ship's arrangement and equipment, may accept other equivalent arrangements or means of protection in accordance with [8.3].

8.2.2 *(1/1/2007)*

Tankers operating with a cargo tank cleaning procedure using crude oil washing are to be fitted with an inert gas system complying with the requirements of [9] and with fixed tank washing machines.

8.2.3 *(1/1/2007)*

Tankers required to be fitted with inert gas systems are to comply with the following provisions:

a) double hull spaces are to be fitted with suitable connections for the supply of inert gas

b) where hull spaces are connected to a permanently fitted inert gas distribution system, means are to be provided to prevent hydrocarbon gases from the cargo tanks entering the double hull space through the system and

c) where such spaces are not permanently connected to an inert gas distribution system, appropriate means are to be provided to allow connection to the inert gas main.

8.2.4 *(1/1/2007)*

The requirements for inert gas systems given in [9] need not be applied to gas carriers:

a) when carrying crude oil and petroleum products having a flashpoint not exceeding 60°C (closed cup test), provided that they comply with IMO Resolution A.567(14), or

b) when carrying flammable cargoes other than crude oil or petroleum products such as cargoes listed in Chapter 17 and 18 of the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, provided that the capacity of tanks used for their carriage does not exceed 3000 m^3, the individual nozzle capacities of tank washing machines do not exceed 17,5 m^3/h and the total combined throughput from the number of machines in use in a cargo tank at any one time does not exceed 110 m^3/h.

8.3 Requirements for equivalent systems

8.3.1 *(1/1/2007)*

When an installation equivalent to a fixed inert gas system is installed, it is to:

a) be capable of preventing dangerous accumulations of explosive mixtures in intact cargo tanks during normal service throughout the ballast voyage and necessary in-tank operations, and

b) be so designed as to minimise the risk of ignition from the generation of static electricity by the system itself.

9 Inert gas systems

9.1 Contents

9.1.1 *(1/1/2016)*

This item [9] gives the specifications for inert gas systems in cargo oil tanks and double hull spaces in oil tankers, chemical tankers and gas carriers as required by this Chapter.

9.2 Engineering specifications

9.2.1 **Definitions** *(1/1/2016)*

For the purposes of this item [9], the following definitions apply:

a) Cargo tanks means those cargo tanks, including slop tanks, which carry cargoes, or cargo residues, having a flashpoint not exceeding 60ºC.

b) Inert gas system includes inert gas systems using flue gas, inert gas generators, and nitrogen generators and means the inert gas plant and inert gas distribution together with means for preventing backflow of cargo gases to machinery spaces, fixed and portable measuring instruments and control devices.

c) Gas-safe space is a space in which the entry of gases would produce hazards with regard to flammability or toxicity.

d) Gas-free is a condition in a tank where the content of hydrocarbon or other flammable vapour is less than 1% of the lower flammable limit (LFL), the oxygen content is at least 21%, and no toxic gases are present.

9.3 Requirements for all systems

9.3.1 General *(1/1/2016)*

a) The inert gas system referred to in chapter II-2 of the Convention is to be designed, constructed and tested to the satisfaction of the Society. It is to be designed to be capable of rendering and maintaining the atmosphere of the relevant cargo tanks non-flammable

b) The system is to be capable of:

   1) inerting empty cargo tanks and maintaining the atmosphere in any part of the tank with an oxygen content not exceeding 8% by volume and at a positive pressure in port and at sea except when it is necessary for such a tank to be gas-free;

   2) eliminating the need for air to enter a tank during normal operations except when it is necessary for such a tank to be gas-free;

   3) purging empty cargo tanks of hydrocarbon or other flammable vapours, so that subsequent gas-freeing operations will at no time create a flammable atmosphere within the tank;

   4) delivering inert gas to the cargo tanks at a rate of at least 125% of the maximum rate of discharge capacity of the ship expressed as a volume.

      For chemical tankers and chemical/product tankers, the Society may accept inert gas systems having a lower delivery capacity provided that the maximum rate of discharge of cargoes from cargo tanks being protected by the system is restricted to not more than 80% of the inert gas capacity; and

   5) delivering inert gas with an oxygen content of not more than 5% by volume to the cargo tanks at any required rate of flow.

c) Materials used in inert gas systems are to be suitable for their intended purpose. In particular, those components which may be subjected to corrosive action of the gases and/or liquids are to be either constructed of corrosion-resistant material or lined with rubber, glass fibre epoxy resin or other equivalent coating material.

d) The inert gas supply may be:

   1) treated flue gas from main or auxiliary boilers, or

   2) gas from an oil or gas-fired gas generator, or

   3) gas from nitrogen generators.

The Society may accept systems using inert gases from one or more separate gas generators or other sources or any combination thereof, provided that an equivalent level of safety is achieved. Such systems are, as far as practicable, to comply with the requirements of this chapter. Systems using stored carbon dioxide are not to be permitted unless the Society is satisfied that the risk of ignition from generation of static electricity by the system itself is minimized.

9.3.2 Safety measures *(1/1/2016)*

a) The inert gas system is to be so designed that the maximum pressure which it can exert on any cargo tank will not exceed the test pressure of any cargo tank.

b) Automatic shutdown of the inert gas system and its component parts are to be arranged on predetermined limits being reached, taking into account the provisions of [9.3.4], [9.4.3] and [9.5.3].

c) Suitable shutoff arrangements are to be provided on the discharge outlet of each generator plant.

d) The system is to be designed to ensure that if the oxygen content exceeds 5% by volume, the inert gas is to be automatically vented to atmosphere.

e) Arrangements are to be provided to enable the functioning of the inert gas plant to be stabilized before commencing cargo discharge. If blowers are to be used for gas-freeing, their air inlets are to be provided with blanking arrangements.

f) Where a double block and bleed valve is installed, the system is to ensure upon loss of power that the block valves are automatically closed and the bleed valve is automatically open.

9.3.3 System components *(1/1/2016)*

a) Non-return devices

1) At least two non-return devices are to be fitted in order to prevent the return of vapour and liquid to the inert gas plant, or to any gas-safe spaces.

2) The first non-return device is to be a deck seal of the wet, semi-wet, or dry type or a double-block and bleed arrangement. Two shut-off valves in series with a venting valve in between may be accepted provided:

- the operation of the valve is automatically executed. Signal(s) for opening/closing is (are) to be taken from the process directly, e.g. inert gas flow or differential pressure; and
- alarm for faulty operation of the valves is provided, e.g. the operation status of "blower stop" and "supply valve(s) open" is an alarm condition.

3) The second non-return device is to be a non-return valve or equivalent capable of preventing the return of vapours and liquids and fitted between the deck water seal (or equivalent device) and the first connection from the inert gas main to a cargo tank. It is to be provided with positive means of closure. As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the first connection to the cargo tanks to isolate the deck water seal, or equivalent device, from the inert gas main to the cargo tanks.

4) A water seal, if fitted, is to be capable of being supplied by two separate pumps, each of which is to be capable of maintaining an adequate supply at all times. The audible and visual alarm on the low level of water in the water seal are to operate at all times.

5) The arrangement of the water seal, or equivalent devices, and its associated fittings are to be such that it will prevent backflow of vapours and liquids and will ensure the proper functioning of the seal under operating conditions.

6) Provision is to be made to ensure that the water seal is protected against freezing, in such a way that the integrity of the seal is not impaired by overheating.

7) A water loop or other approved arrangement is also to be fitted to each associated water supply and drain pipe and each venting or pressure-sensing pipe leading to gas-safe spaces. Means are to be provided to prevent such loops from being emptied by vacuum.

8) Any water seal, or equivalent device, and loop arrangements are to be capable of preventing the return of vapours and liquids to an inert gas plant at a pressure equal to the test pressure of the cargo tanks.

9) The non-return devices are to be located in the cargo area on deck.

b) Inert gas lines

1) The inert gas main may be divided into two or more branches forward of the non-return devices required by [9.3.3] a).

2) The inert gas main is to be fitted with branch piping leading to the cargo tank. Branch piping for inert gas is to be fitted with either stop valves or equivalent means of control for isolating each tank. Where stop valves are fitted, they are to be provided with locking arrangements. The control system is to provide unambiguous information of the operational status of such valves to at least the control panel required in [9.3.4].

3) Each cargo tank not being inerted is to be capable of being separated from the inert gas main by:

- removing spool-pieces, valves or other pipe sections, and blanking the pipe ends; or

- arrangement of two spectacle flanges in series with provisions for detecting leakage into the pipe between the two spectacle flanges; or
- equivalent arrangements to the satisfaction of the Society, providing at least the same level of protection.

4) Means are to be provided to protect cargo tanks against the effect of overpressure or vacuum caused by thermal variations and/or cargo operations when the cargo tanks are isolated from the inert gas mains.

5) Piping systems are to be so designed as to prevent the accumulation of cargo or water in the pipelines under all normal conditions.

6) Arrangements are to be provided to enable the inert gas main to be connected to an external supply of inert gas. The arrangements are to consist of a 250 mm nominal pipe size bolted flange, isolated from the inert gas main by a valve and located forward of the non-return valve. The design of the flange should conform to the appropriate class in the standards adopted for the design of other external connections in the ship's cargo piping system.

7) If a connection is fitted between the inert gas main and the cargo piping system, arrangements are to be made to ensure an effective isolation having regard to the large pressure difference which may exist between the systems. This is to consist of two shutoff valves with an arrangement to vent the space between the valves in a safe manner or an arrangement consisting of a spool-piece with associated blanks.

8) The valve separating the inert gas main from the cargo main and which is on the cargo main side is to be a non-return valve with a positive means of closure.

9) Inert gas piping systems are not to pass through accommodation, service and control station spaces.

10) In combination carriers, the arrangement to isolate the slop tanks containing oil or oil residues from other tanks is to consist of blank flanges which will remain in position at all times when cargoes other than oil are being carried except as provided for in the relevant section of the guidelines developed by IMO (see Note 1).

Note 1: Refer to the Revised Guidelines for inert gas systems (IMO MSC/Circ.353), as amended by IMO MSC/Circ.387.

9.3.4 **Indicators and alarms** *(1/1/2016)*

a) The operation status of the inert gas system is to be indicated in a control panel.

b) Instrumentation is to be fitted for continuously indicating and permanently recording, when inert gas is being supplied:

1) the pressure of the inert gas mains forward of the non-return devices; and

2) the oxygen content of the inert gas.

c) The indicating and recording devices are to be placed in the cargo control room where provided. But where no cargo control room is provided, they are to be placed in a position easily accessible to the officer in charge of cargo operations.

d) In addition, meters are to be fitted:

1) on the navigating bridge to indicate at all times the pressure referred to in b) 1) and the pressure in the slop tanks of combination carriers, whenever those tanks are isolated from the inert gas main; and

2) in the machinery control room or in the machinery space to indicate the oxygen content referred to in b) 2).

e) Audible and visual alarms

1) Audible and visual alarms are to be provided, based on the system designed, to indicate:

- oxygen content in excess of 5% by volume;
- failure of the power supply to the indicating devices as referred to in b);
- gas pressure less than 100 mm water gauge. The alarm arrangement is to be such as to ensure that the pressure in slop tanks in combination carriers can be monitored at all times;
- high-gas pressure; and
- failure of the power supply to the automatic control system.

2) The alarms required in first, third and fifth bullet of the above item 1) are to be fitted in the machinery space and cargo control room, where provided, but in each case in such a position that they are immediately received by responsible members of the crew.

3) An audible alarm system independent of that required in the third bullet of the above item 1) or automatic shutdown of cargo pumps are to be provided to operate on predetermined limits of low pressure in the inert gas main being reached.

4) Two oxygen sensors are to be positioned at appropriate locations in the space or spaces containing the inert gas system. If the oxygen level falls below 19%, these sensors are to trigger alarms, which are to be both visible and

audible inside and outside the space or spaces and are to be placed in such a position that they are immediately received by responsible members of the crew.

9.3.5 Instruction manuals *(1/1/2016)*

Detailed instruction manuals are to be provided on board, covering the operations, safety and maintenance requirements and occupational health hazards relevant to the inert gas system and its application to the cargo tank system (see Note 1). The manuals are to include guidance on procedures to be followed in the event of a fault or failure of the inert gas system.

Note 1: Refer to the Revised Guidelines for inert gas systems (IMO MSC/Circ.353), as amended by IMO MSC/Circ.387.

9.4 Requirements for flue gas and inert gas generator systems

9.4.1 Application *(1/1/2016)*

In addition to the provisions [9.3], for inert gas systems using flue gas or inert gas generators, the provisions of this item [9.4] are to be applied.

9.4.2 System requirements *(1/1/2016)*

a) Inert gas generators

1) two fuel oil pumps are to be fitted to the inert gas generator. Suitable fuel in sufficient quantity is to be provided for the inert gas generators.

2) the inert gas generators are to be located outside the cargo tank area. Spaces containing inert gas generators are to have no direct access to accommodation, service or control station spaces, but may be located in machinery spaces. If they are not located in machinery spaces, such a compartment is to be separated by a gastight steel bulkhead and/or deck from accommodation, service and control station spaces. Adequate positive-pressure-type mechanical ventilation is to be provided for such a compartment.

b) Gas regulating valves

1) A gas regulating valve is to be fitted in the inert gas main. This valve is to be automatically controlled to close, as required in [9.3.2] b). It is also to be capable of automatically regulating the flow of inert gas to the cargo tanks unless means are provided to automatically control the inert gas flow rate.

2) The gas regulating valve is to be located at the forward bulkhead of the forward most gas-safe space through which the inert gas main passes.

c) Cooling and scrubbing arrangement

1) Means are to be fitted which will effectively cool the volume of gas specified in [9.3.1] b) and remove solids and sulphur combustion products. The cooling water arrangements are to be such that an adequate supply of water will always be available without interfering with any essential services on the ship. Provision is also to be made for an alternative supply of cooling water.

2) Filters or equivalent devices are to be fitted to minimize the amount of water carried over to the inert gas blowers.

d) Blowers

1) At least two inert gas blowers are to be fitted and be capable of delivering to the cargo tanks at least the volume of gas required by [9.3.1] b). For systems fitted with inert gas generators, the Society may permit only one blower if that system is capable of delivering the total volume of gas required by [9.3.1] b) to the cargo tanks, provided that sufficient spares for the blower and its prime mover are carried on board to enable any failure of the blower and its prime mover to be rectified by the ship's crew.

2) Where inert gas generators are served by positive displacement blowers, a pressure relief device is to be provided to prevent excess pressure being developed on the discharge side of the blower.

3) When two blowers are provided, the total required capacity of the inert gas system is to be divided evenly between the two and in no case is one blower to have a capacity less than 1/3 of the total required.

e) Inert gas isolating valves

For systems using flue gas, flue gas isolating valves are to be fitted in the inert gas mains between the boiler uptakes and the flue gas scrubber. These valves are to be provided with indicators to show whether they are open or shut, and precautions are to be taken to maintain them gastight and keep the seatings clear of soot. Arrangements are to be made to ensure that boiler soot blowers cannot be operated when the corresponding flue gas valve is open.

f) Prevention of flue gas leakage

1) Special consideration is to be given to the design and location of scrubber and blowers with relevant piping and fittings in order to prevent flue gas leakages into enclosed spaces.

2) To permit safe maintenance, an additional water seal or other effective means of preventing flue gas leakage is to be fitted between the flue gas isolating valves and scrubber or incorporated in the gas entry to the scrubber.

9.4.3 Indicators and alarms *(1/1/2016)*

a) In addition to the requirements in [9.3.4] b), means are to be provided for continuously indicating the temperature of the inert gas at the discharge side of the system, whenever it is operating.

b) In addition to the requirements of [9.3.4] e), audible and visual alarms are to be provided to indicate:

1) insufficient fuel oil supply to the oil-fired inert gas generator;

2) failure of the power supply to the generator;

3) low water pressure or low water flow rate to the cooling and scrubbing arrangement;

4) high water level in the cooling and scrubbing arrangement;

5) high gas temperature;

6) failure of the inert gas blowers; and

7) low water level in the water seal.

9.5 Requirements for nitrogen generator systems

9.5.1 Application *(1/1/2016)*

In addition to the provisions in [9.3], for inert gas systems using nitrogen generators, the provisions of this item [9.5] are to be applied.

9.5.2 System requirements *(1/1/2016)*

a) The inert gas is to be high purity nitrogen produced by separating air into its component gases by passing compressed air through a bundle of hollow fibres, semi-permeable membranes or absorber material.

b) The system is to consist of a feed air treatment system and any number of membrane or absorber modules in parallel necessary to meet the requirements in [9.3.1] d).

c) The system is to be provided with one or more compressors to generate enough positive pressure to be capable of delivering the total volume of gas required by [9.3.1] b).

d) Where two compressors are provided, the total required capacity of the system is preferably to be divided equally between the two compressors, and in no case is one compressor to have a capacity less than 1/3 of the total capacity required.

e) A feed air treatment system is to be fitted to remove free water, particles and traces of oil from the compressed air, while preserving the gas temperature according to specification.

f) The oxygen-enriched air from the nitrogen generator and the nitrogen-product enriched gas from the protective devices of the nitrogen receiver are to be discharged to a safe location (see Note 1) on the open deck.

Note 1: “safe location" needs to address the two types of discharges separately:

- oxygen-enriched air from the nitrogen generator - safe locations on the open deck are:
  - outside of hazardous area;
  - not within 3m of areas traversed by personnel; and
  - not within 6m of air intakes for machinery (engines and boilers) and all ventilation inlets.
- nitrogen-product enriched gas from the protective devices of the nitrogen receiver - safe locations on the open deck are:
  - not within 3m of areas traversed by personnel; and
  - not within 6m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets

g) The air compressor and nitrogen generator may be installed in the engine-room or in a separate compartment. A separate compartment and any installed equipment is to be treated as an "Other machinery space" with respect to fire protection. Where a separate compartment is provided for the nitrogen generator, the compartment is to be fitted with an independent mechanical extraction ventilation system providing six air changes per hour. The compartment is to have no direct access to accommodation spaces, service spaces and control stations.

h) Where a nitrogen receiver or a buffer tank is installed, it may be installed in a dedicated compartment, in a separate compartment containing the air compressor and the generator, in the engine room, or in the cargo area. Where the nitrogen receiver or a buffer tank is installed in an enclosed space, the access is to be arranged only from the open

deck and the access door is to be opened outwards. Adequate, independent mechanical ventilation, of the extraction type, is to be provided for such a compartment.

i) In order to permit maintenance, means of isolation are to be fitted between the generator and the receiver.

j) The system is to be fitted with automatic means to discharge "off-spec" gas to the atmosphere during start-up and abnormal operation.

9.5.3 Indicators and alarms *(1/1/2016)*

a) In addition to the requirements in [9.3.4] b), instrumentation is to be provided for continuously indicating the temperature and pressure of air at the suction side of the nitrogen generator.

b) In addition to the requirements in [9.3.4] e), audible and visual alarms are to be provided to include:

1) failure of the electric heater, if fitted;

2) low feed-air pressure or flow from the compressor;

3) high-air temperature; and

4) high condensate level at automatic drain of water separator.

9.6 Nitrogen /Inert Gas Systems Fitted for Purposes other than Inerting Required by SOLAS Reg. II-2/4.5.5.1 and 4.5.5.2

9.6.1 Application *(1/1/2016)*

This item [9.6] applies to systems fitted on oil tankers, gas tankers or chemical tankers to which SOLAS regulations II-2/4.5.5.1 and 4.5.5.2 do not apply.

9.6.2 Applicable requirements *(1/1/2016)*

Items [9.3.2] b), [9.3.2] d), [9.3.4] b), [9.3.4] c), first and second bullet of [9.3.4] e)1), [9.3.4] e)4), [9.5.2] c), [9.5.2] e), [9.5.2] g), [9.5.2] h), [9.5.3]a) and b), as applicable, apply to the systems.

The requirements in [9.5.2] a), e), f) and j)] apply.

9.6.3 Installation and tests *(1/1/2016)*

All the equipment is to be installed on board and tested under working conditions to the satisfaction of the Surveyor.

9.6.4 Non-return devices *(1/1/2016)*

The two non-return devices as required by [9.3.3] a)1) are to be fitted in the inert gas main. The non-return devices are to comply with [9.3.3] a)2) and [9.3.3] a)3); however, where the connections to the cargo tanks, to the hold spaces or to cargo piping are not permanent, the non-return devices required by [9.3.3] a)1) may be substituted by two non-return valves.

10 Installation of BWMS on-board ships

10.1 General

10.1.1 Application *(1/7/2022)*

This Article details fire safety measures, in addition to that required by SOLAS II-2, related to the installation of Ballast Water Management Systems onboard any ship.

The applicable requirements in Ch 1, Sec 10 and in Ch 1, App 8 are to be complied with.

The requirements in this Article apply for BWMS technologies as listed in Ch 1, App 8, Tab 1. BWMS with alternative technologies will be considered by the Society on case by case basis.

10.2 Fire categorization

10.2.1 General *(1/7/2022)*

BWMR is to be classified as follows for the purpose of applying the requirements of SOLAS Chapter II-2:

- BWMR containing oil-fired inert gas generators (i.e. BWMS cat.3b and 3c as per Ch 1, App 8, Tab 1) is to be treated as machinery spaces of category A
- Other BWMR are to be considered as other machinery spaces and are to be categorized, depending on the ship type (10) or (11) according to SOLAS II-2/9.2.2.3 or (7) according to SOLAS II-2/9.2.2.4, II-2/9.2.3 and II-2/9.2.4.

10.2.2 BWMS located in the cargo area of tankers *(1/7/2022)*

Notwithstanding the above, where a BWMS is located in the cargo area of a tanker as allowed by Ch 1, App 8, [3.2.1], b), the BWMR is to be categorized as (8), a cargo pump-room, according to SOLAS II-2/9.2.4.2.2 for determining the extent of fire protection to be provided.

Note 1: The cargo area of a tanker is defined in Ch 1, App 8, [2.1.2].

10.2.3 Storage of chemicals *(1/7/2022)*

a) Spaces where the storage of liquid or solid chemicals for BWMS is intended are to be categorized as store-rooms for the purpose of applying the requirements of SOLAS Chapter II-2, i.e.:
   - On passenger ships carrying more than 36 passengers:
     - "Other spaces in which flammable liquids are stowed" as defined in SOLAS II-2/9.2.2.3.2.2(14), if flammable products are stored
     - "Store-rooms, workshops, pantries, etc." as defined in SOLAS II-2/9.2.2.3.2.2(13) otherwise.
   - On other ships:
     - "Cargo pump-rooms" as defined in SOLAS II-2/9.2.4.2.2.2(8) if located in the cargo area of a tanker
     - "Service spaces (low risk)" as defined in SOLAS II-2/9.2.2.4.2.2(5), SOLAS II-2/9.2.3.3.2.2(5) or II-2/9.2.4.2.2.2(5) if the surface area is less than 4m^2 and if no flammable products are stored
     - "Service spaces (high risk)" as defined in SOLAS II-2/9.2.2.4.2.2(9), SOLAS II-2/9.2.3.3.2.2(9) or II-2/9.2.4.2.2.2(9) otherwise.

Note 1: It is understood that only chemical injection (cat.6 as per Ch 1, App 8, Tab 1), in-line flocculation (cat.2 as per Ch 1, App 8, Tab 1) and technologies using neutralizer injection (cat.4, 5, 6 and 7 as per Ch 1, App 8, Tab 1) will require chemical or additive storage.

b) Where the storage of chemicals is foreseen in the same room as the ballast water management machinery, this room is to be considered both as a store-room and as a machinery space in line with [10.2.1].

c) When the chemical substances are stored inside integral tanks, the ship's shell plating is not to form any boundary of the tank.

d) Tanks containing chemicals are to be segregated from accommodation, service spaces, control stations, machinery spaces not related to the BWMS and from drinking water and stores for human consumption by means of a cofferdam, void space, cargo pump-room, empty tank, oil fuel storage tank, BWMR or other similar space. On-deck stowage of permanently attached deck tanks or installation of independent tanks in otherwise empty hold spaces should be considered as satisfying this provision.

10.3 BWMR location and boundaries

10.3.1 BWMS using chemical substances *(1/7/2022)*

For BWMS storing, introducing or generating chemicals, the BWMR and chemical substance storage rooms are not to be located in the accommodation area. Any ventilation exhaust or other openings from these rooms are to be located not less than 3m from entrances, air inlets and openings to accommodation spaces.

This requirement need not apply in case the BWMS is located in the engine room.

10.3.2 Ozone-based BWMS *(1/7/2022)*

a) Ozone-based BWMS – i.e. cat.7a and 7b - are to be located in dedicated compartment, separated from any other space by gastight boundaries. Access to the BWMR from any other enclosed space is to be through airlock only, except if the only access to that space is from the open deck.

   Access to the ozone based BWMR may be provided through the engine room only provided:
   - Access from the engine room to the BWMR is through airlock and,
   - An alarm repeater is provided in the BWMR, which will repeat any alarm activated in the engine room.

b) A sign is to be affixed on the door providing personnel with a warning that ozone may be present and with the necessary instructions to be followed before entering the room.

10.3.3 General *(1/7/2022)*

BWMR containing equipment for BWMS of the following types is to be equipped with tested gastight and self-closing doors without any holding back arrangements:

- BWMS storing, introducing or generating chemical substances
- De-oxygenation based on inert gas generator
- Electrolysis

- Ozone injection.

Doors leading to the open deck need however not to be self-closing.

10.4 Fire fighting

10.4.1 Fixed fire-extinguishing system *(1/7/2022)*

a) Where fitted, fixed fire extinguishing systems are to comply with the relevant provisions of the Fire Safety Systems Code.

b) Ozone-based BWMS

BWMR containing equipment related to ozone-based BWMS is to be provided with a fixed fire extinguishing system suitable for category A machinery spaces and capable of manual release.

c) Where a fixed fire-extinguishing system is provided in the BWMR, it should be compatible with the BWMS and the chemical products that are used, produced or stored in the BWMR. Specific attention is to be paid to potential chemical reactions between the fire extinguishing medium and chemical products used for water treatment. Especially, water-based fire-extinguishing systems should be avoided in case of sulfuric acid storage.

d) Foam fixed fire-extinguishing system.

For all kinds of BWMS, in case a foam fire extinguishing system is installed in the BWMR, its efficiency is not to be impaired by chemicals used by the BWMS where relevant.

e) Where a fixed fire-extinguishing system is installed in the BWMR, automatic shutdown of the BWMS upon release of the fixed fire extinguishing system is to be arranged. Any need for cooldown necessary for safe shutdown to be considered in the shutdown sequence.

f) Where BWMS that includes air or O2 storage is located in a room covered by a fixed gas fire-extinguishing system, air or O2 storage is to be taken into account for the gas capacity calculation, unless the discharge pipe from safety valves for air or O2 storage are led directly to outside the room.

10.4.2 Portable fire-fighting equipment *(1/7/2022)*

There is to be at least one portable fire extinguisher that complies with the provisions of the Fire Safety Systems Code and suitable for electrical fires in the BWMR containing UV-type BWMS.

10.5 Fire prevention

10.5.1 Equipment protection *(1/7/2022)*

a) Overcurrent or overvoltage protection is to be installed to protect UV type BWMS.

b) Electrolysis reactors are to be provided with at least with two independent means of monitoring operation. The monitoring system is to initiate audible and visual alarms and automatic shutdown of the BWMS in the event that an anomaly is detected. Requirements for shutdown arrangement are clarified in Ch 1, App 8, [3.1.9].

Note 1: If a pressure relief valve is also provided, the vent of this valve is to be led to a safe location on the open deck, as clarified in Ch 1, App 8, [3.1.5]. The valve should be positioned to optimally remove gas from the electrolysis reactor.

10.5.2 Fire detection *(1/7/2022)*

a) A fixed fire detection and fire alarm system complying with the provisions of the Fire Safety Systems Code is to be installed in spaces containing an inert gas generator or an ozone generator.

b) A section of fire detectors which covers a control station, a service space or an accommodation space is not to include a BWMR containing equipment related to ozone based BWMS.

10.6 Ventilation

10.6.1 Ventilation arrangement *(1/7/2022)*

a) The ventilation systems for BWMR containing BWMS of the following types are to be independent of the ventilation systems serving any other spaces:
   - BWMS storing, introducing or generating chemical substances
   - De-oxygenation, including pasteurization and de-oxygenation (cat.3 and cat.8 as per Ch 1, App 8, Tab 1)
   - Electrolysis
   - Ozone injection.

b) The ventilation exhaust for BWMR containing a nitrogen generator is to be located in the lower part of the room in order to efficiently evacuate dangerous gases – as defined in Ch 1, App 8, [2.1.3] - heavier than air.

c) The ventilation exhaust for BWMR containing electrolysis systems is to be located so as to be able to efficiently evacuate dangerous gases – as defined in Ch 1, App 8, [2.1.3] - that could be generated during the electrolysis process. Due regard is to be paid to the expected quantity and density of such gases when designing the ventilation exhaust.

d) The following requirements apply to ventilation ducts serving BWMR for ozone-based BWMS:
   - The part of the ducts located outside of the BWMR is to be made of steel having a thickness of at least 3 mm for ducts with a free cross-sectional area of less than 0,075 m^2, at least 4 mm for ducts with a free cross-sectional area of between 0,075 m^2 and 0,45 m^2, and at least 5 mm for ducts with a free cross-sectional area of over 0,45 m^2. and
   - The ducts are to be suitably supported and stiffened
   - The outside openings of the ducts are to be fitted with protective screens of not more than 13 mm square mesh.

e) The ventilation system for BWMR containing ozone-based BWMS or ventilation system for hydrogen de gas arrangement as required by Ch 1, App 8, [3.3.1] e) is to be interlocked with the BWMS such that:
   - In case of loss of ventilation (primary and secondary), a visual and audible alarm is to be triggered both inside and outside the BWMR and at a place where a responsible member of the crew is on duty. If the ventilation is not restored after a pre-set time, the BWMS is then to be automatically shut down. Any need for cooldown necessary for safe shutdown is to be considered in the shutdown sequence
   - It is not to be possible to start the BWMS without the ventilation running.

For ventilation systems serving BWMR and containing or conveying a dangerous gas, relevant requirements in Ch 1, App 8, [3.2] are to be satisfied.

10.6.2 **Ventilation rate** *(1/7/2022)*

a) An adequate power ventilation system is to be provided in enclosed BWMR.

b) The ventilation capacity is to be at least 30 air changes per hour where explosive or toxic gases may be generated during operation of the BWMS. The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guidelines) and ‘’safety hazard’’ as listed in Ch.17 of IBC code are to be used as references for identifying those cases.

c) The ventilation capacity may be reduced as follows:
   - Flocculation-type BWMS: 6 air changes per hour
   - De-oxygenation, incl. pasteurization and de-oxygenation (cat.3 and cat.8 as per Ch 1, App 8, Tab 1): 6 air changes per hour
   - Full flow electrolysis: 6 air changes per hour
   - Side-stream electrolysis: 20 air changes per hour
   - Ozone injection: 20 air changes per hour
   - Chemical injection: 6 air changes per hour.

Note 1: More stringent ventilation capacity requirements may arise from other regulations e.g. IBC Code requirements for spaces located in the cargo area.

10.7 Personal equipment

10.7.1 General *(1/7/2022)*

a) Suitable protection equipment are to be available onboard for the protection of the crew members who are engaged in the servicing, maintenance and repair of BWMS storing, introducing or generating chemicals, as recommended by the product manufacturers. The protection equipment is to consist of large aprons, special gloves with long sleeves, suitable footwear, coveralls of chemical-resistant materials, and tight fitting goggles or face shields or both. The protective clothing and equipment is to cover all skin so that no part of the body is unprotected. This protection equipment is to be provided separately without taking into account equipment required by other mandatory requirements.

b) Work clothes and protective equipment are to be kept in easily accessible places and in special lockers. Such equipment is not to be kept within accommodation spaces, with the exception of new, unused equipment and equipment which has not been used since undergoing a thorough cleaning process. Notwithstanding the above, storage rooms for such equipment within accommodation spaces if adequately segregated from living spaces such as cabins, passageways, dining rooms, bathrooms, etc.

c) When a BWMS storing, introducing or generating chemicals is installed on board, suitably marked decontamination showers and an eyewash are to be available in a convenient location in close proximately to the BWMS and the chemical store room(s).

d) An emergency escape breathing apparatus (EEBD) is to be provided in the BWMR. This emergency escape breathing apparatus may be one of the EEBDs provided in accordance with the requirements of SOLAS II-2/13. An EEBD need not be required for BWMS of cat.1 as per Ch 1, App 8, Tab 1.

e) A personal ozone detector, calibrated as per the manufacturer's specifications, is to be provided for each person engaged in the servicing, maintenance and repair of BWMS utilizing ozone.

f) A two-way portable radiotelephone apparatus dedicated for the BWMS service, maintenance and repair is to be provided, in addition to those required by SOLAS for fire-fighting purposes. This two-way radiotelephone apparatus is to be properly identified in order to avoid mix-up with the apparatus intended for fire-fighting operations. Where the BWMS may release explosive gases, this two-way radiotelephone apparatus is to be of a certified safe type suitable for use in zone 1 hazardous areas, as defined in IEC Publication 60079. Where the BWMS stores, utilizes or introduces chemicals, the apparatus is to undergo deep cleaning or de-contamination after use. A two-way portable radiotelephone apparatus need not be required for BWMS of cat.1 as per Ch 1, App 8, Tab 1.