RULES

FOR THE CLASSIFICATION OF SHIPS

Part 9 – MACHINES

January 2025

CROATIAN REGISTER OF SHIPPING

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By the decision of the General Committee to the Croatian Register of Shipping,

RULES FOR THE CLASSIFICATION OF SHIPS
Part 9 – MACHINES

have been adopted on 20th December 2024 and shall enter into force on 1st January 2025

GENERAL TERMS AND CONDITIONS

(March 2022)

Article 1
GENERAL

1.1 CROATIAN REGISTER OF SHIPPING (hereinafter: the *Register*) shall at all times remain an independent contractor and neither the *Register* nor any of its officers, surveyors, auditors, inspectors, agents, appointers, officers or managers shall act as an employee, servant or agent of any other party in the performance of the Services rendered by the *Register*.

1.2 The *Register* acts as a service provider. The Services provided by the *Register* cannot be construed as a commitment by the *Register* to achieve any result or as a warranty.

1.3 The provision of Services is subject to these General Terms and Conditions. No other terms and conditions shall apply, either expressly or by implication, unless expressly agreed in writing between the Parties.

1.4 These General Terms and Conditions shall be incorporated into, or referred to in any Contract and shall prevail over and exclude any other terms and conditions that the Client may wish to impose.

Any amendments to and/or deviations from these General Terms and Conditions, as well as any additional terms and conditions of the Client, shall be binding or valid only if set forth in writing and duly signed by the authorised representatives of both Parties.

1.5 The invalidity of one or more provisions of these General Terms and Conditions shall not affect the remaining provisions.

1.6 The Client acknowledges that the latest version of these General terms and Conditions and the latest version of applicable Rules apply to the Services provided by the *Register*.

1.7 Definitions in these General Terms and Conditions take precedence over other definitions that may appear in other documents issued by the *Register*.

1.8 The Client should at all times be aware of the provisions of these General Terms and Conditions, as they may be further amended, with their latest up to date version available on the web site of the *Register*.

Article 2
DEFINITIONS

2.1 **Certificate** means either a class certificate or statutory certificate, statement, attestation, statement of compliance, and a report following the Services provided by the *Register*.

2.2 **Certification** means the activity of certification in application of international and national standards and international industry practice provided by the *Register*.

Certification is an appraisement given by the *Register* to the Client and cannot be construed as an implied or express warranty of safety, fitness for purpose, seaworthiness of the vessel or its value for sale, insurance or chartering.

The purpose of Certification is to provide classification and statutory services and assistance to the maritime industry, Flag State Administrations, and regulatory authorities relating to maritime safety and pollution prevention.

2.3 **Classification** includes all activities and Services provided by the *Register* in accordance with the Rules. Classification may or may not be accompanied by the issuance of a Certificate of class with reference to the Rules.

Certificate of class is valid only if issued by the *Register*.

However, Certificate of class should not be construed as a guarantee of the safety, fitness for purpose or seaworthiness of the vessel. It is merely an attestation that the vessel complies with the Rules developed and published by the *Register*.

In addition, the *Register* is not a guarantee of the safety of life or property at sea or the seaworthiness of a vessel because, although the classification of a vessel is based on the assumption that the vessel will be properly loaded, operated, and maintained by competent and qualified personnel, the *Register* has no control over how a vessel is operated and maintained between the periodic surveys it conducts.

2.4 **Statutory certification** means certification made by the *Register* on behalf of the Flag State Administrations when and to the extent that the *Register* has been authorised to do so by the respective Flag State.

Statutory certification and services include the assessment of vessels registered by the Flag State and/or ship management companies to determine whether such ships/companies comply with the applicable requirements of international conventions, codes and national legislation, and the issuance of, or assistance in the issuance of, the appropriate certificates and documents.

Statutory certification includes, but is not limited to, certification, survey, and issuance of statutory certificates on behalf of the Flag State.

In cases where the *Register* acts on behalf of Flag State Administrations, the *Register* shall follow guidance issued by IMO (Resolutions, Circulars, etc.) or by IACS through Unified Interpretations (UI), unless otherwise directed by the Flag State.

2.5 **Client** means the shipowner, company, shipyard and/or party requesting Services or taking ownership of a classed vessel. In cases where shipowners have authorized another party to operate the vessel on their behalf, that party shall be considered as the company.

In addition to the above the Client means the person and/or entity that has requested Services from the *Register* and that has entered into a Contract or an agreement for Services with the *Register*.

2.6 **Parties** means the *Register* and Client together.

2.7 **Party** means the *Register* or the Client.

2.8 **Contract** means the contract in the form of a written agreement between the Client and the *Register* requesting Services, including these General Terms and Conditions and the Rules.

The provisions related to the Contract in these General Terms and Conditions shall apply even if there is no written agreement between the Client and the *Register*.

The Client may request the *Register* in writing to make a change to the contracted Services. However, the *Register* shall not be obligated to accept or execute any such change until a written agreement has been signed with the Client regarding the compensation and the possible impact of the change on the schedule as an addendum to the originally contracted Services.

2.9 **Services** shall mean the services specified in 2.2. 2.3 and 2.4, but also other services related to certification, classification and statutory certification, such as, but not limited to: ISM Code certification, ISPS Code, MLC 2006 certification, fuel oil consumption reporting, IHM certification, approval of manufacturers and service providers, certification of materials and products, training activities, conformity assessment, and any other relevant activities such as third party inspections, testing, shore and shipboard trials.

The Services provided by the *Register* are performed on a random basis and in no case include a full inspection of all items.

The *Register* shall provide the Services in accordance with related Contract(s), the provisions of these General Terms and Conditions, Rules, the international and national standards, the international conventions, the EU Regulations, the Flag State requirements and the industry practices applicable to the particular Service and always assuming that the Client is aware of these standards and the industry practices.

When providing Services, the *Register* does not guarantee the accuracy of the information or advice provided.

In providing Services, the *Register* does not assess compliance with standards other than the Rules, international and national standards, international conventions, EU regulations, Flag State requirements and industry practice, to the extent agreed in writing or specified in the Contract.

2.10 The ***Register*** means the Croatian Register of Shipping, an entity organized and existing under Croatian law, which, according to the Law on the Croatian Register of Shipping (Official Gazette No. 1996/81, 2013/76 and 2020/62) and the Charter of the *Register*, is an independent, not-for-profit, but public welfare oriented, public foundation that performs tasks:

- classification of sea-going ships,
- statutory certification of sea-going ships on behalf of the Flag State Administrations,
- classification of inland navigation vessels,
- statutory certification of inland navigation vessels,
- statutory certification of recreational crafts,
- certification of materials and products,
- conformity assessment of recreational crafts,
- conformity assessment of marine equipment,
- conformity assessment of pressure vessels,
- certification/registration of quality management systems.

2.11 **Vessel** means a ship, vessel, unit or offshore structure of any kind, whether or not connected to the shore or sea/river bed, located at sea or in inland waters and intended for transportation or special operations on the water, as decided by the *Register*.

2.12 **Rules** means the Rules for the classification, guidelines, instructions, or other documented evidence of the *Register* related to the Services provided.

The competent interpretation of the requirements specified in the Rules or other regulations published by the *Register* shall be the exclusive responsibility of the *Register's* Head Office, notwithstanding any possible different interpretations by other parties.

In cases where the Rules do not contain detailed requirements, the specific approval by the *Register* shall be based on the principles of the Rules and shall ensure a safety standard equivalent to that of the Rules.

Article 3
RESPONSIBILITIES

3.1 It is the Client's responsibility to ensure that all surveys required for vessel's class maintenance are conducted in a timely manner and in accordance with the Rules.

3.2 The *Register* may suspend or withdraw the vessel's existing Certificate of class in the event of serious deficiencies and replace it with a new Certificate of class with a shortened period of validity during which the deficiencies are to be rectified.

In addition, the *Register* shall suspend or withdraw a vessel's Certificate of class if the deficiencies are of such a magnitude as to endanger the class of the vessel, its safety and integrity, the safety of the crew, passengers, or the marine environment, and shall require that the vessel is to be inspected at the first port of call where the necessary repairs are to be carried out.

3.3 The Client should inform the *Register*:

- (i) in the event of a change in the intended use of a vessel, a conversion and alteration of the hull, machinery installations and other equipment affecting the Class of the vessel assigned by the *Register*. Conversions and alterations must be made under the supervision of the *Register* and must comply with the requirements of the Rules and/or additional requirements of the *Register*,
- (ii) in cases where the vessel has been damaged to such an extent that the Class of the vessel is likely to be affected and the safety and integrity of the vessel is likely to be compromised. In such cases, the vessel must be surveyed at the first port of call or as further directed by the *Register*. The survey shall be to the extent deemed necessary by the *Register*, by taking into account the extent of the damage.
- (iii) in cases where class-related deficiencies and/or defects are found as a result of a Flag State inspection or Port State Control. Should the Client fail to notify the *Register* of the detention of the vessel by Port State Authorities due to class related deficiencies, the *Register* reserves the right to suspend or withdraw the Certificate of class.

3.4 The *Register* shall have full control over Certificates issued and may suspend or withdraw a Certificate at any time in its sole discretion if the Client fails to comply with the following requirements set forth in the *Rules for the Classification of Ships, Part 1 - General Requirements, Chapter 1 - General Information*, as applicable:

- (i) para. 5.3 - *Maintenance of the validity of Certificate of Class*,
- (ii) para. 5.4 - *Period of Validity*,
- (iii) para. 5.5 - *Extension of the Period of Validity*,
- (iv) para. 5.6 - *Suspension and Reinstatement of Class in the Case of Overdue Surveys*, and
- (v) para. 5.7 - *Withdrawal of Class*.

3.5 The *Register* may suspend or withdraw a Certificate at any time in its sole discretion if the Client fails to comply with the following requirements set forth in the *Rules for the Classification of Inland Navigation Vessels, Part 1 - Classification and Surveys, Chapter I - Principles of Classification*, as applicable:

- (i) para. 2.8 - *Maintenance of the Validity of the Certificate of Class*,
- (ii) para. 2.9 - *Extension of validity of the Certificate of Class*,

and following requirements set forth in the *Rules for the Classification of Inland Navigation Vessels, Part 1 - Classification and Surveys, Chapter II - Classification*, as applicable:

- (iii) para. 2.1 – *Suspension of Class*,
- (iv) para. 2.2 – *Withdrawal of Class*.

3.6 In addition to clauses 3.2, 3.4 and 3.5 of this Article, the *Register* reserves the right to terminate the Services and related Contract in the event of a breach of the provisions of these General Terms and Conditions.

3.7 If the Client fails to provide the *Register* with the required access or information at the agreed times or fails to prepare for the Service in a timely manner, the *Register* may suspend the provision of the Service until it receives the Client's instructions for access and/or the required information.

The *Register* shall not be liable for the consequences of such suspension, and the Client shall be responsible for the *Register's* additional fees and other unnecessary costs and expenses incurred by the *Register*.

3.8 The Client is obliged to perform timely payments of the invoices for provided Services. However, the *Register* may retain or withhold any Service or Certificate to the Client in the case of outstanding payments, whether mutually related or not, arising out of the entire business relationship with the Client.

Article 4
HEALTH, SAFETY AND ENVIRONMENT

4.1 Both the *Register* and the Client shall apply reasonable standards to promote safety, health, and environmental protection and to provide a safe working environment for their personnel.

4.2 The Client shall provide the *Register* with all access and information necessary for the safe and efficient performance of the requested Services as required by the Rules.

4.3 During the survey, personnel of the *Register* should have secure access to all work that directly or indirectly affects the Service.

4.4 The *Register* has the right to refuse to conduct an activity or visit an area or site if the *Register* in its sole discretion, believes that relevant risks are unacceptable or are not adequately addressed, contained, or otherwise mitigated. Such a decision shall suspend the obligations of both Parties under the Contract without incurring any liability or penalty until the Parties agree on how to proceed.

Article 5
THIRD PARTIES AND SUBCONTRACTORS

5.1 Each specific Contract, including any Certificates issued, relates specifically to the Client, and no rights, obligations, interests, claims, benefits or Certificates issued shall extend to any third party without the prior written consent of the *Register*.

5.2 The Client shall not be entitled to grant any right to use the Certificates to any third party without the prior written consent of the *Register*.

5.3 The Client shall not without *Register's* consent, cede, assign, transfer, subcontract or deal in any manner with all or any of its rights or obligations under any Service and related Contract.

5.4 With regard to third party rights to access information and Certificates under confidentiality clause reference is to be made to Article 9.

Article 6
TAXES

6.1 Each Party shall be responsible for and shall bear all taxes, duties or similar governmental charges levied or imposed on any activity of that Party.

6.2 Prices, fees, rates, or remuneration are exclusive of any form of sales tax, value added tax, administrative fees and services tax and/or other similar taxes, including any surcharges. If any such indirect tax is or becomes applicable to the Services provided under the Contract, the Client shall be responsible for the payment of such indirect taxes.

Article 7
PAYMENT OF INVOICES

7.1 The provision of Services by the *Register*, whether complete or not, shall include payment of fees thirty (30) days after issuance of the invoice for the portion of the Services performed.

7.2 In the event that the Client fails to meet the requirements for payment in accordance with the instalments and terms of payment contained herein, the *Register* reserves the right to charge the Client with the interest rate in accordance with the applicable laws of the Republic of Croatia.

7.3 If the Client disputes an invoice or part of an invoice, the Client shall notify *Register* thereof in writing without undue delay. If no notification is received by the due date, Client shall be deemed to have accepted the invoice in full. If only part of an invoice is disputed, the undisputed amount must be paid by the due date.

Consequently, no disputes arising between the *Register* and the Client shall interfere with prompt payment of invoices by the Client. Any rights of lien or retention in favour of the Client or otherwise, are hereby excluded.

7.4 In the event of cancellation of all or part of the Services prior to their final completion, the Client shall pay all costs incurred by the *Register* on pro-rata basis for the portion of the Services provided to date. In such event, the *Register* will not claim the Client for loss of profit or reduced income. All reasonable costs directly attributable to the early termination and all amounts due to the *Register* at that time shall become immediately due and payable.

7.5 In the event of termination of the Service and related Contract, the *Register* shall be entitled to retain any payments, deposits or prepayments of fees made by the Client prior to the date of termination up to the amount to which the *Register* is entitled.

Article 8
TERMINATION

8.1 The Parties shall have the right to terminate the Services and the related Contract(s) by written notice to the other Party, and without prejudice to Article 7, in the following cases:

- (i) if the other Party commits a material breach of these General Terms and Conditions and/or the Contract and fails to rectify such breach in accordance with clause 8.4 of this Article,
- (ii) if the other Party becomes insolvent, is unable to pay its debts as they become due, or becomes subject to bankruptcy proceedings, administration, receivership, dissolution, liquidation, winding up or otherwise ceases to carry on its business; or
- (iii) for convenience, after giving the other Party thirty (30) days' prior written notice of termination.

8.2 The Classification issued for the relevant vessel and the Certificates previously issued shall remain valid until the effective date of termination or, in the event of such termination, immediately, subject to compliance with Article 3 and Article 7.

8.3 If, in the reasonable opinion of the *Register*, the Client breaches or is suspected of breaching Article 14 or Article 15, the *Register* shall have the right to terminate the Service and related Contract with immediate effect.

8.4 Notwithstanding the provisions of clause 8.1 of this Article, the Party intending to terminate Services for non-compliance or breach of the provisions of these General Terms and Conditions shall notify the other Party of the non-compliance or violation of the provisions of these General Terms and Conditions and set a reasonable deadline of 15 (fifteen) days for the other Party to remedy the breaches of the provisions of these General Terms and Conditions.

If the Party fails to remedy the breaches of the provisions of these General Terms and Conditions within the aforementioned period, the other Party shall have the right to terminate Services without further notice.

8.5 Termination of the Service and related Contract pursuant to the provisions of these General Terms and Conditions shall not give either Party the right to claim any additional compensation, indemnity or reimbursement from the other Party as a result of such termination, but such termination shall not affect any rights or remedies available to a Party at the time the termination becomes effective or any obligations or liabilities incurred by a Party.

Article 9
CONFIDENTIALITY

9.1 The Parties agree to keep confidential all facts, data, information, etc. related to the other Party's business that they have learned in the course of providing Services. Such information and data shall not be disclosed by the Parties to any third party and shall not be used or misused to the detriment of the other Party.

9.2 The *Register* will keep confidential any data, plans or other technical information received from the Client and will not disclose it to any third party outside the *Register*, unless authorised by the Client. This obligation shall continue to apply after termination of the Services. This obligation shall not apply to any data, plans or other technical information that was in the possession of the *Register* prior to being disclosed to the *Register* by or on behalf of the Client, or that becomes publicly available through no fault of the *Register*, or is otherwise provided to the *Register* by an independent source that is under no obligation of confidentiality to the *Register*.

9.3 Certificates issued by the *Register* to the Client as a result of the Services provided shall not be covered by the confidentiality Article.

Notwithstanding the foregoing, the Client shall be entitled to disclose any data to its affiliates involved in the transactions related to the Services or the Client's core activities.

9.4 Notwithstanding clause 9.1 and clause 9.2 of this Article, the *Register* shall have the right to disclose the Confidential Information to the following parties if required by regulations of:

- (i) authorised representatives of the Flag State Administration,
- (ii) authorised audit teams (i.e., accreditation body or EC auditors),
- (iii) the International Association of Classification Societies (IACS),
- (iv) a court of competent jurisdiction, government agency, or other relevant public authority, in accordance with applicable law, court order, or other public regulation.

9.5 The Client acknowledges that the *Register* is required to provide access to information to the EU Commission or any person acting on its behalf in accordance with applicable EU requirements and that the Client shall give the EU Commission with unrestricted access to the vessels for the purpose of inspection.

9.6 The obligations in this Article shall survive the conclusion of the Service or the termination of related Contract and shall continue for as long as the relevant information remains confidential.

Article 10
INTELLECTUAL PROPERTY

10.1 Each Party shall be the sole owner of all rights to its Intellectual Property created before or after the effective date of these General Terms and Conditions, whether or not associated with any Contract between the Parties.

10.2 The Intellectual Property developed by the *Register* for the provision of the Services, including but not limited to drawings, calculations and reports, shall remain the exclusive property of the *Register*.

Article 11
PROFESSIONAL ETHICS

11.1 Each of the Parties warrants that, with respect to the matters contemplated herein, neither it nor its affiliates has made or will make, directly or indirectly, any offer, payment, gift or authorization of money to any government official or employee, political party, public official or candidate for the benefit or advantage thereof.

11.2 In providing the Services, the *Register* shall strictly adhere to the requirements of its Code of Ethics relating to business activities.

Article 12
FORCE MAJEURE

12.1 For the purposes of these General Terms and Conditions, the term "Force Majeure" includes any event that directly or indirectly prevents the Parties from fulfilling their obligations due to events beyond their control, such as: strikes, wars, riots, piracy, civil commotion, malicious damage, pandemic, compliance with laws or government orders, rules, regulations or directives, sanctions and embargoes, accidents, defects of plants or machinery, seizures, fires, floods, storms and the like.

12.2 If either Party is prevented or delayed from performing its obligations by Force Majeure, such Party shall promptly notify the other Party in writing of the circumstances of the Force Majeure and its influence and, after such notification, shall not be liable for performance of any obligations prevented by the influence of the Force Majeure during its duration. Upon termination of the influence of the Force Majeure, the same Party should proceed with the planned activities in order to fulfil its obligations.

12.3 If one of the Parties is prevented by Force Majeure in its activities and fulfilment of its obligations and this event lasts continuously for three (3) months, the other Party shall be entitled to terminate the Service and related Contract without liability.

12.4 Neither of the Parties shall be liable for non-compliance with these General Terms and Conditions due to Force Majeure. If one of the Parties is prevented from fulfilling its obligations under these General Terms and Conditions due to Force Majeure, it shall immediately notify the other Party in writing within a reasonable period of time, stating the reasons for the Force Majeure and providing relevant evidence, if any.

Article 13
INDEMNIFICATIONS

13.1 Each Party shall indemnify the other Party against all claims arising out of the performance of the Services in respect of bodily injury, illness or death of any of its employees or other representatives and in respect of loss of or damage to the Party's property.

This provision shall apply whether or not the damage is caused or contributed to by the negligence of the other Party. Both Parties are obliged to take out separate insurances for these liabilities.

13.2 The Client shall indemnify the *Register* from and against all claims arising from the Client's violation of the provisions of these General Terms and Conditions and from the misuse of the Certificates issued by the *Register*.

13.3 The Client shall indemnify the *Register* against any financial responsibility or amounts arising from non-payment, late payment or payment of withholding taxes to the non-relevant tax authority or any other relevant governmental body.

13.4 Each Party shall notify the other Party without undue delay as soon as it becomes aware of any incident that could give rise to a claim against the other Party in respect of the Service provided and related Contract.

Article 14
ANTI-CORRUPTION

14.1 Each Party agrees that in performing its obligations under any Service, it will ensure that its affiliates, employees and/or agents, subsidiaries, subcontractors, consultants, and any other persons providing Services will:

- (i) comply with all applicable anti-bribery and anti-corruption laws (collectively, Anti-Bribery Laws) and, in particular, do not, directly or indirectly, offer, promise, grant, authorise the payment of, or confer any financial or other benefit on any public or government official:
  - to a public or governmental official to obtain or retain business with the intent to influence such official in his or her capacity as an official, if such official is not permitted or required by written law to be influenced by the offer, promise or gift; or
  - to another person with the intent to induce or reward the improper performance of a function or activity or for any other illegal purpose,
- (ii) maintain adequate systems and procedures designed to prevent activities, practises, or conduct in connection with services that would constitute an offence under an anticorruption law; and
- (iii) take reasonable steps to prevent similar acts by customers, contractors, subcontractors, agents and other third parties, persons under its control or influence.

14.2 Any failure by a Party to comply with or ensure compliance with its obligations under this Article shall, notwithstanding anything to the contrary in these General Terms and Conditions, be deemed a breach of these General Terms and Conditions which shall entitle the other Party to suspend and/or terminate the Services by notice in writing with immediate effect without further liability to the other Party except for any liability which may have arisen prior to the date of termination or suspension (as the case may be).

14.3 If a Party elects to suspend the provision of Services under these General Terms and Conditions pursuant to this Article, it shall have the sole and absolute discretion to determine:

(i) when it will resume performance (if at all); and

(ii) extend the period for performance of its obligations under the Services in its sole discretion.

Article 15
SANCTIONS

15.1 Each Party shall conduct all activities in compliance with all laws, statutes, rules, economic and trade sanctions (including, but not limited to, U.S. sanctions and EU sanctions) and regulations applicable to such Party, including, but not limited to: child labour, forced labour, collective bargaining, discrimination, abuse, working hours and minimum wages, anti-bribery, anti-corruption, copyright and trademark protection, personal data protection.

15.2 Each Party hereby represents and warrants that it is not or will not be subject to any economic or trade sanctions ("Sanctions") imposed by the United States of America, the European Union, the United Kingdom, any EU Member State, or the United Nations with respect to any country and/or by any sanction giver with respect to any company/individual.

15.3 Each Party represents and warrants that it will strictly comply with all Sanctions.

15.4 Nothing in these General Terms and Conditions shall be construed as causing or obligating either Party to act or refrain from acting in a manner inconsistent with, punishable by, or prohibited by any Sanctions.

15.5 Neither Party shall be obligated to perform any obligation arising under these Terms and Conditions (including, without limitation, the obligation to):

(i) perform, deliver, accept, sell, purchase, pay or receive any funds to, from or through any person or entity; or

(ii) engage in any other action whatsoever,

if doing so violates or is inconsistent with sanctions and/or recommendations of international (intergovernmental) organisations to combat the financing of terrorism and other criminal activities and/or money laundering or exposes such Party to investigation or penalties.

15.6 In the event that a Party breaches any Sanctions or the Party's Business and/or Transactions arising out of or in connection with these General Terms and Conditions breach any Sanctions or otherwise violate the recommendations of one or more international (intergovernmental) organisations for combating the financing of terrorism and other criminal activities and/or money laundering, the other Party shall be entitled to terminate these General Terms and Conditions by written notice with immediate effect without incurring any liability to the other Party, except for liabilities (if any) incurred prior to the date of termination.

Article 16
LIABILITY

16.1 The *Register* is not, and cannot be considered as, an underwriter, consulting engineer, naval architect, shipbuilder, shipowner, or ship management company, nor can it assume the obligations and responsibilities associated with such functions, although the *Register's* experience may enable it to respond to inquiries about matters not covered by its Rules, policies, instructions, or other documented evidence.

16.2 The practices and procedures of the *Register* shall be selected by the *Register* in its sole and absolute discretion based on its experience and knowledge and in accordance with generally accepted professional standards in the relevant field of classification societies.

16.3 Nothing herein contained shall release any designer, naval architect or engineer, shipbuilder or manufacturer, shipyard, vendor, supplier, contractor or subcontractor, repairer or owner, from any information, report, certificate or similar document issued in connection with the provision of Services by the *Register*, operator, manager or other person or entity from any express or implied warranty or other contractual obligation or responsibility, or from any negligent act, error or omission of any kind whatsoever, nor shall they create any right, claim or benefit for any third party.

16.4 The *Register* shall exercise due care in the selection or appointment of its surveyors and all other employees whose presence and work is necessary for the provision of the Services.

16.5 If any person or entity using the Services of the *Register* suffers any loss, damage or expense that is or is shown to have been caused by a negligent act, omission or error of the *Register's* officers, surveyors, auditors, inspectors, agents, appointers, officers or managers, or those purporting to act in the name of and on behalf of the *Register*, or a negligent inaccuracy, advice, report or evidence given by or in the name of or/and on behalf of the *Register*, then the liability of the *Register* is limited in respect of any direct or indirect claim shall be limited to an amount not exceeding five times the fee charged or to be charged by the *Register* for the relevant Service.

16.6 Any liability for consequential damages is expressly excluded.

For purposes of this clause, consequential damages include, without limitation:

(i) indirect or consequential damages,

(ii) loss and/or delay of production, loss of products, loss of use, loss of bargain, loss of revenue, loss of profit or anticipated profit, loss of business and business interruption, in each case directly or indirectly.

16.7 The Parties are not entitled to assign the performance of obligations under these General Terms and Conditions or parts thereof to third parties without the prior written consent of the other Party.

16.8 If during the term of the Contract, there is a transfer of function due to change of status (merger, acquisition, division, etc.), all obligations and rights under these General Terms and Conditions and associated Contract will be transferred to the legal successor of the Party concerned.

Article 17
GOVERNING LAW AND RESOLVING OF DISPUTES

17.1 These General Terms and Conditions and any dispute or claim between the Parties arising from or in connection with it, or the Services provided hereunder, will be governed and interpreted in accordance with the English law.

17.2 The Parties shall use their reasonable efforts to resolve any claim or dispute arising in relation to rendered Service by negotiations within a reasonable time.

17.3 Should the Parties fail to resolve any claim or dispute by negotiations, the dispute shall be exclusively subject to the jurisdiction of the Permanent Arbitration Court with the Croatian Chamber of Economy in Zagreb, Republic of Croatia.

17.4 The Parties agree to keep the any arbitration proceedings confidential.

17.5 Notwithstanding the above, any claim not presented within three (3) months of the completion of the particular Services, or within three (3) months of from the date when the events which are relied on were first discovered by the Client, shall be deemed waived and absolutely time barred.

17.6 Any objections against the line adopted by any of the *Register's* servants in fulfilling their duties or against the conclusions reached are to be raised to the *Register* by the Party as soon as possible.

If the Party is not satisfied with the final conclusions and interpretations by the *Register* the arbitration lays upon the Commission for appeal for Classification and Statutory certification of ships, which is to be formed according to the Regulation 39 of the Charter of the *Register*.

REVIEW OF AMENDMENTS IN RELATION TO PREVIOUS EDITION OF THE RULES

RULES FOR THE CLASSIFICATION OF SHIPS
Part 9 – MACHINES

All major changes in respect to the Rules for the classification of ships, Part 9 – Machines, edition July 2022, as last amended by Amendments No. 4, edition July 2024, throughout the text are shaded (if any).

Items not being indicated as corrected have not been changed.

The grammar and print errors have been corrected throughout the Rules and are not subject to above indication of changes.

This Part of the Rules includes the requirements of the following international Organisations:

International Maritime Organization (IMO)

Conventions:	International Convention for the Safety of Life at Sea, 1974 (SOLAS 74) and all subsequent and applicable amendments adopted up to MSC 108 Protocol of 1988 relating to the International Convention for the Safety of Life at Sea, 1974, as amended (SOLAS PROT 1988) International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78) and all subsequent and applicable amendments adopted up to MEPC 81 Protocol of 1997 to amend the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto
Circulars:	MSC.1/Circ.1425

International Association of Classification Societies (IACS)

Unified Requirements (UR):	A3 (Rev.1 2019), F29 (Rev. 6, 2005), M2 (1971), M3 (Rev. 7, Feb 2024), M9 (Corr. 2, 2007), M10 (Rev. 4, 2013), M11 (1972), M12 (1972), M16 (Rev. 1, 2005), M26 (Corr. 1, 2005), M28 (1978), M42 (Rev.6, Mar 2022), M44 (Corr. 1, Feb 2022), M51 (Corr. 1, Oct 2018), M53 (Rev. 5, May 2023), M56 (Corr.2, Mar 2023), M60 (Rev.1, Nov 2021), M61 (Rev.2, Aug 2023), M63 (Rev.1, Jan 2023), M66 (Corr. 1, Oct 2021), M67 (Rev. 2, 2015), M71 (Corr.1, 2016), M72 (Rev.23 Apr 2023), M73 (Rev.2, May 2023), M74 (Rev. 2, June 2021), Z26 (2015), M77 (Rev. 4, Feb 2023), M79 (Rev. 1, Feb 2020), M80 (2019), M81 (Rev.1, July 2023)
Unified Interpretations:	SC76 (1985), SC94 (Rev. 2, 2016), SC133 (1998), SC189 (2004), SC228 (2008), SC242 (Rev.2, 2020), SC246 (Rev.1, 2015)

International Organisation for Standardisation:

ISO 1122-1:1998 Corr. 1:1999 Corr. 2:2009, ISO 1328-1:2013, ISO 1328-2:2020, ISO 6336-1:2019, ISO 6336-2:2019, ISO 6336-3:2019, ISO 6336-5:2016, ISO 19019:2005

Contents

1 GENERAL

1.1 APPLICATION

1.1.1 This Part of the Rules is applicable to the following engines and machinery:

.1 main internal combustion engines;
.2 main steam turbines;
.3 gears and couplings;
.4 engines driving electric generators, including electric propulsion, or auxiliary and deck machinery units in assembly;
.5 pumps included into the systems covered by the *Rules for the classification of ships, Part 8 - Piping*, *Rules for the classification of ships, Part 17 - Fire Protection* and *Rules for the classification of ships, Part 11 - Refrigerating plant;*
.6 air compressors;
.7 fans of main boilers and turboblowers and fans of internal combustion engines;
.8 fans included into the systems covered by the *Rules for the classification of ships, Part 8 - Piping*;
.9 steering gears;
.10 anchor machinery;
.11 towing winches;
.12 mooring machinery;
.13 hydraulic machinery;
.14 centrifugal separators for fuel and lubricating oil;
.15 main gas turbines;

1.2 SCOPE OF SUPERVISION

l.2.1 General provisions related to the supervision during construction, surveys and classification of ships, as well as the requirements for technical documentation to be submitted to the *Register* for consideration or approval are specified in the *Rules for the classification of ships, Part 1 - General requirements*, *Chapter 2 - Survey during construction and initial survey*.

1.2.2 The *Register* carries out the supervision during manufacture of the machinery and equipment listed in 1.1.1, except for manually driven machinery.

1.2.3 Documentation

1.2.3.1 Documents for the approval of internal combustion engines are specified in Annex A of these Rules.

1.2.3.2 Documents for the approval of other machinery referred to by in these Rules.

For each type of machinery that is required to be approved the documents listed in the Table 1.2.3.2 and as far as applicable to the type of machinery shall be submitted to the *Register* for approval (A) or for information (R) by the manufacturer. Where considered necessary, the *Register* may request further documents to be submitted.

Table 1.2.3.2
Documentation of machinery other than engines subject to the *Register* consideration

No.	Item	Approval (A) / Review (R)
1	Machinery particulars as per data sheet or specification	R
2	General view plans with machinery longitudinal and transverse sections	R
3	Drawings of casings of blocks, cylinders, covers and other parts, cast or welded, with welding details and instructions	A
4	Drawings of crankshafts, thrust shafts and other shafts	A
5	Drawings of pistons, piston rods and connecting rods	R
6	Drawings of cylinder covers and cylinder liners	R
7	Drawings of pinions, gear wheels and their shafts	A
8	Drawings of driving and driven parts of hydraulic gears, disengaging and flexible couplings	A
9	Drawings of thrust block, if not integral with the machinery	A
10	Drawings of rotors of steam and gas turbines and compressors as well as discs and impellers	A
11	Drawings of high pressure fuel oil piping and their protection	A
12	Drawings of insulation and protection of exhaust gas piping associated with the machinery	A
13	Schematic drawings of fuel oil, lubricating oil, cooling, exhaust gas, control, governing, alarm, protection and other systems, associated with the machinery	A
14	Schematic drawings of the machinery hydraulic piping systems with hydraulic drives	A
15	Drawings of securing machinery structure to its foundation and arrangement of foundation bolts	A

No.	Item	Approval (A) / Review (R)
16	Strength calculations of machinery parts, required by these Rules	A
17	List of main parts of machinery with material specification and all details for test pressure values	A
18	Operating and service manuals	R
19	Testing programs of non-mass produced and mass-produced machinery	A

1.2.4 The machinery parts stated in Table 1.2.4 are subject to supervision of the *Register* in the process of manufacture, regarding their compliance with the approved technical documentation and the requirements of the *Rules for the classification of ships*, *Part 25 - Metallic materials* and the *Rules for the classification of ships, Part 26 - Welding*.

Table 1.2.4
Machinery parts which are subject to supervision of the *Register*

No.	Item	Material	***Rules for the classification of ships, Part 25-Metallic materials,* ref. No.**
1	**2**	**3**	**4**
1	**INTERNAL COMBUSTION ENGINES;** see Annex A of these *Rules*		
2	**STEAM TURBINES**		
2.1	Casings of turbines	Cast iron	3.13.2
		Nodular cast iron	3.13.3
		Cast steel	3.12
		Rolled steel	3.5
2.2	Manoeuvring gear casing and nozzle boxes	Cast steel	3.12
2.3	Solid rotors, disks and shafts	Forged steel	3.11
2.4	Blades	Forged steel	3.11
		Cast steel	3.12
2.5	Shrouds and lashing wire	–	–
2.6	Nozzles and diaphragms	Cast iron	3.13.2
		Nodular cast iron	3.13.3
		Cast steel	3.12
		Forged steel	3.11
2.7	Gland seals	–	–
2.8	Couplings	Forged steel	3.11
		Cast steel	3.12
2.9	Bolts for joints of casing and couplings	Forged steel	3.11
3	**GEARS, REVERSIBLE AND FLEXIBLE COUPLINGS**		
3.1	Casing	Forged steel	3.11
		Cast iron	3.13.2
		Nodular cast iron	3.13.3
		Cast steel	3.12
		Rolled steel	3.2
		Aluminium alloy	5.2
3.2	Shafts	Forged steel	3.11
3.3	Pinions, gear wheels and tooth rims	Forged steel	3.11
		Cast steel	3.12
3.4	Elements transferring torque:		
	.1 Non-flexible parts	Rolled steel	3.2
		Forged steel	3.11
		Cast steel	3.12
		Nodular cast iron	3.13.3
		Aluminium alloy	5.1 and 5.2

Table 1.2.4 (continued)
Machinery parts which are subject to supervision of the *Register*

1	2	3	4
	.2 Flexible parts	Rubber	–
		Synthetic materials	–
		Spring steel	–
3.5	Coupling bolts	Forged steel	3.11
4	**COMPRESSORS AND PISTON TYPE PUMPS**		
4.1	Crankshafts	Cast steel	3.12
		Forged steel	3.11
		Nodular cast iron	3.13.3
4.2	Connecting rods, piston rods	Forged steel	3.11
4.3	Pistons	Cast iron	3.13.2
		Nodular cast iron	3.13.3
		Cast steel	3.12
		Forged steel	3.11
		Copper alloy	4.2
		Aluminium alloy	5.2
4.4	Cylinder blocks and cylinder covers	Cast iron	3.13.2
		Nodular cast iron	3.13.3
		Cast steel	3.12
4.5	Cylinder liners	Cast iron	3.13.2
		Nodular cast iron	3.13.3
5	**CENTRIFUGAL PUMPS, FANS AND AIR BLOWERS**		
5.1	Shafts	Forged steel	3.11
		Rolled steel	3.2
5.2	Impellers, blades	Cast steel	3.12
		Copper alloy	4.2
		Aluminium alloy	5.2
5.3	Casings	Cast iron	3.13.2
		Nodular cast iron	3.13.3
		Rolled steel	3.2
		Copper alloy	4.2
		Aluminium alloy	5.2
6	**STEERING GEAR**		
6.1	Tiller of main and emergency gear	Forged steel	3.11
		Cast steel	3.12
6.2	Rudder quadrant	Cast steel	3.12
6.3	Rudder stock yoke	Forged steel	3.11
6.4	Pistons with rods	Forged steel	3.11
		Cast steel	3.12
6.5	Cylinders	Cast iron	3.13.2
		Nodular cast iron	3.13.3
		Steel pipe	3.10.2
		Cast steel	3.12
6.6	Drive shaft	Forged steel	3.11
6.7	Pinions, gear wheels and tooth rims	Forged steel	3.11
		Cast steel	3.12
		Nodular cast iron	3.13.3
7	**WINDLASSES, CAPSTANS AND TOWING WINCHES**		
7.1	Drive and intermediate shafts	Forged steel	3.11
7.2	Pinions, gear wheels and tooth rims	Forged steel	3.11
		Cast steel	3.12
		Nodular cast iron	3.13.3

Table 1.2.4 (continued)
Machinery parts which are subject to supervision of the *Register*

1	2	3	4
7.3	Sprockets	Cast steel	3.12
		Cast iron	3.13.2
		Nodular cast iron	3.13.3
7.4	Claw clutches	Cast steel	3.12
		Forged steel	3.11
7.5	Brake band	Rolled steel	3.2
8	**HYDRAULIC DRIVES, SCREW, GEAR AND ROTARY PUMPS**		
8.1	Shaft, screw, rotor	Forged steel	3.11
		Cast iron	3.12
		Copper alloy	4.1 and 4.2
8.2	Piston rod	Forged steel	3.11
		Copper alloy	4.1
8.3	Piston	Forged steel	3.11
		Cast steel	3.12
8.4	Casing, cylinder and housing of screw pump	Cast steel	3.12
		Cast iron	3.13.2
		Nodular cast iron	3.13.3
		Copper alloy	4.2
8.5	Pinions	Forged steel	3.11
		Cast iron	3.13.2
		Nodular cast iron	3.13.3
		Copper alloy	4.1
		Cast steel	3.12
9	**FUEL AND LUBRICATING OIL SEPARATORS**		
9.1	Bowl shaft	Forged steel	3.11
9.2	Bowl body, bowl discs	Forged steel	3.11
9.3	Drive pinions	Forged steel	3.11
10	**GAS TURBINES**		
10.1	Casings of turbines and compressors, diaphragms and combustion chambers	Cast steel	3.12
		Rolled steel	3.5
10.2	Rotors and discs of turbines	Forged steel	3.11
10.3	Rotors and discs of compressors	Forged steel	3.11
10.4	Turbine blades	Cast steel	3.12
		Rolled steel	3.5
		Forged steel	3.11
10.5	Compressor blades	Forged steel	3.11
		Cast steel	3.12
10.6	Shrouds and lashing wire	–	–
10.7	Flame tubes of combustion chambers	Rolled steel	3.5
10.8	Heat-exchanging surfaces of regenerators	Rolled steel	3.5
10.9	Sealings	–	–
10.10	Flanges of couplings	Forged steel	3.11
		Cast steel	3.12
10.11	Bolts for turbine, compressor casing joints and rotor elements	Forged steel	3.11
NOTE: Selection of materials in accordance with item 1.6.			

1.2.5 Rotors, shafts and disks of steam and gas turbines, as well as bolts for joining of high-pressure turbine casings shall be subjected to ultrasonic examination in the process of manufacture.

Propulsion gearing shafts and tillers weighing more than 100 kg, gears wheels and tooth rims the weight of which is over 250 kg shall also be subjected to ultrasonic examination.

Ultrasonic examination shall be carried out in accordance with requirements specified in the *Rules for the classification of ships, Part 25 - Metallic materials* and the *Rules for the classification of ships, Part 26 – Welding*.

The positions subjected to control shall be mutually agreed by the *Register* and manufacturer. Zones where experience shows defects are most likely to occur shall be tested.

Moving blades of propulsion and auxiliary turbines, inlet guide blades of propulsion turbines and gas turbine blades shall be tested by means of magnetic particles or liquid penetrants.

1.2.6 The *Register* may require to carry out the non-destructive testing of other machinery parts, if there are doubts about the absence of defects in the part material.

1.3 HYDRAULIC TESTS

1.3.1 Machinery parts except internal combustion engine parts, operating under excessive pressure shall be subjected to a hydraulic test by a pressure p_{is} after final machining and before protective coating is applied. The hydraulic test pressure is found by the formula:

$$p_{is} = (1,5 + 0,1 \cdot k) \cdot p \qquad [\text{MPa}] \qquad (1.3.1)$$

where:

p – working pressure, [MPa];
k – factor taken from Table 1.3.1

Table 1.3.1
Factor *k* values

Material	Temperature [ºC], up to	Factor *k* in dependence of working temperature and working pressure									
		120	200	250	300	350	400	430	450	475	500
Carbon steel	*p* [MPa], up to	–	20	20	20	20	10	10	10	–	–
	k	0	0	1	3	5	8	11	14	–	–
Molybdenum and molybdenum--chrome steel with at least 0,4% molybdenum content	*p* [MPa], up to	–	–	–	–	20	20	20	20	20	20
	k	0	0	0	0	0	1	2	3,5	6	11
Cast iron	*p* [MPa], up to	6	6	6	6	–	–	–	–	–	–
	k	0	2	3	4	–	–	–	–	–	–
Bronze, brass and copper	*p* [MPa], up to	20	3	3	–	–	–	–	–	–	–
	k	0	3,5	7	–	–	–	–	–	–	–

In all cases, the value of test pressure shall not be lower than the pressure established with the safety valve fully open but not less than 0,4 MPa for cooled spaces or parts and various seals and not less than 0,2 MPa in all other cases. If temperature or working pressure exceed the ratings indicated in Table 1.3.1, the value of test pressure shall be approved by the *Register* in each case.

1.3.2 The machinery parts and assemblies may be tested separately along the spaces by the test pressure prescribed in compliance with the working pressure and temperature inside each space.

1.3.3 Parts of internal combustion engines shall be tested according to the requirements specified in Table 1.7.2.

1.3.4 The machinery parts and assemblies containing oil products or their vapours (reduction gear casings, sumps, etc.) under hydrostatic or atmospheric pressure shall be subjected to testing for oil-tightness by the method approved by the *Register*. Oil-tightness tests of welded structures may be confined to welded seams only.

1.4 OPERATION TESTS

1.4.1 On completion of assembly, adjustment and running-in, each piece of machinery shall be bench tested under the load conditions prior to installation aboard the ship. The test program shall be approved by the *Register*.

In some cases, bench tests may be substituted by tests aboard the ship in agreement with the *Register*.

1.4.2 The prototype of the machinery shall be tested under a program providing for checking reliability and long-lasting operational capacity of machinery as a whole, as well as its particular components.

1.5 GENERAL TECHNICAL REQUIREMENTS

1.5.1 The design and construction of the machinery specified in 1.1.1 shall ensure their reliable operation under environmental conditions according to the requirements stated in the *Rules for the classification of ships, Part 7-Machinery Installations*, 1.6.

1.5.2 The design features of the main engines intended for installation aboard single-shaft ships shall provide for a possibility of emergency operation at reduced power in case of a failure of parts, the replacement of which cannot be carried out aboard the ship or demands much time.

1.5.3 The cast and welded steel parts, as well as cast iron parts of machinery shall be heat treated during manufacture in compliance with the requirements specified in the *Rules for the classification of ships, Part 25 - Metallic materials* and in the *Rules for the classification of ships, Part 26 - Welding*, 2.2.

1.5.4 Elements of connection used in moving parts of machinery and gears, as well as elements of connection difficult for access shall be properly designed or to have special arrangements aimed at preventing their self-loosening and self-releasing.

1.5.5 The heated machinery surfaces shall be covered with fire-resistant heat insulation, according to the requirements specified in the *Rules for the classification of ships, Part 7 - Machinery Installations*, 1.11.9.

1.5.6 The machinery parts that are in contact with a corrosive medium shall be made of an anticorrosive material or to have corrosion-resistant coatings.

Sea water cooling spaces of engines and coolers shall be provided with protectors.

1.5.7 The remote and automatic control systems, emergency protections and the warning alarms included, shall comply with the requirements specified in the *Rules for the classification of ships, Part 13-Automation*.

1.5.8 Pumping and piping of machinery shall comply with the corresponding requirements of the *Rules for the classification of ships, Part 8 - Piping*.

1.5.9 Electrical equipment of engines and auxiliaries shall comply with the corresponding requirements of the *Rules for the classification of ships, Part 12 - Electrical Equipment*.

1.5.10 The Alternative Certification Scheme for the machinery specified in 1.1.1 may be arranged with product manufacturers and sub-suppliers subject to the agreement with Register in accordance with IACS UR Z26.

1.6 MATERIALS AND WELDING

1.6.1 Materials used for the constructions of machine elements shall comply with the requirements stated in the *Rules for the classification of ships, Part 25 - Metallic materials*.

Materials for details listed in Table 1.2.4 specified in 2.5, 2.7, 2.8, 2.9, 3.4, 3.5, 5.3, 6.3, 6.4, 6.5, 7.3, 7.4, 7.5, 8.1, 8.2, 8.3, 8.4, 8.5, 9.1, 9.2, 9.3, 10.6, 10.8, 10.9, 10.10 and 10.11 may be selected according to standards. In that case the use of these materials is subject to approval by the *Register*, during the inspection of technical documentation.

1.6.2 Materials for steam and gas turbines, reduction gears, steering gears, windlasses, mooring and towing winches listed in Table 1.2.4 in 2.1, 2.2, 2.3, 2.4, 2.6, 3.2, 3.3, 3.4.1, 6.1, 6.6, 7.1, 10.1, 10.2, 10.3, 10.4, and 10.5 are in the process of manufacture controlled by the *Register*.

1.6.3 At the discretion of the *Register* supervision may be required also during manufacture of pipes and fittings that form the system of the engine which work under pressure.

1.6.4 In case of using alloy steel and alloy cast iron for the manufacture of engine's details, data about chemical composition, mechanical and special properties that make their application to a special part possible, have to be submitted to the *Register*.

1.6.5 Material for parts of steam and gas turbines that work at high temperature (400°C and more) must be tested for tensile stress at design temperature.

1.6.6 Spheroid or nodular cast iron can be applied for parts exposed to temperature up to 300°C and grey cast iron for parts exposed to temperature up to 250°C.

1.6.7 If the parts are manufactured by welding, the requirements stated in the *Rules for the classification of ships, Part 26 - Welding* have to be complied with.

1.7 CERTIFICATION OF INTERNAL COMBUSTION ENGINE COMPONENTS

1.7.1 General

The engine manufacturer is to have a quality control system that is suitable for the actual engine types to be certified by the *Register*. The quality control system is also to apply to any sub-suppliers. The *Register* reserves 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 *Register* requires that certain parts are verified and documented by means of Register Certificate (RC), Work Certificate (W) or Test Report (TR).

1.7.1.1 *Register* Certificate (RC): this is a document issued by the *Register* stating:

- conformity with Rules 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).

1.7.1.2 Work's Certificate (W): 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 *Register* Certificate and endorsed by the *Register* if:

- the test was witnessed by the *Register* Surveyor; or
- an Alternative Certification Scheme (ACS) agreement is in place between the *Register* 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 *Register* and independent from the manufacturer and/or material supplier.

1.7.1.3 Test Report (TR): 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.

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 *Register*, 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.

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

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 *Register*.

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.

1.7.2 Parts to be documented

1.7.2.1 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 Table 1.7.2.1

1.7.2.2 For components and materials not specified in Table 1.7.2.1, consideration will be given by the *Register* upon full details being submitted and reviewed.

Table 1.7.2.1
Summary of required documentation for engine components

Part 4), 5), 6), 7), 8)	Material properties 1)	Non-destructive examination 2)	Hydraulic testing 3)	Dimensional inspection, including surface condition	Visual inspection (surveyor)	Applicable to engines:	Component certificate
Welded bedplate	W(C+M)	W(UT+CD)			fit-up + post-welding	All	RC
Bearing transverse girders GS	W(C+M)	W(UT+CD)			X	All	RC
Welded frame box	W(C+M)	W(UT+CD)			fit-up + post-welding	All	RC
Cylinder block GJL			W10)			>400 kW/cyl	
Cylinder block GJS			W10)			>400 kW/cyl	
Welded cylinder frames	W(C+M)	W(UT+CD)			fit-up + post-welding	CH	RC
Engine block GJL			W10)			>400 kW/cyl	
Engine block GJS	W(M)		W10)			>400 kW/cyl	
Cylinder liner	W(C+M)		W10)			D>300mm	
Cylinder head GJL			W			D>300mm	
Cylinder head GJS			W			D>300mm	
Cylinder head GS	W(C+M)	W(UT+CD)	W		X	D>300mm	RC
Forged cylinder head	W(C+M)	W(UT+CD)	W		X	D>300mm	RC
Piston crown GS	W(C+M)	W(UT+CD)			X	D>400mm	RC
Forged piston crown	W(C+M)	W(UT+CD)			X	D>400mm	RC
Crankshaft: made in one piece	SC(C+M)	W(UT+CD)		W	Random, of fillets and oil bores	All	RC
Semi-built Crankshaft (Crankthrow, forged main journal and journals with flange)	SC(C+M)	W(UT+CD)		W	Random, of fillets and shrink fittings	All	RC

Part [4), 5), 6), 7), 8)]	Material properties [1)]	Non-destructive examination [2)]	Hydraulic testing [3)]	Dimensional inspection, including surface condition	Visual inspection (surveyor)	Applicable to engines:	Component certificate
Exhaust gas valve cage			W			CH	
Piston rod	SC(C+M)	W(UT+CD)			Random	D>400mm CH	RC
Cross head	SC(C+M)	W(UT+CD)			Random	CH	RC
Connecting rod with cap	SC(C+M)	W(UT+CD)		W	Random, of all surfaces, in particular those shot peened	All	RC
Coupling bolts for crankshaft	SC(C+M)	W(UT+CD)		W	Random, of interference fit	All	RC
Bolts and studs for main bearings	W(C+M)	W(UT+CD)				D>300mm	
Bolts and studs for cylinder heads	W(C+M)	W(UT+CD)				D>300mm	
Bolts and studs for connecting rods	W(C+M)	W(UT+CD)		TR of thread making		D>300mm	
Tie rod	W(C+M)	W(UT+CD)		TR of thread making	Random	CH	RC
High pressure fuel injection pump body	W(C+M)		W			D>300mm	
	W(C+M)		TR			D≤300mm	
High pressure fuel injection valves (only for those not auto-fretted)			W			D>300mm	
			TR			D≤300mm	
High pressure fuel injection pipes including common fuel rail	W(C+M)		W for those that are not auto-fretted			D>300mm	
	W(C+M)		TR for those that are not auto-fretted			D≤300mm	
High pressure common servo oil system	W(C+M)		W			D>300mm	
	W(C+M)		TR			D≤300mm	
Cooler, both sides [9)]	W(C+M)		W			D>300mm	
Accumulator	W(C+M)		W			All engines with accumulators with a capacity of >0,5 l	
Piping, pumps, actuators, etc. for hydraulic drive of valves, if applicable	W(C+M)		W			>800 kW/cyl	
Engine driven pumps (oil, water, fuel, bilge) other than pumps high pressure fuel injection pumps and hydraulic drive-pumps			W			>800 kW/cyl	

Part 4), 5), 6), 7), 8)	Material properties 1)	Non-destructive examination 2)	Hydraulic testing 3)	Dimensional inspection, including surface condition	Visual inspection (surveyor)	Applicable to engines:	Component certificate
Bearings for main, crosshead, and crankpin	TR(C)	TR (UT for full contact between base material and bearing metal)		W		>800 kW/cyl	

NOTES:

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 Cylinder head GS, Forged cylinder head), the NDE method can be performed at earlier appropriate stages in the production of the component, see item 1.7.1.1.
3. Hydraulic testing 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 IACS URs.
5. For turbochargers, see 2.20.
6. Crankcase explosion relief valves are to be type tested in accordance with IACS UR M66 and documented according to IACS UR M9.
7. Oil mist detection systems are to be type tested in accordance with IACS UR M67 and documented according to IACS UR M10.
8. For speed governor and overspeed protective devices, see IACS UR M3.
9. Charge air coolers need only be tested on the water side.
10. Hydraulic testing 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.
11. Symbols used in Table 1.7.2.1

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

2 INTERNAL COMBUSTION ENGINES

2.1 GENERAL PROVISIONS

2.1.1 All engines for main function or emergency duty shall be type approved according to requirements stated in these Rules.

Engines used for main function or emergency duty with power output of more than 130 kW shall be delivered with a Certificate of the *Register*.

Application of these Rules for engines of power equal or less than 130 kW is subject to the special consideration by the *Register*.

2.1.2 For engines neither used for main function nor for emergency duty, type approval and the Certificate of the *Register* are not required, but engines shall comply with requirements stated in 2.3.2, 2.3.3, 2.6.4 and 2.6.5.

2.2 GENERAL REQUIREMENTS

2.2.1 The engines shall be capable of working with an overload exceeding the rated power by at least 10% for not less than one hour.

2.2.2 The engines intended for propulsion installations shall comply also with the requirements in the *Rules for the classification of ships, Part 7 - Machinery Installation*, 1.4.

2.2.3 Minimum stable speed of the direct-drive main engines shall be not in excess of 30% of the rated speed.

2.2.4 Irregularity of speed of a/c diesel-generating sets intended for parallel operation shall be such that the amplitude of angle oscillations of the generator shaft does not exceed $\frac{3{,}5^o}{p}$, where p – number of pairs of generator poles.

2.2.5 The crosshead type engines whose scavenge spaces are in open connection with the cylinders shall be provided with the fire-extinguishing system approved by the *Register* which is entirely separate from the fire-extinguishing system of the engine room.

The scavenge spaces of main engines in ships with unattended machinery spaces of category A shall be provided with a fire detection system and fire alarm (see the *Rules for the classification of ships, Part 17 - Fire protection*, 4.2.2.1).

2.2.6 Diesel-generating sets intended as emergency units shall be provided with self-contained fuel supply, lubricating and cooling systems.

2.2.7 Rated power of the engine shall be determined under ambient conditions stated in Table 2.2.7.

Table 2.2.7
Ambient conditions

Ambient conditions	Area of navigation 1 (unrestricted)	Area of navigation 2-8 (restricted)
Atmospheric pressure	100 kPa	100 kPa
Air temperature	45°C	45°C
Humidity	60%	50%
See water temperature	32°C	25°C

2.3 CRANKCASE

2.3.1 General

2.3.1.1 The mating surfaces of the frame parts forming the engine crankcase shall be close-fitting, oil-tight and gas-tight. The frame parts (bed plates, columns, cylinder blocks, etc.) shall be fixed together by means of calibrated pieces.

2.3.2 Protection of internal combustion engines against crankcase explosions

For the purpose of the present item, the following definitions apply:

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

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

High-Speed Engines – diesel engines having a rated speed of 1400 rpm and above.

The requirements of the present item are to be implemented for engines:

.1 when an application for certification of the engine is dated on or after 1st January 2015; or

.2 which are installed in new ships for which the date of contract for construction is on or after 1st January 2015.

NOTE: The *date of contract for construction* means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder.

2.3.2.1 Crankcase construction and crankcase doors shall 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 by 2.3.3. Crankcase doors shall be fastened sufficiently securely for them not be readily displaced by a crankcase explosion.

2.3.2.2 Additional relief valves shall be fitted on separate spaces of crankcase such as gear or chain cases for camshaft or similar drives, when the gross volume of such spaces exceeds 0,6 m^3.

2.3.2.3 Scavenge spaces in open connection to the cylinders shall be fitted with explosion relief valves.

2.3.2.4 Crankcase explosion relief valves shall comply with 2.3.3.

2.3.2.5 Ventilation of crankcase, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted except for dual fuel engines where crankcase ventilation shall be provided in accordance with 2.21.3.2.

.1 Crankcase ventilation pipes, where provided, shall be as small as practicable to minimise the inrush of air after a crankcase explosion.

.2 If a forced extraction of the oil mist atmosphere from the crankcase is provided (for mist detection purposes for instance), the vacuum in the crankcase is not to exceed 250 Pa.

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

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

2.3.2.7 The following warning notice shall be fitted either on the control stand or, preferably, on a crankcase door on each side of the engine:

"Whenever overheating is suspected inside the crankcase, the crankcase doors or inspection sight holes shall not be opened before the enough engine cooling time is over after the engine has been stopped".

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

.1 for alarm and slow down purposes, for low speed diesel engines of 2250 kW and above, or having cylinders of more than 300 mm bore. They are to initiate the alarm and slow down procedures;

.2 for alarm and automatic shutoff purposes, for medium and high speed diesel engines of 2250 kW and above, or having cylinders of more than 300 mm bore, as a part of automatic shutoff arrangements.

The *Register* may permit overriding automatic shutoff devices. The consequences of overriding automatic shutoff arrangements are to be established and documented.

Oil mist detection arrangements are to be of a type approved by the *Register*, tested in accordance with IACS UR M67 *Type Testing Procedure for Crankcase Oil Mist Detection and Alarm Equipment* and comply with 2.3.2.9 to 2.3.2.10. Engine bearing temperature monitors or equivalent devices used as safety devices have to be of a type approved by the *Register* for such purposes. Engine bearing temperature monitors shall be provided for journal and connecting rod bearings.

NOTE: An equivalent device for high speed engines could be interpreted as measures applied to these engines, where specific design features to preclude the risk of crankcase explosions are incorporated.

2.3.2.9 The oil mist detection system and arrangements shall be installed in accordance with the engine designer's and oil mist manufacturer's instructions or recommendations. The following particulars shall be included in the instructions:

.1 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.

.2 Evidence of study to justify the selected location of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry and the predicted crankcase atmosphere where oil mist can accumulate.

.3 The manufacturer's maintenance and test manual.

.4 Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist detection equipment.

2.3.2.10 A copy of the oil mist detection equipment maintenance and test manual required by 2.3.2.9 shall be provided on board ship.

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

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

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

2.3.2.14 Alarms and shutdowns for the oil mist detection system shall be in accordance with the *Rules for the classification of ships, Part 13 - Automation*, Table 4.1. System arrangements shall comply with the above, Chapter 2.4 and Table 4.1.

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

2.3.2.16 The oil mist detection system shall 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.

2.3.2.17 Where oil mist detection equipment includes the use of programmable electronic systems, the arrangements shall be in accordance with the *Register* requirements for such systems.

2.3.2.18 Plans of showing details and arrangements of oil mist detection and alarm arrangements shall be submitted for approval.

2.3.2.19 The equipment together with detectors shall 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 shall be to the satisfaction of the *Register*.

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

2.3.2.21 Where alternative methods are provided for the prevention of the build-up of oil mist (that may lead to a potentially explosive condition within the crankcase), details shall be submitted to the *Register* for consideration. The following information shall be included in the details to be submitted for consideration:

.1 Engine particulars – type, power, speed, stroke, bore and crankcase volume.
.2 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.
.3 Evidence to demonstrate that the arrangements are effective in preventing the build-up of potentially explosive conditions together with details of in-service experience.
.4 Operating instructions and the maintenance and test instructions.

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

2.3.3 Crankcase explosion relief valves for crankcases of internal combustion engines

2.3.3.1 Internal combustion engines having a cylinder bore of 200 mm and above or a crankcase volume of 0,6 m^3 and above shall be provided with crankcase explosion relief valves in accordance with 2.3.3.3 as follows:

.1 Engines having a cylinder bore not exceeding 250 mm shall have at least one valve near each end, but, over eight crankthrows, an additional valve shall be fitted near the middle of the engine.
.2 Engines having a cylinder bore exceeding 250 mm but not exceeding 300 mm shall have at least one valve in way of each alternate crankthrow, with a minimum of two valves.
.3 Engines having a cylinder bore exceeding 300 mm shall have at least one valve in way of each main crankthrow.

2.3.3.2 Engines shall be fitted with components and arrangements complying with 2.3.3.3.8 (except .8, .9 and .10.2) when:

.1 an application for certification of the engine is dated on or after 1st January 2006; or
.2 installed in new ships for which the date of contract for construction is on or after 1st January 2006.

The requirements .8, .9 and .10.2 of item 2.3.3.3 apply, in both cases above, from 1st January 2008.

NOTE: The *date of contract for construction* means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. Reference is to be made to para 5.14 of the *Rules for the classification of ships, Part 1 – General requirements, Chapter 1 – General information*, also.

2.3.3.3 Relief valves shall comply with the following:

.1 The free area of each relief valve shall be not less than 45 cm^2.
.2 The combined free area of the relief valves fitted on an engine must not be less than 115 cm^2 per cubic metre of the crankcase gross volume.
.3 The total volume of the stationary parts within the crankcase may be discounted in estimating the crankcase gross volume (rotating and reciprocating components shall be included in the gross volume).
.4 Crankcase explosion relief valves shall 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.
.5 The valve discs in crankcase explosion relief valves shall be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.
.6 Crankcase explosion relief valves shall be designed and constructed to open quickly and be fully open at a pressure not greater than 0,2 bar.
.7 Crankcase explosion relief valves shall be provided with a flame arrester that permits flow for crankcase pressure relief and prevents passage of flame following a crankcase explosion.
.8 Crankcase explosion relief valves shall be type tested in a configuration which represents the installation arrangements that will be used on an engine. Type testing shall be done in accordance with the IACS UR M66 Type Testing Procedure for Crankcase Explosion Relief Valves.
For the contracted for construction date see the note in 2.3.3.2.
.9 Where crankcase relief valves are provided with arrangements for shielding emissions from the valve following an explosion, the valve shall be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.
.10 Crankcase explosion relief valves shall be provided with a copy 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 shall contain the following information:
  .1 Description of valve with details of function and design limits,
  .2 Copy of the type test certificate,
  .3 Installation instructions,
  .4 Maintenance and service instructions to include testing and renewal of any sealing arrangements,
  .5 Actions required after an explosion in the crankcase.

.11 A copy of the installation and maintenance manual required by .10 shall be provided on board ship.

.12 Plans of showing details and arrangements of crankcase explosion relief valves shall be submitted for approval in accordance with 1.2.3.1.

.13 Valves shall be provided with suitable markings that include the following information:
  .1 Name and address of manufacturer,
  .2 Designation and size,
  .3 Month/year of manufacture,
  .4 Approved installation orientation.

2.3.4 Draining arrangements

2.3.4.1 The engine frame and conjugated parts shall be provided with draining arrangements (draining grooves, pipes, etc.) and other facilities preventing penetration of fuel and water into the circulating lubricating oil.

2.3.4.2 The cooling spaces of the cylinder blocks shall be fitted with draining arrangements providing complete drainage.

2.3.4.3 The crankcase drain holes shall be fitted with gratings or screens to prevent stray object from getting into the drain piping.

The above requirement also applies to engines having a dry crankcase.

2.4 CRANKSHAFTS

2.4.1 General

2.4.1.1 These requirements for the design of crankshafts shall be applied to internal combustion engines for propulsion and auxiliary purposes, where the engines are capable of continuous operation at their rated power when running at rated speed.

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 and/or analysis are to be submitted to the *Register* in order to demonstrate equivalence to these Rules.

2.4.1.2 These Rules apply only to solid-forged and semi-built crankshafts of forged or cast steel, with one crank throw between main bearings.

2.4.1.3 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 the highest stresses are:
  .1 fillet transitions between the crankpin and web as well as between the journal and web;
  .2 outlets of crankpin oil bores.

When journal diameter is equal or larger than the crankpin one, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate documentation of fatigue safety may be required.

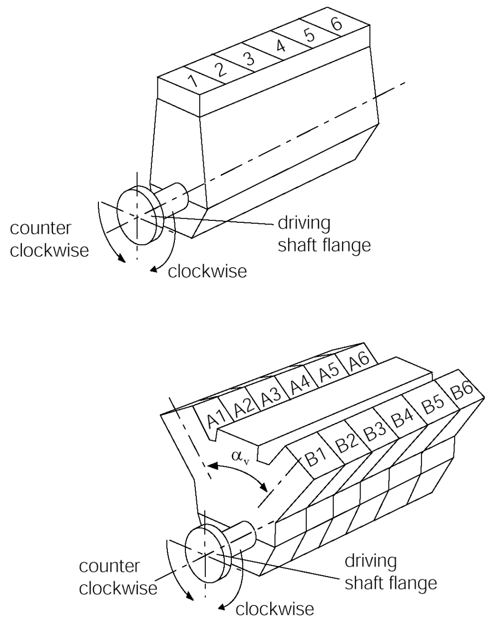


Fig. 2.4.1.4-1
Designation of the cylinders

Calculation of crankshaft strength consists initially in determining the nominal alternating bending (see 2.4.2.) and nominal alternating torsional stresses (see 2.4.3) which, multiplied by the appropriate stress concentration factors (see 2.4.4), result in an equivalent alternating stress (i.e. uni-axial stress, see 2.4.6). This equivalent alternating stress is then compared with the fatigue strength of the selected crankshaft material (see 2.4.7). This comparison will show whether or not the crankshaft concerned is dimensioned adequately (also in 2.4.7).

2.4.1.4 For the calculation of crankshafts, the following documents and particulars shall be submitted to *Register*:
  .1 crankshaft drawing, containing all data in respect of the geometrical configuration of the crankshaft;
  .2 type designation and kind of engine (in-line engine or V-type engine with adjacent connecting rods, forked connecting rod, or articulated-type connecting rod);
  .3 operating and combustion method (2-stroke or 4-stroke cycle, direct injection, pre-combustion chamber, etc.);
  .4 number of cylinders;
  .5 rated power, [kW];
  .6 rated engine speed, [rpm];
  .7 direction of rotation (see figure 2.4.1.4-1);
  .8 firing order with the respective ignition intervals (in degrees of crank angle, [°CA]);
  .9 angle between cylinders for V-engines, α_v (see figure 2.4.1.4-1);
  .10 cylinder diameter, [mm];
  .11 stroke [mm];
  .12 maximum net cylinder pressure p_{max}, [bar];
  .13 charge air pressure (before inlet valves or scavenge ports, whichever applies), [bar];
  .14 nominal compression ratio;

.15 connecting rod length L_c, [mm];
.16 all individual reciprocating masses acting on one crank (e.g. mass of piston, rings, pin, piston rod, crosshead, reciprocating part of connecting rod) in case of in-line type engines, [kg];
.17 all individual reciprocating masses for the cylinder unit with master and articulated-type connecting rod, or forked and inner connecting rod (e.g. mass of piston, rings, pin, piston rod, crosshead, reciprocating part of connecting rod), in case of V-type engines, [kg];
.18 digitised cylinder gas pressure curve, [bar] versus crank angle, [°CA], presented at equidistant crank angle intervals (at least every 5°CA). In case of V-type engines angle α_v shall be integrally divisible by these intervals;
.19 for engines with articulated-type connecting rod (see figure 2.4.1.4-2):
- distance from the crankshaft axis to link point L_A [mm],
- link angle α_N [°],
- connecting rod length L_N [mm];
- maximum cylinder pressure p_{max} [bar],
- charge air pressure (before inlet valves or scavenge parts, whichever applicable) [bar],
- nominal compression ratio,
- digitised cylinder gas pressure curve, [bar] versus crank angle, [°CA], presented at equidistant crank angle intervals;

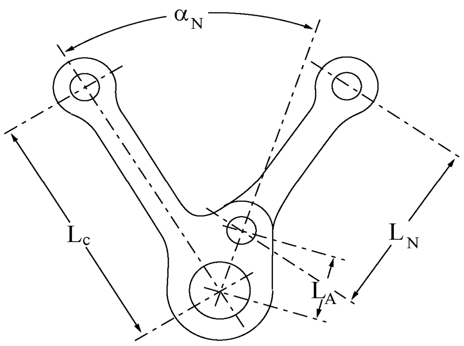


Fig. 2.4.1.4-2
Articulated-type connecting rod

.20 details of crankshaft material:
- material designation (according to ISO, EN, HRN, or other recognised national standard);
- mechanical properties of material (minimum values obtained from longitudinal test specimens) in compliance with the requirements of the *Rules for the classification of ships, Part 25 – Metallic materials*;
  - tensile strength [N/mm²],
  - yield strength [N/mm²],
  - reduction in area at break [%],
  - elongation A_5 [%],
  - impact energy KV [J];
- type of forging (free form forged, continuous grain flow forged, drop-forged, etc. with description of the forging process);
- heat treatment procedure;
- surface treatment procedure of fillets, journals, pins and oil holes (induction hardened, flame hardened, nitrided, rolled, shot peened, etc. with full details concerning hardening);
- hardness at surface [HV];
- hardness as a function of depth ([HV] versus [mm]);
- extension of surface hardening;
- particulars for calculation of alternating torsional stresses (see 2.4.2.2).

2.4.2 Calculation of alternating stresses due to bending moments and shearing forces

2.4.2.1 The calculation is based on a statically determined system, composed of a single crank throw supported in the centre of adjacent bearings and subject to gas and inertia forces. The bending length is taken as the length between the two main bearings (distance L_3, see figures 2.4.2.1-1 and 2.4.2.1-2), where:

L_1 – distance between main journal centre line and crankweb centre (see also figure 2.4.2.1-3 for crankshaft without overlap), [mm];

L_2 – distance between main journal centre line and connecting-rod centre, [mm];

L_3 – distance between two adjacent main journal centre lines, [mm].

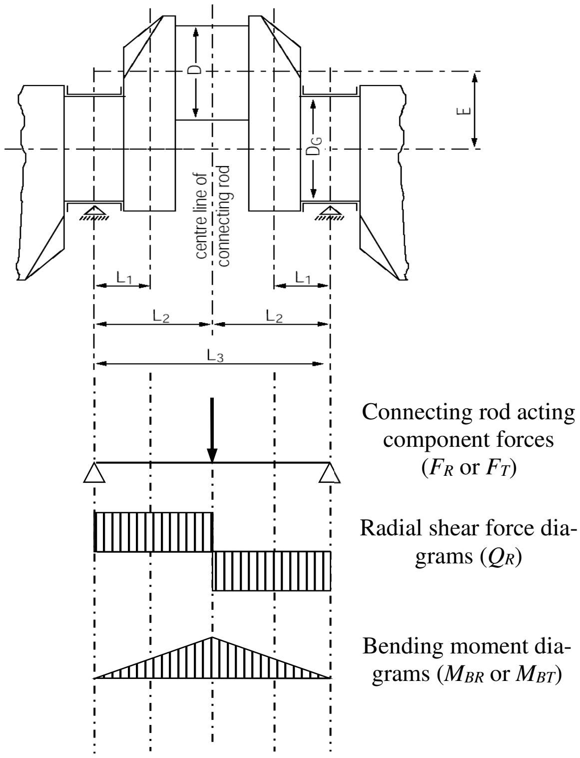


Fig. 2.4.2.1-1
Crank throw for in-line engine

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 figure 2.4.2.1-1).

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 figure 2.4.2.1-2).

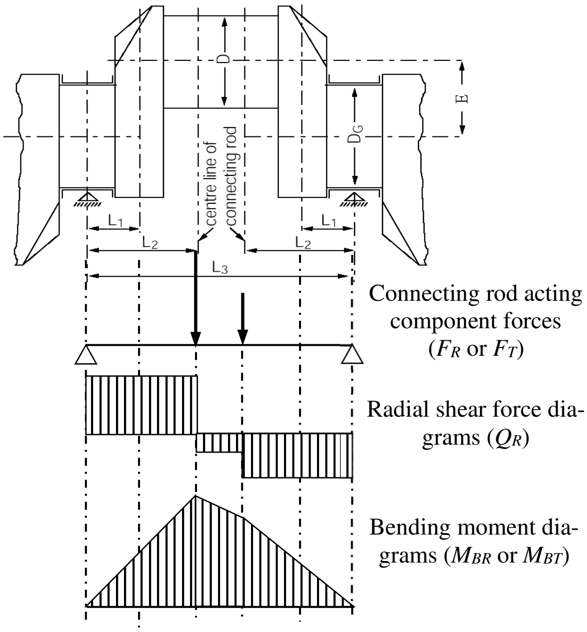


Fig. 2.4.2.1-2
Crank throw for V-type engine with two adjacent connecting rods

Details regarding the calculation of forces acting on crank throw, both for in-line and V-type engines with adjacent connecting rods are given in the Work Instruction QW 114 *Guidance for the calculation of crankshafts for internal combustion engines* of the *Register.*

.1 **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 figure 2.4.2.1-3 and figure 2.4.4.1).

Mean stresses are neglected.

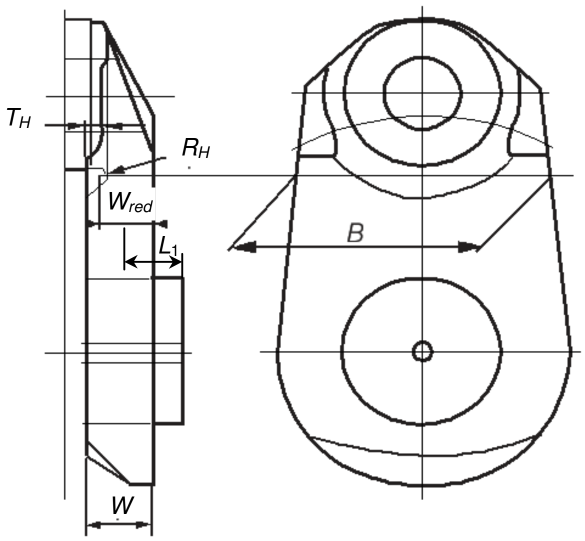


Fig. 2.4.2.1-3

Reference area of crankweb cross section, for crankshaft without overlap

.2 **Bending acting in outlet of crankpin oil bore**

The two relevant bending moments are taken in the crankpin cross-section through the oil bore:

M_{BRO} – bending moment of the radial component of the connecting-rod force;

M_{BTO} – bending moment of the tangential component of the connecting-rod force.

The alternating stresses due to these bending moments are to be related to the cross-sectional area of the axially bored crankpin.

Mean bending stresses are neglected.

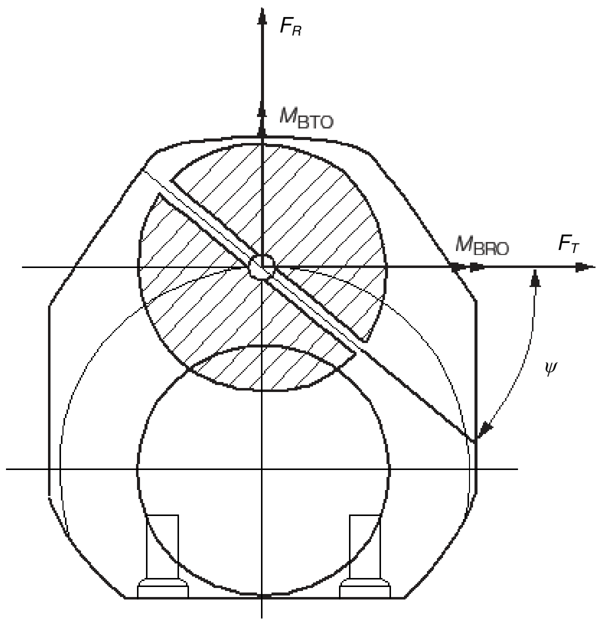


Fig. 2.4.2.1-4
Crankpin cross section through the oil bore

2.4.2.2 Calculation of nominal alternating bending and compressive stresses in web

The radial and tangential forces due to gas and inertia loads acting upon the crankpin at each connecting rod position shall be calculated for each crank position over one working cycle.

Using the forces calculated over one working cycle and taking into account of the distance from the main bearing midpoint, the time curve of the bending moments M_{BRF}, M_{BRO}, M_{BTO} and radial forces Q_{RF} (as defined in .1 and .2 of 2.4.2.1) shall then be calculated.

In 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) shall 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 shall then be calculated according to:

$$X_N = \pm\frac{1}{2}\left(X_{\max} - X_{\min}\right) \qquad (2.4.2.2\text{-}1)$$

where :

X_N – alternating force, moment or stress;

X_{max} – maximum value within one working cycle;

X_{min} – minimum value within one working cycle.

.1 **Nominal alternating bending and compressive stresses in web cross section**

The nominal alternating bending and compressive stresses are calculated as follows:

$$\sigma_{BFN} = \frac{M_{BRFN}}{W_{eq}} \cdot 10^3 \cdot K_e \qquad (2.4.2.2\text{-}2)$$

$$\sigma_{QFN} = \pm \frac{Q_{RFN}}{A} \cdot K_e \qquad (2.4.2.2\text{-}3)$$

where:

σ_{BFN} – nominal alternating bending stress related to cross-section of the web, [N/mm²];

M_{BRFN} – alternating bending moment related to the centre of the web, [Nm] (see Fig 2.4.2.1-1 and 2.4.2.1-2):

$$M_{BRFN} = \pm \frac{1}{2}\left(M_{BRF\max} - M_{BRF\min}\right) \qquad (2.4.2.2\text{-}4)$$

W_{eq} – sectional modulus related to cross-section of web, [mm³]:

$$W_{eq} = \frac{B \cdot W^2}{6} \qquad (2.4.2.2\text{-}5)$$

K_e – empirical factor which considers to some extent the influence of adjacent cranks and bearing restraint;
= 0,8 for 2-stroke engines;
= 1,0 for 4-stroke engines;

σ_{QFN} – nominal alternating compressive stress due to radial force related to cross-section of the web, [N/mm²];

Q_{RFN} – alternating radial force related to the web, [N] (see Fig 2.4.2.1-1 and 2.4.2.1-2):

$$Q_{RFN} = \pm \frac{1}{2}\left(Q_{RF\max} - Q_{RF\min}\right) \qquad (2.4.2.2\text{-}6)$$

A – area related to cross-section of the web, [mm²]:

$$A = B \cdot W \qquad (2.4.2.2\text{-}7)$$

.2 **Nominal alternating bending stress in outlet of crankpin oil bore**

The nominal alternating bending stress is calculated as follows:

$$\sigma_{BON} = \frac{M_{BON}}{W_e} \cdot 10^3 \qquad (2.4.2.2\text{-}8)$$

where:

σ_{BON} – nominal alternating bending stress related to the crank pin diameter, [N/mm²];

M_{BON} – alternating bending moment calculated at the outlet of crankpin oil bore, [Nm]:

$$M_{BON} = \pm \frac{1}{2}\left(M_{BO\max} - M_{BO\min}\right) \qquad (2.4.2.2\text{-}9)$$

$$M_{BO} = M_{BTO}\cos\psi + M_{BRO}\sin\psi \qquad (2.4.2.2\text{-}10)$$

ψ – angular position (see figure 2.4.2.1-4), [°]

W_e – section modulus related to cross-section of axially bored crankpin, [mm³]:

$$W_e = \frac{\pi}{32} \cdot \frac{D^4 - D_{BH}^4}{D} \qquad (2.4.2.2\text{-}11)$$

2.4.2.3 Calculation of alternating bending stresses in fillets

The calculation of stresses shall be carried out for the crankpin fillet as well as for the journal fillet.

.1 Alternating bending stress in crankpin fillet, σ_{BH}, is calculated as follows:

$$\sigma_{BH} = \left(\pm\alpha_B \cdot \sigma_{BFN}\right) \quad \text{[N/mm²]} \qquad (2.4.2.3\text{-}1)$$

where:
α_B – stress concentration factor for bending in crankpin fillet (determination-see 2.4.4)

.2 Alternating bending stress in journal fillet, σ_{BG}, (not applicable to semi-built crankshaft) is calculated as follows:

$$\sigma_{BG} = \pm\left(\beta_B \cdot \sigma_{BFN} + \beta_Q \cdot \sigma_{QFN}\right) \quad \text{[N/mm²]} \qquad (2.4.2.3\text{-}2)$$

where:
β_B – stress concentration factor for bending in journal fillet (determined according to 2.4.4);
β_Q – stress concentration factor for shearing (determined according to 2.4.4).

2.4.2.4 Calculation of alternating bending stresses in outlet of crankpin oil bore

Alternating bending stress in outlet of crankpin oil bore, σ_{BO}, is calculated as follows:

$$\sigma_{BO} = \pm\left(\gamma_B \cdot \sigma_{BON}\right) \quad \text{[N/mm²]} \qquad (2.4.2.4)$$

where:
γ_B – stress concentration factor for bending in journal fillet (determined according to 2.4.4).

2.4.3 Calculation of alternating torsional stresses

2.4.3.1 The calculation for nominal alternating torsional stresses shall be undertaken by the engine manufacturer (according to the information contained in 2.4.3.2) and submit it to the *Register*.

The manufacturer shall specify the maximum nominal alternating torsional stress.

2.4.3.2 Calculation of nominal alternating torsional stresses

The maximum and minimum torques shall 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 shall be made for the damping that exist in the system and for unfavourable conditions (misfiring in one of the cylinders, where misfiring is defined as cylinder condition when no combustion occurs but only compression cycle). The speed step calculation shall be selected in such a way that any resonance found in the operational speed range of the engine shall be detected precisely enough.

Where barred speed ranges are necessary, they shall be arranged so that satisfactory operation is possible despite their existence. There shall be no barred speed ranges above a speed ratio of $\lambda \geq 0{,}8$ for normal firing conditions.

The values obtained by such calculation are to be submitted to the Register.

.1 The nominal alternating torsional stress referred to crankpin or journal, τ_N, in every mass point, which is essential to the assessment, results from the following equation:

$$\tau_N = \frac{M_{TN}}{W_p} \cdot 10^3 \quad \text{[N/mm²]} \qquad (2.4.3.2\text{-}1)$$

where:

M_{TN} – maximum alternating torque, [Nm]:

$$M_T = \pm \frac{1}{2}\left(M_{T\max} - M_{T\min}\right) \qquad (2.4.3.2\text{-}2)$$

W_P – polar section modulus related to cross section of axially bored crankpin or bored journal, [mm³]:

$$W_p = \frac{\pi}{16}\left(\frac{D^4 - D_{BH}^4}{D}\right), \text{ or}$$

$$W_p = \frac{\pi}{16}\left(\frac{D_G^4 - D_{BG}^4}{D_G}\right)$$

M_{Tmax} – maximum value of the torque, [Nm];

M_{Tmin} – minimum value of the torque, [Nm].

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 crankshaft shall be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum value specified by 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 to the *Register* for assessment.

2.4.3.3 Calculation of alternating torsional stresses in fillets and outlet of crankpin bore

The calculation of stresses shall be carried out for the crankpin fillet, the journal fillet and the outlet of crankpin oil bore.

.1 Alternating torsional stress in crankpin fillet:

$$\tau_H = \alpha_T \cdot \tau_N \quad \text{[N/mm²]} \qquad (2.4.3.3\text{-}1)$$

where:

α_T – stress concentration factor for torsion in crankpin fillet (determined according to 2.4.4);

τ_N – nominal alternating torsional stress related to crankpin diameter, [N/mm²].

.2 Alternating torsional stress in journal fillet (not applicable to semi-built crankshafts):

$$\tau_G = \beta_T \cdot \tau_N \quad \text{[N/mm²]} \qquad (2.4.3.3\text{-}2)$$

where:

β_T – stress concentration factor for torsion in journal fillet (determined according to 2.4.4).

τ_N – nominal alternating torsional stress related to journal diameter, [N/mm²].

.3 Alternating stress in outlet of crankpin oil bore:

$$\sigma_{TO} = \gamma_T \cdot \tau_N \quad \text{[N/mm²]} \qquad (2.4.3.3\text{-}3)$$

where:

γ_T – stress concentration factor for torsion in outlet of crankpin oil bore (determined according to 2.4.4).

τ_N – nominal alternating torsional stress related to crankpin diameter, [N/mm²].

2.4.4 Evaluation of stress concentration factors

2.4.4.1 The stress concentration factors are evaluated by means of the formulae according to items 2.4.4.2, 2.4.4.3 and 2.4.4.4 applicable to the fillets and crankpin oil bore of solid forged web-type crankshafts and to the crankpin fillets of semi-built crankshafts. It must be noticed that stress concentration factor formulae concerning the oil bore are only applicable to a radial drilled oil hole. All formulae are based on investigations of FVV (*Forschungsvereinigung Verbrennungs kraftmaschinen*) 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 Appendix III of the *Guidance for the calculation of crankshafts for internal combustion engines (QW114)* of the *Register* may be undertaken. This calculation method is to be applied to crankshafts whose application for design approval is dated on or after 1 January 2012.

All crank dimensions necessary for the calculation of stress concentration factors are shown in figure 2.4.4.1.

The stress concentration factors for bending (α_B, β_B) are defined as the ratio of the maximum equivalent von Mises stress (occurring in the fillets under bending load) to the nominal bending stress related to the web cross-section.

The stress concentration factor for compression (β_Q) in the journal fillet is defined as the ratio of maximum equivalent von Mises stress (occurring in the fillet due to the radial force) to the nominal compressive stress related to the web cross section.

The stress concentration factors for torsion (α_T, β_T) are 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.

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.

When reliable measurements and/or calculations are available, which can allow direct assessment of stress concentration factors, the relevant documents and their analysis method have to be submitted to the *Register* in order to demonstrate their equivalence to present Rules evaluation.

This is always to be performed when dimensions are outside of any of the validity ranges for the empirical formulae presented in 2.4.4.2 to 2.4.4.4.

Appendix III and Appendix VI of the *Guidance for the calculation of crankshafts for internal combustion engines (QW114)* of the *Register* 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.

All crank dimensions necessary for the calculation of stress concentration factors are shown in figure 2.4.4.1.

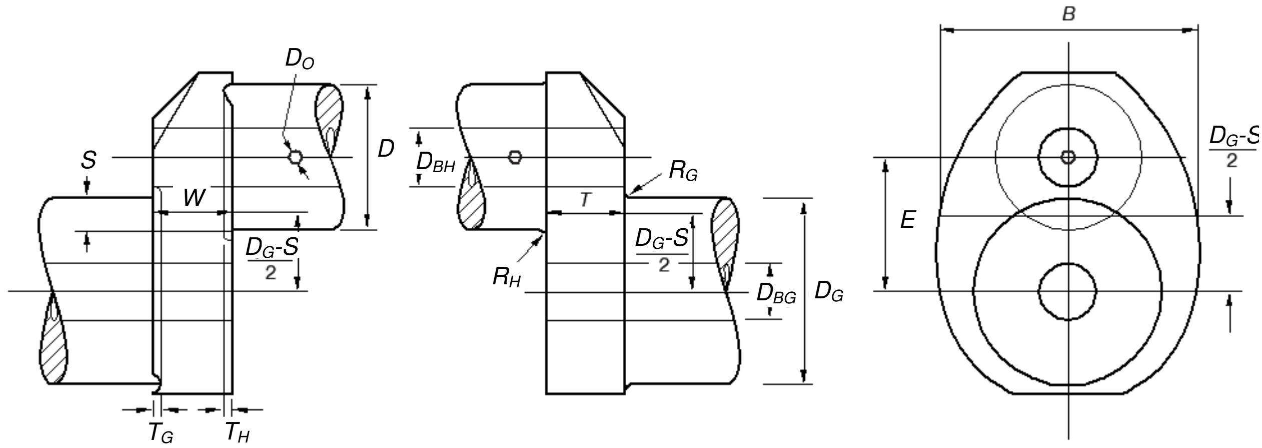


Fig. 2.4.4.1
Crank dimensions necessary for the calculation of stress concentration factors

Actual dimensions shown in figure 2.4.4.1:

D – crankpin diameter, [mm];
D_{BH} – diameter of axial bore in crankpin, [mm];
D_O – diameter of oil bore in crankpin, [mm];
R_H – fillet radius of crankpin, [mm];
T_H – recess of crankpin, [mm];
D_G – journal diameter, [mm];
D_{BG} – diameter of bore in journal, [mm];
R_G – fillet radius of journal, [mm];
T_G – recess of journal, [mm];
E – pin eccentricity, [mm];
S – pin overlap, [mm]:

$$S = \frac{D + D_G}{2} - E \text{ [mm];}$$

W – web thickness, [mm]. In the case of 2 stroke semi-built crankshafts, if $T_H > R_H$, then the web thickness must be considered as equal to (see figure 2.4.2.1-3):

$$W_{red} = W - (T_H - R_H)$$

B – web width, [mm]. In the case of 2 stroke semi-built crankshafts web width must be taken in way of crankpin fillet radius centre according to figure 2.4.2.1-3.

The following related dimensions (within the specified ranges for which the investigations have been carried out) are applied for the calculation of stress concentration factors:

$r = R_H/D$ for range $0{,}03 \le r \le 0{,}13$ for crankpin fillets;
$r = R_G/D$ for range $0{,}03 \le r \le 0{,}13$ for journal fillets;
$s = S/D$ for range $s \le 0{,}5$. Low range of s can be extended to large negative values provided that:
If calculated $f_u < 1$ then the recess factor f_u is not to be considered, i.e. $f_u = 1$;
If $s < -0.5$ then $f(s, w)$ and $f(r, s)$ are to be evaluated replacing actual value of s by $s = -0{,}5$.
$w = W/D$ for crankshafts with overlap,
$w = W_{red}/D$ for crankshafts without overlap,
both w for the same range $0{,}2 \le w \le 0{,}8$
$b = B/D$ for range $1{,}1 \le b \le 2{,}2$
$d_O = D_O/D$ for range $0 \le d_O \le 0{,}2$
$d_G = D_{BG}/D$ for range $0 \le d_G \le 0{,}8$
$d_H = D_{BH}/D$ for range $0 \le d_H \le 0{,}8$
$t_H = T_H/D$
$t_G = T_G/D$

2.4.4.2 Crankpin fillet

.1 The stress concentration factor for bending (α_B) is determined as follows:

$$\alpha_B = 2{,}6914 \cdot f(s,w) \cdot f(w) \cdot f(b) \cdot f(r) \cdot f(d_G) \cdot f(d_H) \cdot f_u \qquad (2.4.4.2\text{-}1)$$

where:

$f(s,w) = -4{,}1883 + 29{,}2004 \cdot w - 77{,}5925 \cdot w^2 + 91{,}9454 \cdot w^3 -$
$-40{,}0416 \cdot w^4 + (1 - s) \cdot (9{,}5440 - 58{,}3480 \cdot w +$
$+159{,}3415 \cdot w^2 - 192{,}5846 \cdot w^3 + 85{,}2916 \cdot w^4) +$

$+(1-s)^2 \cdot (-3{,}8399 + 25{,}0444 \cdot w - 70{,}5571 \cdot w^2 +$
$+87{,}0328 \cdot w^3 - 39{,}1832 \cdot w^4)$

$f(w) = 2{,}1790\, w^{0{,}7171}$
$f(b) = 0{,}6840 - 0{,}0077b + 0{,}1473b^2$
$f(r) = 0{,}2081\, r^{-0{,}5231}$
$f(d_G) = 0{,}9993 + 0{,}27d_G - 1{,}0211d_G^2 + 0{,}5306d_G^3$
$f(d_H) = 0{,}9978 + 0{,}3145d_H - 1{,}5241d_H^2 + 2{,}4147d_H^3$
$f_u = 1 + (t_H + t_G) \cdot (1{,}8 + 3{,}2s)$

.2 The stress concentration factor for torsion (α_T) is determined as follows:

$$\alpha_T = 0{,}8 f(r,s) \cdot f(b) \cdot f(w) \qquad (2.4.4.2\text{-}2)$$

where:

$f(r,s) = r^{[-0{,}322 + 0{,}1015(1-s)]}$
$f(b) = 7{,}8955 - 10{,}654\,b + 5{,}3482\,b^2 - 0{,}857\,b^3$
$f(w) = w^{(-0{,}145)}$

2.4.4.3 Journal fillet (not applicable to semi-built crankshaft)

.1 The stress concentration factor for bending (β_B) is determined as follows:

$$\beta_B = 2{,}7146 \cdot f_B(s,w) \cdot f_B(w) f_B(b) f_B(r) \cdot f_B(d_H) \cdot f_B(d_G) \cdot f_u \qquad (2.4.4.3\text{-}1)$$

where:

$f_B(s,w) = -1{,}7625 + 2{,}9821w - 1{,}5276w^2 + (1-s) \cdot (5{,}1169 -$
$-5{,}8089w + 3{,}1391w^2) + (1-s)^2 \cdot (-2{,}1567 +$
$+ 2{,}3297w - 1{,}2952w^2)$
$f_B(w) = 2{,}2422\, w^{0{,}7548}$
$f_B(b) = 0{,}5616 + 0{,}1197b + 0{,}1176b^2$
$f_B(r) = 0{,}1908\, r^{-0{,}5568}$
$f_B(d_G) = 1{,}0012 - 0{,}6441d_G + 1{,}2265\, d_G^2$
$f_B(d_H) = 1{,}0022 - 0{,}1903d_H + 0{,}0073\, d_H^2$
$f_u = 1 + (t_H + t_G) \cdot (1{,}8 + 3{,}2s)$

.2 The stress concentration factor for compression due to the radial force (β_Q) is determined as follows:

$$\beta_Q = 3{,}0128 f_Q(s) \cdot f_Q(w) \cdot f_Q(b) \cdot f_Q(r) \cdot f_Q(d_H) \cdot f_u \qquad (2.4.4.3\text{-}2)$$

where:

$f_Q(s) = 0{,}4368 + 2{,}1630(1-s) - 1{,}5212(1-s)^2$
$f_Q(w) = \dfrac{w}{0{,}0637 + 0{,}9369 \cdot w}$
$f_Q(b) = -0{,}5 + b$
$f_Q(r) = 0{,}5331\, r^{-0{,}2038}$
$f_Q(d_H) = 0{,}9937 - 1{,}1949d_H + 1{,}7373\, d_H^2$
$f_u = 1 + (t_H + t_G) \cdot (1{,}8 + 3{,}2s)$

.3 The stress concentration factor for torsion (β_T) is determined as follows:

– if the diameters and fillet radii of crankpin and journal are of the same size:

$$\beta_T = \alpha_T \qquad (2.4.4.3\text{-}3)$$

– if crankpin and journal diameters and/or radii are of different sizes:

$$\beta_T = 0{,}8 \cdot f(r,s) \cdot f(b) \cdot f(w) \qquad (2.4.4.3\text{-}4)$$

where:

$f(r,s)$, $f(b)$ i $f(w)$ are determined in accordance with 2.4.4.2 (see calculation of α_T). However, the radius of the journal fillet r shall be related to the journal diameter: $r = \dfrac{R_G}{D_G}$

2.4.4.4 Outlet of crankpin oil bore

.1 The stress concentration factor for bending (γ_B) is determined as follows:

$$\gamma_B = 3 - 5{,}88 \cdot d_0 + 34{,}6 \cdot d_0^2 \qquad (2.4.4.4\text{-}1)$$

.2 The stress concentration factor for torsion (γ_T) is determined as follows:

$$\gamma_T = 4 - 6 \cdot d_0 + 30 \cdot d_0^2 \qquad (2.4.4.4\text{-}2)$$

2.4.5 Additional bending stresses

2.4.5.1 In addition to the alternating bending stresses in fillets (see 2.4.2.3) further bending stresses due to misalignment and bedplate deformation as well as due to axial and bending vibrations shall be considered by applying σ_{add} as given by the Table 2.4.5.

Table 2.4.5

Type of engine	σ_{add} [N/mm²]
crosshead engines	±30
trunk piston engines	±10

Note: The additional stress of ±30 N/mm² is composed of two components:

.1 an additional stress of ±20 N/mm² resulting from axial vibration;
.2 an additional stress of ±10 N/mm² resulting from misalignment / bedplate deformation.

2.4.5.2 It is recommended that a value of ±20 N/mm² be used for the axial vibration component for assessment purposes where axial vibration calculation results of the complete dynamic system (engine /gearing /shafting /propeller) are not available.

2.4.5.3 Where axial vibration calculation results of the complete dynamic system are available, the calculated figures may be used instead.

2.4.6 Calculation of equivalent alternating stress

2.4.6.1 In the fillets, bending and torsion lead to two different biaxial stress fields, which can be represented by an equivalent von Mises stress, with the additional assumptions that bending and torsion stresses are time phased and the corresponding peak values occur at the same location.

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 combination of these two stress fields with the assumption that bending and torsion are time phased.

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 von Mises criterion.

2.4.6.2 The equivalent alternating stress is calculated for the crankpin fillet in accordance with the formula given:

$$\sigma_v = \pm\sqrt{(\sigma_{BH} + \sigma_{add})^2 + 3\tau_H^2} \quad \text{[N/mm²]} \quad (2.4.6.2)$$

2.4.6.3 The equivalent alternating stress is calculated for the journal fillet in accordance with the formula given:

$$\sigma_v = \pm\sqrt{(\sigma_{BG} + \sigma_{add})^2 + 3\tau_G^2} \quad \text{[N/mm²]} \quad (2.4.6.3)$$

2.4.6.4 The equivalent alternating stress is calculated for the outlet of the crankpin oil bore in accordance with the formula given:

$$\sigma_v = \pm\frac{1}{3}\sigma_{BO} \cdot \left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\sigma_{TO}}{\sigma_{BO}}\right)^2}\right] \text{[N/mm²]} \quad (2.4.6.4)$$

Note: σ_{BH}, σ_{BG}, σ_{add}, τ_H, τ_G, σ_{BO} and σ_{TO} – see 2.4.2.3, 2.4.3.3, 2.4.5 and 2.4.4.4.

2.4.7 Calculation of fatigue strength and acceptability criteria

2.4.7.1 The fatigue strength shall be understood as the value of equivalent von Mises alternating stress which a crankshaft can permanently withstand at the most highly stressed points.

2.4.7.2 Where the fatigue strength for a crankshaft cannot be furnished by reliable measurements, the allowable fatigue strength of crankshaft may be evaluated by means of the following formulae:

.1 Allowable fatigue strength of crankshaft related to the crankpin diameter:

$$\sigma_{DW} = \pm K(0{,}42 \cdot \sigma_B + 39{,}3) \cdot \left[0{,}264 + 1{,}073 \cdot D^{-0{,}2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{R_X}}\right] \text{[N/mm²]} \quad (2.4.7.2\text{-}1)$$

.2 Allowable fatigue strength of crankshaft related to the journal diameter:

$$\sigma_{DW} = \pm K(0{,}42 \cdot \sigma_B + 39{,}3) \cdot \left[0{,}264 + 1{,}073 \cdot D_G^{-0{,}2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{R_G}}\right] \text{[N/mm²]} \quad (2.4.7.2\text{-}2)$$

where:

K – factor for different types of crankshafts without surface treatment. Values greater than 1 are only applicable to fatigue strength in fillet area.

K = 1,05 – for continuous grain flow forged or drop-forged crankshafts;
= 1,0 – for free form forged crankshafts (without continuous grain flow);
= 0,93 – for cast steel crankshafts manufactured by companies using the cold rolling process approved by the *Register*, with cold rolling treatment in fillet area.

R_X = R_H – in the fillet area;
= $D_O/2$ – in the oil bore area;

σ_B – minimum tensile strength of crankshaft material, [N/mm²].

For other parameters see 2.4.4.1.

When a surface treatment process is applied, it must be approved by the *Register*. Guidance for calculation of surface treated fillets and oil bore outlets is presented in Appendix V of the *Guidance for the calculation of crankshafts for internal combustion engines (QW114)* of the *Register*.

2.4.7.3 The formulae 2.4.7.2-1 and 2.4.7.2-2 are subject to the following conditions:

.1 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) shall be smoothly finished.

.2 For calculation purposes R_H, R_G or R_X are to be taken as not less than 2 mm.

2.4.7.4 As an alternative the fatigue strength of the crankshaft can be determined by experiment based either on full size crankthrow (or crankshaft), or on specimens taken from a full size crankthrow. For evaluation of test results, see Appendix IV of the *Guidance for the calculation of crankshafts for internal combustion engines (QW114)* of the *Register*.

2.4.7.5 Acceptability criteria

The sufficient dimensioning of a crankshaft is confirmed by a comparison of the equivalent alternating stress and the fatigue strength. This comparison has to be carried out for the crankpin fillet, the journal fillet and the outlet of crankpin oil bore, based on the formula:

$$Q = \frac{\sigma_{DW}}{\sigma_v} \quad (2.4.7.5\text{-}1)$$

Adequate dimensioning of the crankshaft is ensured if the smallest of all acceptability factors (Q) satisfies the criterion:

$$Q \geq 1{,}15 \quad (2.4.7.5\text{-}2)$$

2.4.8 Calculation of shrink-fits of semi-built crankshafts

2.4.8.1 All crank dimensions necessary for the calculation of the shrink-fit are shown in figure 2.4.8.1.

where:

D_A – outside diameter of web or twice the minimum distance x between centre-line of journals and outer contour of web, whichever is less, [mm];

D_S – shrink diameter, [mm];

D_G – journal diameter, [mm];

D_{BG} – diameter of axial bore in journal, [mm];

L_S – length of shrink-fit, [mm];

y – distance between the adjacent generating lines of journal and pin, [mm]:
$y \geq 0{,}05\ D_S$
Where y is less than 0,1 D_S, special consideration shall be given to the effect of the stress due to the shrink on the fatigue strength at the crankpin fillet.

Respecting the radius of the transition from the journal to the shrink diameter, the following shall be complied with:

$$R_G \geq 0{,}015 D_G \text{ and } R_G \geq 0{,}5 \cdot (D_S - D_G),$$

where the greater value shall be considered.

The actual oversize, Z, of the shrink-fit shall be within the limits Z_{min} and Z_{max} calculated in accordance with 2.4.8.3 and 2.4.8.4.

In the case where 2.4.8.2 condition cannot be fulfilled then the calculation methods presented in 2.4.8.3 and 2.4.8.4 for Z_{min} and Z_{max} are not applicable due to multizone-plasticity problems. In such case Z_{min} and Z_{max} have to be established based on FEM calculations.

2.4.8.2 Maximum permissible hole in the journal pin

The maximum permissible hole diameter, D_{BG}, in the journal pin is calculated in accordance with the following formula:

$$D_{BG} = D_S \cdot \sqrt{1 - \frac{4000 \cdot S_R \cdot M_{max}}{\mu \cdot \pi \cdot D_S^2 \cdot L_S \cdot \sigma_{SP}}} \text{ [mm]} \qquad (2.4.8.2)$$

where:

S_R – safety factor against slipping, however a value $S_R \geq 2$ shall be taken unless documented by experiments;

M_{max} – absolute maximum value of the torque M_{Tmax} in accordance with 2.4.3.2;

μ – coefficient of static friction, however a value $\mu \leq 0{,}2$ is to be taken unless documented by experiments;

σ_{SP} – minimum yield strength of material for journal pin, [N/mm²].

This condition serves to avoid plasticity in the hole of the journal pin.

2.4.8.3 Necessary minimum oversize of shrink-fit

The necessary minimum oversize, Z_{min}, is determined by the greater value calculated according to:

$$Z_{min} \geq \frac{\sigma_{SW} \cdot D_S}{E_m} \text{ [mm]} \qquad (2.4.8.3\text{-}1)$$

and

$$Z_{min} \geq \frac{4000}{\pi\ \mu} \cdot \frac{S_R \cdot M_{max}}{E_m D_S L_S} \cdot \frac{1 - Q_A^2 \cdot Q_S^2}{(1 - Q_A^2) \cdot (1 - Q_S^2)} \text{ [mm]} \qquad (2.4.8.3\text{-}2)$$

where:

E_m – Young's modulus, [N/mm²];

σ_{SW} – minimum yield strength of material for crank web, [N/mm²];

Q_A – web ratio; $Q_A = \frac{D_S}{D_A}$;

Q_S – shaft ratio; $Q_S = \frac{D_{BG}}{D_S}$;

D_S, L_S – as defined in 2.4.8.1;

μ, M_{max}, S_R – as defined in 2.4.8.2.

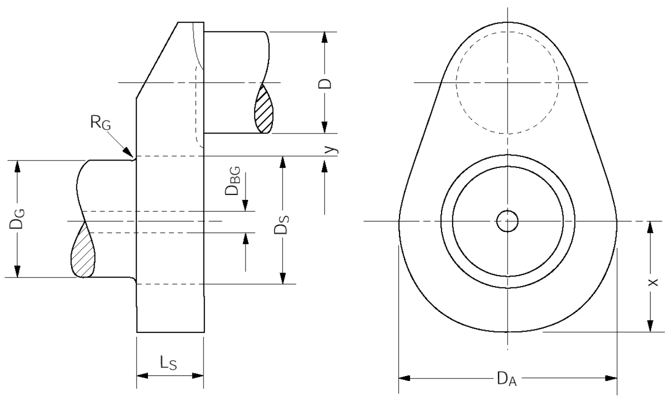


Fig. 2.4.8.1
Crank throw of semi-built crankshaft

2.4.8.4 Maximum permissible oversize of shrink-fit

The maximum permissible oversize of shrink-fit, Z_{max}, is calculated in accordance with the following formula:

$$Z_{max} \leq D_S \cdot \left(\frac{\sigma_{SW} \cdot}{E_m} + \frac{0{,}8}{1000} \right) \text{ [mm]} \qquad (2.4.8.4)$$

where for σ_{SW}, D_S and E_m see 2.4.8.1 and 2.4.8.3.

This condition serves to restrict the shrinkage induced mean stress in the fillet.

2.4.9 Additional requirements for crankshafts

2.4.9.1 The fillet radius at the junction of the web with the journal or pin is not to be less than 0,05*D*.

Where crankshafts have flanges, the fillet radius at the junction with the journal is not to be less than 0,08*D*.

2.4.9.2 The edges of the holes shall be rounded to a radius of not less than 25% of the diameter of the hole with a smooth finish.

2.4.9.3 Reference marks shall be provided on the outer sides of junction of the webs with the pins and journals.

2.4.9.4 Where the thrust bearing is built in the engine frame, the diameter of the thrust shaft in way of the bearing is not to be less than that of the crankshaft and also to comply with the requirements stated in the *Rules for the classification of ships, Part 7 - Machinery Installations*, 2.3.

2.5 SCAVENGING AND SUPERCHARGING

2.5.1 In the event of failure of one turbocharger the main engine shall, generally, operate at a power which maintains the ship's running with a speed ensuring easy steering.

2.5.2 Even at low engine speeds, main engine shall be supplied with sufficient charge air to ensure reliable operation.

Engines may be equipped with separate directly or independently driven air compressor for low engine speeds and manoeuvring operation.

If by low speeds and manoeuvring operation an engine can be operated only with independently driven charge air compressor, a stand-by air compressor or an equivalent device of approved type shall be installed.

2.5.3 Where supercharging air is cooled, the scavenge manifolds shall be fitted with thermometers and condensate drain cocks after each air cooler.

2.5.4 The scavenge manifolds of two-stroke engines with pumps which are not of centrifugal type, as well as the scavenge manifolds having direct connection with the cylinders, shall be provided with relief valves set for a pressure exceeding that of scavenging air by not more than 50%.

The free area of the relief valves is not to be less than 30 cm² per cubic metre of the manifold capacity including the volume of the under piston spaces in crosshead engines fitted with diaphragms if these spaces are not used as scavenging pumps.

2.5.5 Scavenge manifolds and under piston spaces shall be provided with drain means for removing accumulations of sludge and water.

2.5.6 The air intake pipes of engines and supercharging units shall be fitted with safety nets.

2.6 FUEL SYSTEM

2.6.1 The high-pressure oil fuel pumps of the main engines shall be equipped with device for quickly shutting-off the fuel supply to any cylinder of the engine. Exemption from this requirement is allowed for engines with cylinders not over 180 mm in diameter having grouped oil fuel pumps.

2.6.2 The high-pressure oil fuel pipes shall be made from thick-walled seamless steel pipes without welded or soldered intermediate joints.

2.6.3 Precautions shall be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.

2.6.4 Jacketed piping system

2.6.4.1 The requirements of this item are applicable to:
- .1 new ships,
- .2 existing ships in international navigation,
- .3 other existing ships with propulsion engines of total installed power greater than 375 kW, expanding their navigational area, being converted into passenger ships, or changing their propulsion engines.

2.6.4.2 The requirements are implemented to internal combustion engines installed in any of the ship parts, regardless of their purpose and position. The term internal combustion engine implies here engines with one or several cylinders, having separate or common fuel oil pumps, excluding lifeboat engines.

2.6.4.3 External high-pressure fuel oil delivery lines between the high-pressure fuel pumps and fuel injectors shall be protected with a jacketed piping system. The system shall be capable of containing fuel from a high-pressure line failure. A jacketed pipe incorporates an outer pipe into which the high-pressure fuel pipe is placed, forming a permanent assembly. The jacketed piping system shall include a means for collection of leakages and prevent either oil spill or spraying on engine parts or engine surrounding, which may cause fire. Arrangements shall be provided with an alarm in case of a fuel line failure.

2.6.4.4 Surfaces with temperatures above 220°C, which may be impinged as a result of a fuel oil system failure, shall be properly insulated.

2.6.4.5 As far as practicable oil fuel lines shall be arranged far apart from hot surfaces, electrical installations or other sources of ignition and screened or otherwise suitably protected to prevent oil spraying or oil leakage onto the sources of ignition, hot surfaces, or machinery air intakes. The number of joints in such piping system shall be kept to a minimum.

2.6.5 High pressure oil fuel delivery lines on small engines

2.6.5.1 Existing ships of navigational area 5, 6, 7 or 8, with total installed propulsion engine power less than 375 kW, expanding their navigational area, being converted into passenger ships, or changing their propulsion engines, instead of complying to the requirements 2.6.4, may have appropriate alternative protection of high pressure oil fuel pipes and oil pumps approved by the *Register*.

2.6.5.2 Alternative protection shall have a similar function as the jacketed piping system, i.e. prevent oil spraying or oil leakage from failed high-pressure oil fuel pipes onto hot surfaces.

2.6.5.3 The protection shall completely surround high-pressure oil fuel pipes, where the existing non-heated areas of the engine may be considered as parts of the protection.

2.6.5.4 Surface temperature of all engine parts within the protection, when the engine runs on its maximal power, shall not exceed 220°C.

2.6.5.5 The protection shall be of enough strength and have an enough covering area, capable to resist to the flow spraying from a failed high-pressure oil fuel pipe in operation and capable to prevent spraying onto heated surfaces and to restrict the area with which the leaked oil fuel may get into contact. If the protection is non-metallic, its material shall be inflammable and resistant to absorption of oil fuel.

2.6.5.6 In case when leaked fuel may get into contact with heated surfaces appropriate draining devices shall be provided, capable of fast transport of spilled oil fuel to the safe place. This place may be a spilled oil tank. Flowing of leaked oil fuel to non-heated engine surfaces may be accepted, provided that leaking to the heated surfaces has been prevented by the appropriate protection, or by some other means.

2.6.5.7 In case when the protection contains sockets for high-pressure oil fuel pipes joints, these sockets shall be of watertight type, to prevent leakage.

2.7 LUBRICATION

2.7.1 The lubricators supplying oil for lubricating the cylinders shall be fitted with an arrangement enabling to control the amount of oil delivered to each point. To supervise the oil supply to all points to be lubricated, flow indicators shall be provided in position convenient for observation.

2.7.2 Every union supplying lubricating oil to the two-stroke engine cylinders as well as the unions arranged in the upper part of the cylinder liner shall be provided with a non-return valve.

2.8 COOLING

2.8.1 Where telescopic devices are employed for cooling pistons or for supplying lubricating oil to moving parts, protection from hydraulic shocks shall be provided.

2.9 STARTING ARRANGEMENTS

2.9.1 Mechanical starting arrangements

2.9.1.1 The manifold supplying starting air from the master starting air valve to the cylinder starting valves shall be fitted with at least one relief valve and with a device relieving the manifold of pressure after the engine has been started.

The relief valve shall be loaded to a pressure not more than 1,2 times than in the starting air manifold. The relieving device and the relief valve may be fitted directly on the master starting air valve.

Alternative device designed to protect the starting air manifold from the effects of inner explosions is also admitted.

2.9.1.2 Flame arrester shall be fitted on each branch pipe for air supply to the starting valves in the reversible engine cylinder covers.

In case of non-reversible engines at least one flame arrester shall be fitted on the manifold supplying starting air from the main starting valve to the manifold that supplies air to the starting valves in the engine cylinder covers.

Provision of the flame arresters is non-compulsory for the engines with a cylinder bore of 230 mm and less.

2.9.1.3 The remaining requirements for mechanical starting arrangements (number and capacity of air compressors and air receivers) have been defined in the *Rules for the classification of ships, Part 8 - Piping*, 11.1 and 11.2.

2.9.2 Electrical starting

2.9.2.1 The requirements for electrical starting arrangements have been defined in the *Rules for the classification of ships, Part 12 - Electrical equipment,* 13.7.

2.9.2.2 It is recommended that the engines that are electrically started are equipped with an engine driven generator for automatic charging of the starting battery.

2.9.3 Starting of emergency generator

2.9.3.1 Emergency diesel-generator shall be in compliance with requirements specified in the *Rules for the classification of ships, Part 8 - Piping*, 11.1.8 and in the *Rules for the classification of ships, Part 12 - Electrical equipment.*

2.10 EXHAUST ARRANGEMENTS

2.10.1 In two-stroke engines fitted with the exhaust gas turbo-blowers which operate on the impulse system, provision shall be made to prevent broken piston rings from entering the turbine casing.

2.11 CONTROLS AND GOVERNORS

2.11.1 General

2.11.1.1 The starting and reversing arrangements shall eliminate the possibility of:

.1 running the engine in the direction opposite to the desired one;
.2 reversing the engine when the fuel oil supply is cut-in;
.3 starting the engine before reversal is completed;
.4 starting the engine with the power-driven turning gear engaged.

2.11.2 Speed governor and overspeed protective device for main internal combustion engines

2.11.2.1 Each main engine shall be fitted with a speed governor so adjusted that the engine speed cannot exceed the rated speed by more than 15%.

2.11.2.2 In addition to this speed governor each main engine having a rated power of 220 kW and above, and which can be declutched or which drives a controllable pitch propeller, shall be fitted with a separate overspeed protective device so adjusted that the engine speed cannot exceed the rated speed by more than 20%. Equivalent arrangements may be accepted upon special consideration.

The overspeed protective device, including its driving mechanism, has to be independent from the required governor.

2.11.2.3 Electronic speed governors of main internal combustion engines as a part of the engine remote control system shall comply with the *Rules for the classification of ships, Part 13 - Automation*, 2.5 and with the following:

- .1 if lack of power to the governor may cause major and sudden changes in the present speed and direction of thrust of the propeller, backup power supply shall be provided;
- .2 local control of the engines is always to be possible, and to this purpose, it shall be possible to disconnect the remote signal from the local control position, bearing in mind that the speed control according to 2.11.2.1 is not available unless an additional separate governor is provided for such local mode of control.

In addition, electronic speed governors and their actuators shall be type tested according to IACS UR E10.

NOTE: The rated power and corresponding rated speed are those for which classification of the installation has been requested.

2.11.3 Speed governor, overspeed protective and governing characteristics of generator prime movers

2.11.3.1 Prime movers for driving generators of the main and emergency sources of electrical power shall be fitted with a speed governor. The speed governor shall prevent 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. In the case 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 2.11.3.5.

2.11.3.2 At all loads between no load and rated power the permanent speed variation should not be more than ±5% of the rated speed.

2.11.3.3 Prime movers shall be selected in such a way that they will meet the load demand within the ship's mains.

Application of electrical load should be possible with 2 load steps. It shall be such that prime movers – running at no load – can suddenly be loaded to 50% of the rated power of the generator followed by the remaining 50% after an interval sufficient to restore the speed to steady state. Steady state conditions should be achieved in not more than 5 seconds.

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

Application of electrical load in more than 2 load steps can only be permitted, if the conditions within the ship's mains permit the use of such prime movers which can only be loaded in more than 2 load steps (see figure 2.11.3.7 for guidance on 4-stroke diesel engines expected maximum possible sudden power increase) and provided that this is already allowed for in the designing stage. This shall be verified in the form of system specifications to be approved and to be demonstrated at ship's trials. In this case, due consideration shall be given to the power required for the electrical equipment to be automatically switched on after black-out and to the sequence in which it is connected. This applies analogously also for generators to be operated in parallel and where the power has to be transferred from one generator to another in the event of any one generator has to be switched off.

2.11.3.4 Emergency generator sets shall satisfy the governor conditions as per items 2.11.3.1 and 2.11.3.2 when:

- a) their total consumer load is applied suddenly;
- b) their total consumer load is applied in steps, subject to:
  - .1 the total load is supplied within 45 seconds since power failure on the main switchboard;
  - .2 the maximum step load is declared and demonstrated;
  - .3 the power distribution system is designed such that the declared maximum step loading is not exceeded;
  - .4 the compliance of time delays and loading sequence with the above shall be demonstrated at ship's trials.

2.11.3.5 In addition to the speed governor, each prime mover with a rated power of 220 kW and above, driving an electric generator shall be fitted with a separate overspeed protective device so adjusted that the speed cannot exceed the rated speed by more than 15%.

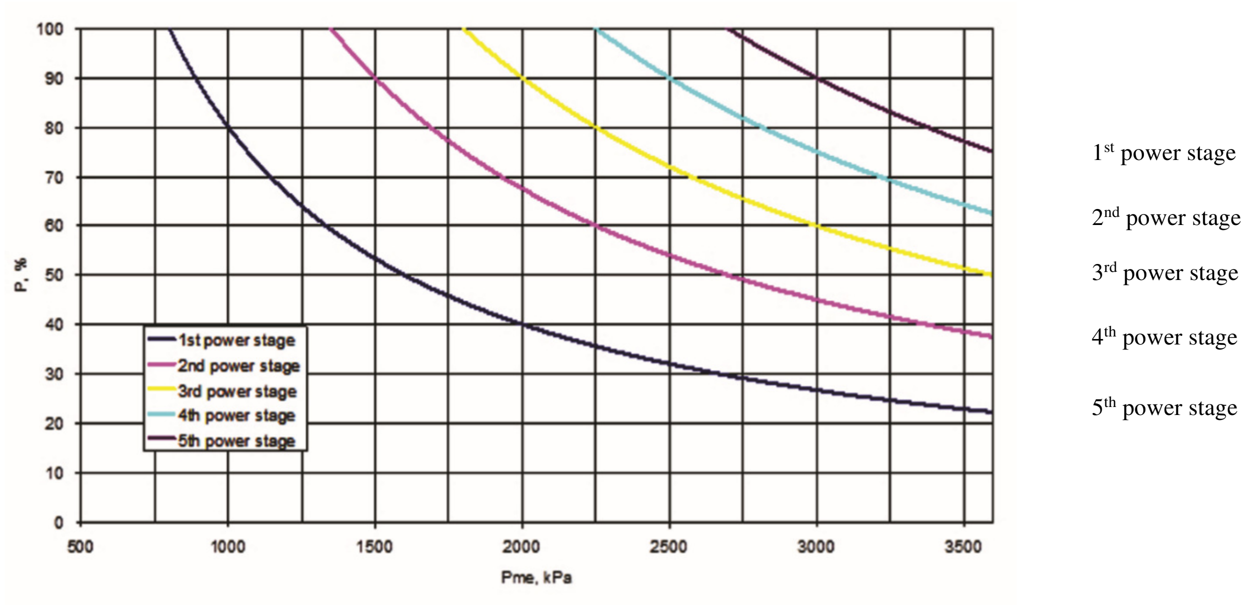


Fig. 2.11.3.7
Reference values for maximum possible sudden power increases as a function of brake mean effective pressure, P_{me}, at declared power (four-stroke diesel engines)

Legend:
Pme : declared power mean effective pressure
P : power increase referred to declared power at site conditions

2.11.3.6 For a/c generating sets operating in parallel, governing characteristics of the prime movers shall 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 of the largest machine or 25% of the rated power of the individual machine in question, whichever is the less.

For an a/c generating set intended to operate in parallel, facilities shall be provided to adjust the governor sufficiently fine to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.

2.11.3.7 For guidance, the loading for 4-stroke diesel engines may be limited as given by figure 2.11.3.7.

2.12 INSTRUMENTS FOR CONTROL MEASUREMENT AND SIGNALISATION

2.12.1 The control stations of the main engines shall be fitted with instruments for measuring:

.1 crankshaft speed and in reversible engines and in propulsion systems where disengaging couplings (clutches) are provided, also the direction of propeller shaft rotation;
.2 revolutions per minute of turbo-blowers;
.3 lubricating oil pressure before the engine;
.4 pressure in the fresh water cooling system;
.5 pressure in the sea water cooling system;
.6 starting air pressure before the master starting valve;
.7 fuel pressure before high-pressure pumps (where a fuel -booster pump is provided);
.8 pressure in the cooling systems of the fuel valves and pistons;
.9 pressure in the reverse gear system;
.10 pressure in the scavenge air manifolds;
.11 temperature of exhaust gases at each cylinder (for engines with cylinder bore of 180 mm and over);
.12 exhaust gas temperature before and after the turbo -blowers;
.13 cooling water or oil temperature at the engine inlet and at the outlet from each cylinder and piston for engines with cylinder bore of more than 180 mm; for engines with cylinder bore up to 180 mm only at the engine inlet and outlet;
.14 lubricating oil temperature before the engine;
.15 air temperature after the air coolers;
.16 current and voltage in the charging circuit and voltage in the discharging circuit of the starting storage batteries(for electrically-started engines).
.17 fuel temperature before high-pressure pumps (for fuel requiring preheating).

Where gearing with the circulating lubricating oil system is provided, the main engine control station shall be fitted with instruments for measuring pressure of the lubricating oil delivered to the gearing, and temperature of the outlet oil. Devices for visual checking of the oil flow to each bearing shall be fitted directly on the gearing.

Where hydraulic, pneumatic or electrical couplings are provided, the main engine control station shall be fitted with the instruments for control of the electrical power supply or pressure in the system.

In equipping the control stations with measuring instruments, the requirements specified in the *Rules for the classification of ships, Part 7 - Machinery Installations*, 1.8 shall be also observed.

2.12.2 Main and auxiliary engines above 37 kW shall be fitted with an alarm device with audible and luminous signals in case of failure in the lubricating oil system as well as pressure drop in lubricating oil system.

The following warning alarm instruments are recommended to be installed:

.1 pressure drop in the fresh water cooling systems;
.2 drop of lubricating oil level in the gravity tank of the turbo-blowers;
.3 rise of the lubricating oil temperature at the engine inlet;
.4 rise of the cooling water or oil temperature at the engine outlet;
.5 drop of the temperature of heavy fuel oil preheating;
.6 pressure drop in the exhaust valve hydraulic control system.

2.12.3 The control stations of auxiliary engines shall be fitted with instruments in compliance with 2.12.1, under numbers 1, 3, 4, 5, 6, 7, 10, 11, 13 (at the engine inlet and outlet only), 14 and 16.

2.12.4 Where a remote control station is provided, with local control station retained, the latter shall be fitted with instruments for measuring the parameters specified in 2.12.1.1, 2.12.1.3 to 2.12.1.6 and 2.12.1.8.

2.13 TORSIONAL VIBRATION DAMPERS

2.13.1 The air outlet from the torsional vibration damper shall be possible when it is filled with oil or silicon liquid.

2.13.2 In general, lubrication of torsional vibration damper springs shall be carried out from the engine lubricating system.

2.13.3 Construction of damper provided for fitting on the free end of the crankshaft shall enable connecting of torsional vibrations measuring device to the same end of crankshaft.

2.14 TESTING OF INTERNAL COMBUSTION ENGINES

TYPE TESTING OF INTERNAL COMBUSTION ENGINES

2.14.1 General

2.14.1.1 Type approval of internal combustion engine types consists of drawing approval, specification approval, conformity of production, approval of type testing programme, type testing of engines, review of the obtained results, and the issuance of the Type Approval Certificate. The requirements for drawing approval and specification approval of engines and components are specified in Annex A of these Rules.

2.14.1.2 For the purpose of these Rules head, the following definitions apply:

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

2.14.2 Objectives

2.14.2.1 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.

2.14.2.2 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.

2.14.3 Validity

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

2.14.3.2 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 Register.

2.14.3.3 A type of engine is defined by:

- 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) [1)]
- cylinder power, speed and cylinder pressures [2)]

NOTES:

1) 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 *Register* 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 b_{mep} 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.

2) 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 and modification of crankshaft calculation and crankshaft drawings are approved, an increase 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

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

2.14.3.4 If an engine has been design approved, and internal testing per Stage A, as defined in 2.14.5, 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 1., 2 measurements with one running hour in between;
- Maximum permissible torque (normally 110%) at 100% speed corresponding to load point 3 or maximum permissible power (normally 110%) and speed according to nominal propeller curve corresponding to load point 3a., ½ hour;
- 100% power at maximum permissible speed corresponding to load point 2, ½ hour;

2.14.3.5 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, etc.) separately approved. The scope of these tests shall be proposed by the designer/licensor taking into account of impact on engine.

2.14.4 Safety precautions

2.14.4.1 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.

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

2.14.4.3 The inspection for jacketing of high-pressure fuel oil lines and proper screening of pipe connections (as required in 2.14.8.9 fire measures) is also to be carried out before the test runs.

2.14.4.4 Interlock test of turning gear is to be performed when installed.

2.14.5 Test programme

2.14.5.1 The type testing is divided into 3 stages:

- 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 *Register* or stipulated by the designer are to be presented to the *Register* before starting stage B;
- Stage B - witnessed tests; this is the testing made in the presence of Classification Register personnel;
- Stage C - component inspection; this is the inspection of engine parts to the extent as required by the *Register*.

2.14.5.2 The complete type testing program is subject to approval by the *Register*. The extent the Surveyor's attendance is to be agreed in each case, but at least during stage B and C.

2.14.5.3 Testing prior to the witnessed type testing (stage B and C), is also considered as a part of the complete type testing program.

2.14.5.4 Upon completion of complete type testing (stage A through C), a type test report is to be submitted to the Register 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 *Register*;
- detailed description of the load and functional tests conducted during stage B;
- inspection results from stage C.

2.14.5.5 As required in 2.14.2 the type testing is to substantiate the capability of the design and its suitability for the intended operation. Special testing such as low cycle fatigue (LCF) and endurance testing will normally be conducted during stage A.

2.14.5.6 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 2.14.3.

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.

2.14.6 Measurements and recordings

2.14.6.1 During all testing the ambient conditions (air temperature, air pressure and humidity) are to be recorded.

2.14.6.2 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 [1)];
- 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).

NOTES:

[1)] For engines where the standard production cylinder heads are not designed for such measurements, 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 reliability 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.

2.14.7 Stage A - internal tests

2.14.7.1 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.

2.14.7.2 At least the following conditions are to be tested:

- Normal case includes 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 *Register* or stipulated by the designer.

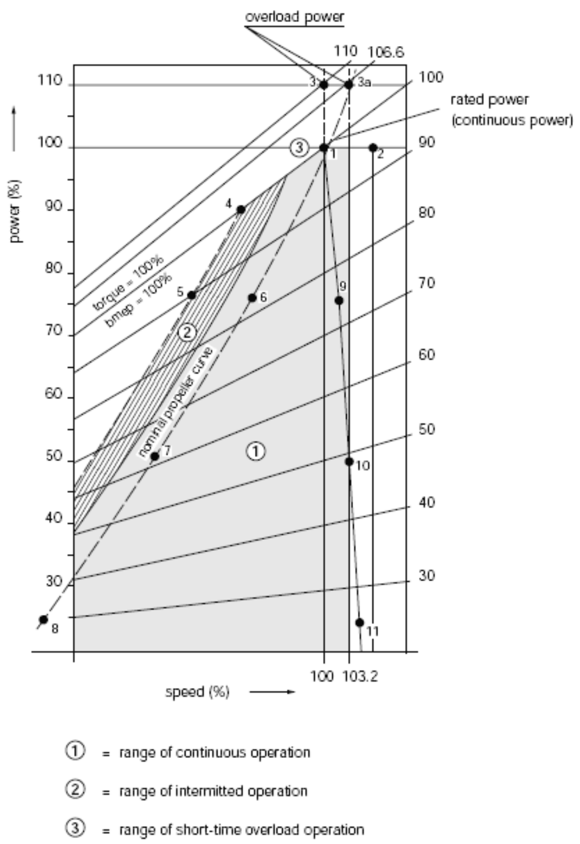
2.14.8 Stage B - witnessed tests

2.14.8.1 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.

2.14.8.2 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 without load during the speed overshoot.

2.14.8.3 Load points at which the engine shall be operated is to be according to the power and speed diagram (see Figure 2.14.8.3). The data to be measured and recorded when testing the engine at the various load points have to include all engine parameters listed in 2.14.6. 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.

Figure 2.14.8.3
Load points



2.14.8.4 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.

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

2.14.8.5 Operation with damaged turbocharger

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.)

2.14.8.6 Functional tests

- 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 IACS UR M3.1 and M3.2 are to be carried out.

2.14.8.7 Integration test

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 Register for selected cases based on the FMEA required in IACS UR M44.

2.14.8.8 Fire protection measures

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 *Register*. Readings obtained are to be randomly verified by use of contact thermometers.

2.14.9 Stage C - Opening up for Inspections

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

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

2.14.9.3 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 extent 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).

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

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

FACTORY ACCEPTANCE TEST AND SHIPBOARD TRIALS OF INTERNAL COMBUSTION ENGINES

2.14.10 Safety precautions

2.14.10.1 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.

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

2.14.10.3 The overspeed protective device is to be set to a value, which is not higher than the overspeed value that was demonstrated during the type test for that engine. This set point shall be verified by the surveyor.

2.14.11 General

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

2.14.11.2 Adequate test bed facilities for loads as required in 2.14.12.3 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.

2.14.11.3 The testing consists of workshop and shipboard (quay and sea trial) testing.

2.14.11.4 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 Register may request temperature measurements as required by 2.14.8.9.

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

2.14.12 Works trials (Factory Acceptance Test)

2.14.12.1 Objectives

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.

2.14.12.2 Records

.1 The following environmental test conditions are to be recorded:
- Ambient air temperature;
- Ambient air pressure;
- Atmospheric humidity.

.2 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 IACS UR M73 and M35/36);
- Charge air temperature;
- Charge air pressure;
- Turbocharger speed (to the extent that monitoring is required in IACS UR M73).

.3 Calibration records for the instrumentation are, upon request, to be presented to the attending Surveyor of the *Register*.

.4 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.

.5 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.

2.14.12.3 Test loads

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

.2 Propulsion engines driving propeller or impeller only.

A) 100% power (MCR) at corresponding speed n_0 at least 60 min.
B) 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:
Only required once for each different engine/turbocharger configuration.

C) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
D) 90% (or normal continuous cruise power), 75%, 50% and 25% power (at engine speed n_0 and idle) in accordance with the nominal propeller curve, the sequence to be selected by the engine manufacturer.
E) Reversing manoeuvres (if applicable).

NOTE:
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 Register. In that case, the fuel delivery system is to be blocked to that power.

.3 Engines driving generators for electric propulsion.

A) 100% power (MCR) at corresponding speed n_0: at least 60 min.
B) 110% power at engine speed n_0: 15 min. - after having reached steady conditions.
C) Governor tests for compliance with IACS UR M3.1 and M3.2 are to be carried out.
D) 75%, 50% and 25% power and idle, the sequence to be selected by the engine manufacturer.

NOTE:
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 utilised in the electric distribution system can be activated before the engine stalls.

.4 Engines driving generators for auxiliary purposes

A) 100% power (MCR) at corresponding speed n0: at least 60 min.
B) 110% power at engine speed n0: 15 min. - after having reached steady conditions.
C) Governor tests for compliance with IACS UR M3.1 and M3.2 are to be carried out.
D) 75%, 50% and 25% power and idle, the sequence to be selected by the engine manufacturer.

NOTE:
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 utilized in the electric distribution system can be activated before the engine stalls.

.5 Propulsion engines also driving power take off (PTO) generator.

A) 100% power (MCR) at corresponding speed n_0: at least 60 min.
B) 110% power at engine speed n_0: 15 min. - after having reached steady conditions.
C) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
D) 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve or at constant speed n_0, the sequence to be selected by the engine manufacturer.

NOTE:
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.

.6 Engines driving auxiliaries.

A) 100% power (MCR) at corresponding speed n_0: at least 30 min.
B) 110% power at engine speed n_0: 15 min. - after having reached steady conditions.
C) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
D) 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:
After running on the test bed, the fuel delivery system is normally to be so adjusted that overload power cannot be delivered in service, unless intermittent overload power is approved. In that case, the fuel delivery system is to be blocked to that power.

2.14.12.4 Turbocharger matching with engine

.1 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.

.2 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 stabilised 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 and at the engine load corresponding to a charge air pressure of about 0.6 bar (but without auxiliary blowers running).
- No continuous surging 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.

2.14.12.5 Integration tests

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 *Register* for selected cases based on the FMEA required in IACS UR M44.

2.14.12.6 Component inspections

Random checks of components to be presented for inspection after works trials are left to the discretion of the *Register*.

2.14.13 Shipboard trials

2.14.13.1 Objectives

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).

2.14.13.2 Starting capacity

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.

2.14.13.3 Monitoring and alarm system

The monitoring and alarm systems are to be checked to the full extent for all engines, except items already verified during the works trials.

2.14.13.4 Test loads

.1 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.

.2 The suitability of the engine to operate on fuels intended for use is to be demonstrated.

NOTE:
Tests other than those listed below may be required by statutory instruments (e.g. EEDI verification).

.3 Propulsion engines driving fixed pitch propeller or impeller.

A) At rated engine speed n_0: at least 4 hours.
B) At engine speed $1.032n_0$ (if engine adjustment permits, see 2.14.12.3): 30 min.
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:
During stopping tests according to Resolution MSC.137 (76), see 2.14.13.5 for additional requirements in the case of a barred speed range.

.4 Propulsion engines driving controllable pitch propellers.

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 UR M51.4.5.1 for additional requirements in the case of a barred speed range.

.5 Engine(s) driving generator(s) for electrical propulsion and/or main power supply

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.

NOTE:
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.

C) Demonstration of the generator prime movers' and governors' ability to handle load steps as described in IACS UR M3.2.

.6 Propulsion engines also driving power take off (PTO) generator.

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.

.7 Engines driving auxiliaries.

A) 100% power (MCR) at corresponding speed n_0: at least 30 min.

B) Approved intermittent overload: testing for duration as approved.

2.14.13.5 Torsional vibrations

Where a barred speed range (BSR) is required, passages through this BSR, 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 BSR in reverse rotational direction, especially during the stopping test.

NOTE:
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 BSR. Steady fuel index means an oscillation range less than 5% of the effective stroke (idle to full index).

2.15 INTERNAL COMBUSTION ENGINES DRIVING A GENERATOR FOR EMERGENCY SOURCE OF ELECTRICAL POWER

2.15.1 Internal combustion engine driving a generator for emergency source of electrical power in passenger ships shall be:

.1 driven by a suitable prime mover with an independent supply of fuel having a flashpoint (closed cup test) of not less than 43°C;

.2 started automatically upon failure of the electrical supply from the main source of electrical power. The automatic starting system and the characteristic of the prime mover shall be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 seconds;

.3 ensure that it will function at full rated power when the ship is in the normal position or at limit values of static and dynamic inclination (see the *Rules for the classification of ships, Part 7- Machinery installation*, 1.6.2.).

2.15.2 Internal combustion engine driving a generator for emergency source of electrical power in cargo ships shall meet the following requirements:

.1 driven by a suitable prime mover with an independent supply of fuel as specified in 2.15.1.1.

.2 started automatically upon failure of the electrical supply from the main source of electrical power. Supplying the required load shall be as quickly as it is safe and practicable, but not exceeding 45 seconds.

.3 ensure that it will function at full rated power when the ship is in the normal position or at limit values of static and dynamic inclination (see the *Rules for the classification of ships, Part 7- Machinery installation*, 1.6.2).

2.15.3 Starting arrangements for emergency generating sets:

.1 Emergency generating sets shall 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, heating arrangements approved by the *Register*, shall be provided to ensure ready starting of the generating sets.

.2 Each emergency generating set arranged to be automatically started shall be equipped with starting devices approved by the *Register* with a stored energy capability of at least three consecutive starts. A second source of energy shall be provided for an additional three starts within 30 min, unless manual starting can be demonstrated to be effective.

.3 Ships need not be provided with a second independent means of starting required in the last sentence of the regulation 2.15.3.2 if the automatic starting is equipped with a source of stored energy protected so as to preclude its complete depletion. Additionally, 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.

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

.5 When manual starting is not practicable, the requirements of 2.15.3.2 shall be complied with.

2.15.4 If the emergency generator is used during lay time in port for the supply of the ship mains, its prime mover shall comply with the following requirements:

.1 The prime mover shall be arranged with fuel oil filters and lubrication oil filters, monitoring equipment and protection devices as required for the prime mover for main power generation and for unattended operation.

.2 The fuel oil supply tank to the prime mover shall 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 by the *Rules for the classification of ships, Part 12-Electrical equipment, 9.3, 19.1.2, 19.3.3* and *19.4.2*, dependent on the ship type.

.3 The prime mover shall 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.

The remaining requirements in this case are stated in the *Rules for the classification of ships, Part 12 - Electrical equipment,* 9.1.8.

2.15.5 Alarms and safeguards for emergency diesel engines

2.15.5.1 Field of application

These requirements apply to reciprocating internal combustion engines, which use distillate marine fuels covered by ISO 8217:2017, required to be immediately available in an emergency and capable of being controlled remotely or automatically operated.

2.15.5.2 Information to be submitted

Information demonstrating compliance with these requirements is to be submitted to the relevant *Register*. The information is to include instructions to test the alarm and safety systems.

2.15.5.3 Alarms and safeguards

1. Alarms and safeguards are to be fitted in accordance with Table 2.15.5.
2. 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.
3. Regardless of the engine output, if shutdowns additional to those specified in Table 2.15.5 are provided except for the overspeed shutdown, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.
4. The alarm system is to function in accordance with IACS UR M29, with additional requirements that grouped alarms are to be arranged on the bridge.
5. In addition to the fuel oil control from outside the space, a local means of engine shutdown is to be provided.
6. Local indications of at least those parameters listed in Table 2.15.5 are to be provided within the same space as the reciprocating internal combustion engines and are to remain operational in the event of failure of the alarm and safety systems.

Table 2.15.5

Alarms and safeguards for emergency diesel engines

Parameter	Alarm activation	Shutdown with alarm
Fuel oil leakage from high pressure pipes (fuel injection pipes and common rails)	x	
Lubricating oil temperature 1)	high	
Lubricating oil pressure	low	
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	
Pressure or flow of cooling water 1	low	
Temperature of cooling water (or cooling air)	high	
Overspeed activated 1)		x

Note:
1) for engines having a power of or more than 220 kW.
2) for engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.

2.15.5 Alarms and safeguards for emergency diesel engines

2.15.5.1 Field of application

These requirements apply to diesel engines required to be immediately available in an emergency and capable of being controlled remotely or automatically operated.

2.15.5.2 Information to be submitted

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

Table 2.15.5
Alarms and safeguards for emergency diesel engines

Parameter	< 220kW	≥ 220kW
Fuel oil leakage from pressure pipes	low value alarm	low value alarm
Lubricating oil temperature	-	high value alarm
Lubricating oil pressure	low value alarm	low value alarm
Oil mist concentration in crankcase (for engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm)	-	high value alarm
Pressure or flow of cooling water	-	low value alarm
Temperature of cooling water (or cooling air)	high value alarm	high value alarm
Overspeed activated	-	alarm activated and shut down

2.15.5.3 Alarms and safeguards

.1 Alarms and safeguards are to be fitted in accordance with the Table 2.15.5

.2 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.

.3 Regardless of the engine output, if shutdowns additional to those specified in the Table 2.15.5 are provided except for the overspeed shutdown, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.

.4 The alarm system is to function in accordance with the *Rules for the classification of ships, Part 13 - Automation*, Table 4.1, with additional requirements that grouped alarms are to be arranged on the bridge.

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

.6 Local indications of at least those parameters listed in Table 2.15.5 are to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.

2.16 LIFEBOAT PROPULSION ENGINE

2.16.1 Every lifeboat shall be powered by a compression ignition engine. No engine shall be used for any lifeboat if its fuel has a flashpoint of 43°C or less (closed cup test).

2.16.2 The engine shall be provided with either a manual starting system, or a power starting system with two independent rechargeable energy sources. Any necessary starting aids shall also be provided. The engine starting systems and starting aids shall start the engine at an ambient temperature of –15°C within 2 min of commencing the start procedure unless, in the opinion of the *Register* having regard to the particular voyages in which the ship carrying the lifeboat is constantly engaged, a different temperature is appropriate. The starting systems shall not be impeded by the engine casing, thwarts or other obstructions.

2.16.3 The engine shall be capable of operating for not less than 5 minutes after starting from cold with the lifeboat out of the water.

Engine cooling water pump shall be of self-primed type and shall be capable to withstand the operation of 5 minutes with the lifeboat out of the water.

2.16.4 The engine shall be capable of operating when the lifeboat is flooded up to the centreline of the crankshaft.

2.16.5 Provision shall be made for ahead and astern propulsion of the lifeboat.

2.16.6 The exhaust pipe shall be so arranged as to prevent water from entering the engine in normal operation. Adequate insulation or cooling shall be arranged for hot parts of the exhaust pipe.

2.16.7 The lifeboat engine, transmission and engine accessories shall be enclosed in a fire-retardant casing or other suitable arrangements providing similar protection. Such arrangements shall also protect persons from coming into accidental contact with hot or moving parts and protect the engine from exposure to weather and sea. Adequate means shall be provided to reduce the engine noise.

2.16.8 The lifeboat engine and accessories shall be designed to limit electromagnetic emissions so that engine operation does not interfere with the operation of radio life-saving appliances used in the lifeboat.

2.16.9 Means shall be provided for recharging all engine starting, radio and searchlight batteries. Radio batteries shall not be used to provide power for engine starting.

2.16.10 The lifeboat engine shall be capable to function at full rated power when it is in the normal position or at limit values of static and dynamic inclination (see the *Rules for the classification of ships, Part 7 - Machinery Installations*, 1.6.2).

2.16.11 The lifeboat engine and its accessories shall be made of suitable and, as far as possible, of maintenance free materials.

2.16.12 The engine in a free-fall lifeboat shall comply with 2.16.3.

2.16.13 In case of installation of engine in a free-fall lifeboat, the engine might be provided with additional securing arrangement.

2.16.14 Satisfactory provisions shall be made to prevent:

.1 intrusion of water into the air inlet of the engine;

.2 damage by frost to the engine and pipe systems;

.3 spillage of lubricating oil from the engine;

.4 noxious exhaust or smoke emission from fire insulation and paints on the engine.

2.16.15 Water-resistant instructions for starting and operating the engine shall be provided and mounted in a conspicuous place near the engine starting controls.

2.16.16 Tools and spare parts for engine shall be provided.

2.16.17 The requirements specified in the regulation 2.17.3. and 2.17.4. apply also to the lifeboat engines.

2.16.18 The procedure of testing of lifeboat propulsion engines is stated in IMO Resolution MSC.81(70), chapter 6.10.

2.17 LIFEBOAT PROPULSION ENGINE FOR SELF-RIGHTING PARTIALLY ENCLOSED AND TOTALLY ENCLOSED LIFEBOATS

2.17.1 Lifeboat propulsion engine for self-righting partially enclosed and totally enclosed lifeboats shall comply with 2.16 and in addition with 2.17.2; 2.17.3 and 2.17.4.

2.17.2 The engine and transmission shall be controlled from the helmsman's position.

2.17.3 The engine and engine installation shall be capable of running in any position during capsize and continue to run after the lifeboat returns to the upright or shall automatically stop on capsizing and be easily restarted after the lifeboat returns to the upright and the water has been drained from the lifeboat. The design of the fuel and lubricating systems shall prevent the loss of fuel and the loss of more than 250 ml of lubricating oil from the engine during capsize.

2.17.4 Air-cooled engines shall have a duct system to take in cooling air from, and exhaust it to, the outside of the lifeboat. Manually operated dampers shall be provided to enable cooling air to be taken in from, and exhausted to, the interior of the lifeboat.

2.17.5 The procedure of testing of propulsion engines for self-righting partially enclosed and totally enclosed lifeboats is stated in IMO Resolution MSC.81(70), chapters 6.10 and 6.14.

2.18 RESCCUE BOAT PROPULSION ENGINE

2.18.1 A rescue boat shall be fitted with an inboard engine or outboard motor. If it is fitted with an outboard motor, the rudder and tiller may form part of the engine. Notwithstanding the requirements of 2.16.1, petrol-driven outboard engines with an approved fuel system may be fitted in rescue boats provided the fuel tanks are specially protected against fire and explosion.

2.18.2 In case the rescue boat is fitted with an inboard internal combustion engine, this engine shall be a diesel engine.

2.18.3 The requirements specified in the regulation 2.16.2, 2.16.3, 2.16.4, 2.16.5, 2.16.6, 2.16.8, 2.16.9 and 2.16.15 apply also to the rescue boat inboard engines.

2.18.4 The procedure of testing of rescue boat propulsion engines is stated in IMO Resolution MSC.81(70), chapter 7.

2.19 LIFEBOAT ENGINE QUALITY CONTROL

2.19.1 Lifeboat engine shall be subjected to such production tests as are necessary to ensure that they are manufactured to the same standards as the type approved engine.

2.19.2 Manufacturers shall be required to initiate a quality control procedure to ensure that lifeboat engines are produced to the same standard as the prototype engine approved by the *Register*, and to keep records of any production tests carried out in accordance with the instructions of the *Register*.

2.20 TURBOCHARGERS

2.20.1 General

2.20.1.1 These requirements are applicable for turbochargers with regard to design approval, type testing and certification and their matching on engines.

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.

NOTES:

The requirements of this head, except for item 2.20.4, are to be uniformly implemented to turbochargers with the date of application for certification on or after 1 July 2024. Turbochargers with an existing type approval on 1 July 2024 are not required to be re-type approved in accordance with this head until the current Type Approval reaches its expiry date.

The requirements of item 2.20.4 are to be uniformly implemented to turbochargers with the date of application for certification of an individual turbocharger on or after 1 July 2024.

The "date of application for certification" is the date of whatever document the Register requires/accepts as an application or request for certification of a new turbocharger type or of a turbocharger type that has undergone substantive modifications in respect of the one previously type approved, or for renewal of an expired type approval certificate.

2.20.1.2 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).

2.20.1.3 Turbochargers are categorised 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.

2.20.2 Documentation to be submitted

2.20.2.1 For turbochargers of category A:

- Containment test report;
- Cross sectional drawing with principal dimensions and names of components;

- Test program.

2.20.2.2 For turbochargers of category B and C:

- Cross sectional drawing with principal dimensions and materials of housing components for containment evaluation;
- Documentation of containment in the event of disc fracture, see 2.20.3.2.

Operational data and limitations as:

- Maximum permissible operating speed (rpm);
- Alarm level for overspeed;
- 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;
- Arrangement of lubrication system, all variants within a range;
- Type test reports;
- Test program.

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 beyond the 110%.

2.20.2.3 For turbochargers of category C:

- 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 2.20.3.3 (*NOTE: Applicable to two sizes in a generic range of turbochargers*);
- Information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue;
- Operation and maintenance manuals (*NOTE: Applicable to two sizes in a generic range of turbochargers*).

2.20.3 Design requirements and corresponding type testing

2.20.3.1 General

2.20.3.1.1 The turbochargers shall be designed to operate under conditions stated in the *Rules for the classification of ships, Part 7 - Machinery Installations*, 1.6. The component lifetime and the alarm level for speed shall be based on 45°C air inlet temperature.

2.20.3.1.2 The air inlet of turbochargers shall be fitted with a filter.

2.20.3.2 Containment

2.20.3.2.1 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.

2.20.3.2.2 For turbochargers of 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: A generic range means a series of turbocharger which are of the same design, but scaled to each other.

2.20.3.2.3 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.

2.20.3.2.4 Containment tests shall be performed at working temperature a temperature which is not lower than the maximum allowable temperature of the turbocharger to be specified by the manufacturer.

2.20.3.2.5 Manufacturers are to determine whether cases more critical than those defined in item 2.20.3.2.3. and item 2.20.3.2.4 exist with respect to containment safety. Where such a case is identified, evidence of containment safety shall also be provided for that case.

2.20.3.2.6 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 highspeed 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. In general, totally new designs will call for a new reference containment test.

2.20.3.2.7 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.

- 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)

NOTE:
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.

2.20.3.3 Disc-shaft shrinkage fit

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 (*NOTE: Applicable to Category C*).

2.20.3.4 Type testing

2.20.3.4.1 Turbocharger type testing is applicable to Categories B and C.

2.20.3.4.2 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.

2.20.3.4.3 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, see 2.14.

2.20.3.4.4 The suitability of the turbocharger for such kind of operation is to be preliminarily stated by the manufacturer.

2.20.3.4.5 The rotor vibration characteristics shall be measured and recorded in order to identify possible sub-synchronous vibrations and resonances.

2.20.3.4.6 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 turbocharger shall be opened for examination, with focus on possible rubbing and the bearing conditions.

2.20.3.4.7 The extent of the surveyor's presence during the various parts of the type tests is left to the discretion of the *Register*.

2.20.4 Certification

2.20.4.1 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.

2.20.4.2 For category C, this shall be verified by means of periodic product audits of an Alternative Certification Scheme (ACS) by the *Register*.

2.20.4.3 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 overspeed test may be waived for forged wheels that are individually controlled by an approved non-destructive method.

2.20.4.4 Turbochargers shall be delivered with:

- For category C, a *Register* 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.

2.20.4.5 The same applies to replacement of rotating parts and casing.

2.20.4.6 Alternatively to the above periodic product audits, individual certification of a turbocharger and its parts may be made at the discretion of the *Register*. However, such individual certification of category C turbocharger and its parts shall also be based on test requirements specified in the above mentioned bullet points.

2.20.5 Alarms and Monitoring

2.20.5.1 For all turbochargers of Categories B and C, indications and alarms as listed in the table are required.

2.20.5.2 Indications may be provided at either local or remote locations.

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 inlet, pressure	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 turbo-charger(s) being activated last in the sequence, provided all turbochargers share the same intake air filter and they are not fitted with waste gates.*

3 STEAM TURBINES

3.1 GENERAL REQUIREMENTS

3.1.1 The main geared turbine set shall be capable of reversing from full speed ahead at the rated power to astern speed, and reversing in the opposite direction, by using back-steam.

3.1.2 The turbine sets intended for propulsion shall comply also with the requirements of the *Rules for the classification of ships, Part 7 - Machinery Installations*, 1.4.

In multi-screw ships with a fixed-pitch propeller a turbine set of each shaft shall be provided with an astern turbine.

3.1.3 Auxiliary turbines shall be started without pre-heating.

3.1.4 In single screw ships fitted with cross compound steam turbines, the arrangements shall 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 turbine and either the high pressure or medium pressure turbine can exhaust direct to the condenser. Adequate arrangements and controls shall be provided for these operating conditions so that the pressure and temperature of the steam will not exceed those which the turbines and condenser can safely withstand.

The necessary pipes and valves for these arrangements shall be readily available and properly marked. A fit up test of all combinations of pipes and valves shall be performed prior to the first sea trials.

The permissible power/speeds when operating without one of the turbines (all combinations) shall be specified and information provided on board.

The operation of the turbines under emergency conditions shall be assessed for the potential influence on shaft alignment and gear teeth loading conditions.

3.2 ROTOR

3.2.1 The strength of rotor parts shall be calculated for maximum power as well as for other possible loads at which stresses may rise to maximum values.

Moreover, a checking calculation of stresses shall be made for the rotor and parts thereof at a speed exceeding the maximum values by 20%.

3.2.2 The critical speed of the rotor shall be in excess of the rated speed corresponding to the rated power by not less than 20%. The critical speed of the rotor may be reduced provided there is an ample proof of the reliability of the turbine under all operating conditions..

3.2.3 Each new design of blading requires a calculation of vibration with subsequent verification of vibration characteristics by experiments.

3.2.4 The construction of blade tendon with detachable part of the disk side and other similar constructions which may cause considerable local loosening of the rim are not allowed.

3.2.5 Completely assembled turbine rotors shall be dynamically balanced in a machine of an appropriate sensitivity to the dimensions and weight of the rotor.

3.3 CASING

3.3.1 In cast steel and welded turbine casings it is permitted for some elements and branches for connecting receivers, piping, fittings and wires for the attachment of heat insulation, to be joined by welding before the final heat treatment.

3.3.2 The connection of the astern turbine steam inlet branch with the turbine casing shall not be rigid.

3.3.3 Gaskets between the flanges of horizontal and vertical joints of turbines shall not be used. Planes of the joints are allowed to be coated with graphite paste for the purpose of sealing.

3.3.4 The diaphragms fixed in the turbine casing shall have a possibility of radial thermal expansion within permissible misalignment.

3.3.5 The diaphragms shall be designed for a load corresponding to the maximum pressure drop in the stage. The actual deflection of the diaphragms shall be less than that which may cause touching of the disks or of the rotor shaft sealing.

3.3.6 The low pressure turbine casing shall be provided with openings for the inspection of blading in the last stages. The turbines with built-in condensers shall be provided with openings for the inspection of the upper rows of condenser tubes and, where possible, for access inside the condenser.

3.3.7 The turbine shall be so designed as to allow lifting bearing caps without dismantling the turbine casing, ends of sealing arrangements and pipelines.

3.4 BEARINGS

3.4.1 In main turbines sleeve bearings shall be used. For turbines designed for quick starting when in cold condition, it is recommended to use bearings with self-aligning shells.

3.4.2 Thrust bearings of the main turbines shall, as a rule, be of single-collar type. The use of bearings of other types shall be approved by the *Register*.

The bearings loaded with specific pressure of more than 2 N/mm² are recommended to be fitted with pivoted races or with devices for automatic equalisation of pressure exerted on the pads.

3.4.3 The thickness of antifriction lining of thrust bearing pads shall be less than the minimum axial clearance in the turbine blading, but not less than 1 mm.

3.5 SUCTION, GLAND - SEALING AND BLOWING SYSTEMS

3.5.1 The main turbine sets shall be provided with a steam suction and gland-sealing system, with automatic control of pressure of the sealing steam.

In addition to automatic control, provision shall also be made for manual control of the steam suction and gland-sealing system.

3.5.2 Each turbine shall have a blowing system to ensure complete removal of condensate from all stages and spaces of the turbine.

The blowing system shall be so arranged as to prevent the condensate from entering the turbines being at standstill.

3.6 CONTROL, SAFETY DEVICES AND GOVERNORS

3.6.1 Each main turbine set shall be provided with a manoeuvring gear designed for control and manoeuvring purposes. Manoeuvring valves for a turbine set of 7500 kW and over shall be power-driven. Emergency manual control of the valves shall be provided as well.

3.6.2 The time required for resetting the controls of the turbine set manoeuvring gear from full ahead to full astern or vice versa shall not be in excess of 15 s. The gear shall be so arranged as to prevent the simultaneous admission of steam to the ahead and astern turbine.

3.6.3 The main and auxiliary turbines shall be provided with an automatic safety device (quick-closing stop valve) automatically shutting off the admission of steam into the turbine when speed 15% over rated speed is reached.

Where two or more turbines are coupled to the same gear wheel set, the *Register* may agree that only one overspeed protective device shall be provided for all the turbines.

The quick-closing stop valve shall be actuated by the overspeed device directly connected with the turbine shaft. An oil actuator receiving impulse from an impeller directly driven by the turbine shaft may be used as an overspeed device.

In case of turbines with different pressure, each turbine shaft shall be fitted with an overspeed device.

The turbine sets intended for use in the plants incorporating reverse gear installations, controllable pitch propeller or other arrangements disengaging the turbine from the shafting shall be fitted, in addition to the overspeed device with a speed governor limiting the turbine speed when the load is changed before the overspeed device is put into operation.

Auxiliary turbines driving electric generators shall have both:

– a speed governor which, with fixed setting, shall control the speed within the limit of 10% for momentary variation and 5% permanent variation when the full load is suddenly taken off; and
– an overspeed protective device which shall be independently driven from speed governor, and shall prevent the design speed being exceeded by more than 15% when the full load is suddenly taken off.

3.6.4 Each turbine shall be fitted with a hand-operated device to shut off the steam in emergency by closing the quick-acting stop valve.

In case of the propulsion turbine set, this device shall be operated from two positions, one located on one of the turbines and the other in the control station.

In case of auxiliary turbine set this device shall be located adjacent to the overspeed device.

3.6.5 The steam pipeline between the manoeuvring gear and nozzle box shall be of the volume as small as practicable to eliminate impermissible overspeed of the turbine when the quick-closing valve is shut in emergency.

3.6.6 In turbine receiving steam from main pipelines, branch pipe shall be fitted with non-return stop valves to automatically close simultaneously with the quick- closing stop valve.

Where exhaust steam from auxiliary systems is led to the main turbines it shall be cut off in case of emergency operation of the quick - closing stop valve.

3.6.7 The propulsion turbine sets and turbines for driving electric generators in addition to the overspeed device shall be fitted with devices capable of automatically actuating the quick-closing stop valve and shutting off the admission of steam into the turbine in the following case:

.1 drop of the lubricating oil pressure in the system below the value specified by the manufacturer;
.2 rise of pressure or water level in the condenser above the value specified by the manufacturer;
.3 maximum shifting of rotor in any turbine incorporated in the propulsion turbine set.

All above mentioned devices are also recommended for turbines driving cargo pumps, as well as for turbines driving ballast pumps.

Shutting off the admission of steam to the ahead turbine because of dropping of the lubricating oil pressure, shall not cause interruption of the admission of steam to the astern turbine.

3.6.8 To prevent an inadmissible rise of the lubricating oil temperature in any of the propulsion turbine bearings, provision shall be made for an alarm signal system.

3.6.9 To provide a warning of excessive pressure to personnel in the vicinity of the exhaust end of steam turbines, a sentinel valve or equivalent shall be provided at the exhaust end of all turbines. The valve discharge outlets shall be visible and suitably guarded if necessary. When, for auxiliary turbines, the inlet steam pressure exceeds the pressure for which the exhaust casing and associated piping up to exhaust valve are designed, means to relieve the excess pressure shall be provided.

3.6.10 Efficient steam strainers shall be provided at steam inlets to manoeuvring valves or at steam inlets to ahead and astern high pressure turbines.

3.7 INSTRUMENTS

3.7.1 The main turbine set control stations shall be fitted with instruments for measuring the following:

.1 revolutions per minute of the turbine shaft and shafting;
.2 steam pressure and temperature after the manoeuvring valve, in the nozzle boxes of ahead and astern turbines, in the governing stage chamber, bleed mains and the suction and gland-sealing system;
.3 outlet lubricating oil temperature in each bearing (the use of remote temperature

indicators does not eliminate the necessity of fitting local thermometers);

.4 conditions of pre starting, reversing, stand-by keeping and bringing to prolonged inoperative state;

.5 lubricating oil pressure in the pressure pipeline after the oil cooler;

.6 vacuum in compliance with the *Rules for the classification of ships, Part 8 - Piping*, 14.4.

3.7.2 Apart from the instruments specified in 3.7.1, the propulsion turbine sets shall be provided with the following:

.1 instruments for checking lubricating oil supply to each bearing;

.2 indicators for determining the axial position of the rotor;

.3 regular devices for measuring the wear of white metal of shells and segments of each journal and thrust bearing;

.4 bridge gauges or other instruments for checking vertical and horizontal positions of each rotor;

.5 instruments for checking the steam pressure and temperature under emergency conditions with any turbine cylinder being shut off.

3.7.3 The auxiliary turbines for driving generators shall be fitted with instruments in compliance with 3.7.1.

3.7.4 The turbine set shall be fitted with the warning alarm means for the following parameters:

.1 drop of the lubricating oil pressure in the lubricating oil system;

.2 rise of the lubricating oil temperature at each bearing outlet;

.3 rise of the lubricating oil pressure at the turbine set inlet;

.4 rise of the pressure or water level in the condenser;

.5 axial shift of rotors;

.6 engagement of overspeed device;

.7 engagement of emergency stopping of the turbine.

4 GEARS, REVERSIBLE AND FLEXIBLE COUPLINGS

4.1 GENERAL REQUIREMENTS

4.1.1 The reverse-reduction gearing intended for propulsion shall also comply with the requirements of the *Rules for the classification of ships, Part 7 - Machinery Installations*, 1.4.

4.1.2 The parts rotating at speeds from 5 to 20 m/s shall be statically balanced, while those rotating at speeds over 20 m/s shall be subjected to dynamic balancing.

The accuracy of dynamic balancing shall be obtained from the formulae:

$$f = \frac{24000}{n} \quad \text{for } v > 300 \text{ m/s} \qquad (4.1.2.1)$$

$$f = \frac{63000}{n} \quad \text{for } v = 20 \text{ m/s} \qquad (4.1.2.2)$$

where:

v – distance between the centre of gravity and the geometrical axis of rotation of the part concerned, [μm];

n – rotational speed, [rps].

Intermediate values from 20 to 300 m/s shall be determined by linear interpolation.

Elements of couplings shall be balanced together with the parts they are rigidly adjoined to.

4.1.3 The design of the main gearing shall provide an easy access to all bearings. The gear cases shall have a sufficient number of sight openings with easily detachable covers for carrying out internal inspection. The sight openings shall be so arranged as to allow for inspection of the teeth over their full length and of the bearings inside the gearing. The application of this requirement to the planetary gearboxes is subject to special consideration by the *Register*.

4.1.4 The gear cases shall be provided with ventilating arrangements. The vent pipes shall be led to the upper weather deck or other positions where uptake is provided.

The ends of the vent pipes shall be fitted with flame-arresting devices and arranged so as to prevent water from getting into the gearing.

4.1.5 Where the main thrust bearing is housed in the gearing case, the lower part of the case shall have proper strengthening.

4.1.6 Each sleeve and thrust bearing shall be provided with a temperature measuring device.

4.2 GEARING

4.2.1 Definitions and general requirements

4.2.1.1 The following definitions apply in the present chapter (see also standard ISO 1122-1):

Gear – toothed member designed to transmit motion to, or receive motion from, another toothed member, by means of successively engaging teeth.

Gear pair – mechanism consisting of two gears able to rotate around axes relative positions of which are fixed and one gear turns the other by the action of teeth successively in contact.

Pinion – the gear of a gear pair which has the smaller number of teeth.

Wheel – the gear of a gear pair which has the larger number of teeth.

External gearing – a gear pair consisting of a pinion and a wheel, both with external toothing.

Internal gearing – a gear pair consisting of a pinion with external toothing and a wheel with internal toothing.

Planetary gear – combination of coaxial elements in which one or more are **annulus gears** (with internal toothing) and one or more are **planet carriers**. They turn around common axes and support one or more **planet gears** which mesh the annulus gears and one or more **sun gears**.

4.2.1.2 The requirements of this chapter are applicable to propulsion and auxiliary gearing with cylindrical pinions and wheels, external and internal toothing, having spur or helical teeth with involute profile, provided that the axes of the shafts are parallel.

4.2.1.3 Planetary gears shall be balanced. The rim of the epicyclical wheel with more than 3 planetary gears shall be self-adjustive in radial direction.

4.2.2 Pinions and gear wheels

4.2.2.1 The following calculation procedures are mainly based on the actual edition of ISO 6336 series international standards series for the calculation of load capacity of spur and helical gears.

These requirements apply to enclosed gears, both intended for main propulsion and for essential auxiliary services, which accumulate a large number of load cycles (several millions), whose gear set is intended to transmit a maximum continuous power equal to, or greater than:

- 220 kW for gears intended for main propulsion
- 110 kW for gears intended for essential auxiliary services

The following calculation procedures deal with the determination of load capacity of external and internal involute spur and helical gears, having parallel axis, with regard to surface durability (pitting) and tooth root bending strength and to this purpose the relevant basic equations are provided in 4.2.2.8 to 4.2.2.15.

All influence factors are defined regarding their physical interpretation. Some of the influence factors are determined by the gear geometry or have been established by conventions. These factors are to be calculated in accordance with the equations provided. Other factors, which are approximations, can be calculated according to methods acceptable to the *Register*.

The values in formulae which refer to pinions have an index 1, and the values referring to wheels have an index 2. This is valid both for outer and inner gear pairs.

4.2.2.2 The hardness of the pinion teeth material shall be at least 15% higher than that of the wheel teeth material. This requirement does not apply to gears with strengthened surface (carburated, nitrided, surface hardened, etc.).

4.2.2.3 The radius of curvature of tooth root fillets shall be at least 0,3m_n.

4.2.2.4 The strength of teeth and other parts of pinions and wheels shall be confirmed by calculation. The additional loads due to torsional vibrations, stormy weather, manoeuvres, towage, different loading of a ship, propeller resistance irregularity and its dependence on number of blades shall be taken into account.

4.2.2.5 In designing the propulsion gears for ships with ice strengthening, the requirements of 4.2.3.2 shall be taken into account.

4.2.2.6 Technical documentation of gearing, which shall be submitted to the *Register* for approval, shall contain the following data:

a – centre distance [mm] (for internal gearing: a <0);
a_d – sum of radii of reference circle [mm];
b – common facewidth of a gear pair at reference cylinder [mm];
b_1, b_2 – root face width of pinion, wheel [mm] (not to be taken higher than: $b+2m_n$);
d – reference diameter [mm];
d_1, d_2 – reference diameter of pinion, wheel [mm];
d_{a1}, d_{a2} – tip diameter of pinion, wheel [mm];
d_{b1}, d_{b2} – base diameter of pinion, wheel [mm];
d_{f1}, d_{f2} – root diameter of pinion, wheel [mm];
d_{w1}, d_{w2} – working diameter of pinion, wheel [mm];
F_t – nominal tangential load [N];
F_{bt} – nominal tangential load on base cylinder in the transverse section [N];
HV_1, HV_2 – Vickers hardness of tooth surface [HV];
h – tooth depth [mm];
h_{ao} – tooth root height factor of the tool (basic rack):
ISO recommendation: h_{ao} =1,25
DIN recommendation: 1,10≤ h_{ao} ≤1,30;
k – tip shortening factor,
m_n – normal module [mm];
m_t – transverse module [mm];
n_1, n_2 – rotational speed of pinion, wheel [rpm];
N_{pl} – number of satellites in planetary gears;
P – maximum continuous power transmitted by the gear set [kW];
Q – gearing quality i.e. grade of accuracy;
R_{m1}, R_{m2} – tensile strength of the material for pinion, wheel [N/mm²];
R_{eH1}, R_{eH2} – yield strength of the material for pinion, wheel [N/mm²];
R_{z1}, R_{z2} – average peak-to-valley surface roughness, [µm];
S_F – safety factor for tooth root stress.
S_H – safety factor for contact stress (pitting)
T_1, T_2 – torque in way of pinion, wheel [Nm];
u – gear ratio, $u=z_2/z_1$;
v – linear velocity at pitch diameter [m/s];
x_1, x_2 – addendum modification factor of pinion, wheel;
z_1, z_2 – number of teeth of pinion, wheel (for internal gearing: z_2 <0);
z_{n1}, z_{n2} – virtual number of teeth of pinion, wheel;
α_n – normal pressure angle at reference cylinder [°];
α_t – transverse pressure angle at reference cylinder [°];
α_{tw} – transverse pressure angle at working pitch cylinder [°];
β – helix angle at reference cylinder [°];
β_b – helix angle at base cylinder [°];
ν_{40} – kinematic viscosity of lubricating oil at 40°C [mm²/s];
ν_{50} – kinematic viscosity of lubricating oil at 50°C (if ν_{40} is unknown) [mm²/s];
φ – angle of twist, due to torsion, for the driving shaft at full load for dual tandem gears [°];
ρ_{ao} – tooth fillet radius factor of the tool (basic rack)
ISO recommendation: ρ_{ao} =0,38
DIN recommendation: 0,25≤ρ_{ao} ≤0,45;
σ_{FE} – bending endurance limit;
σ_{Hlim} – endurance limit for contact stress [N/mm²]
σ_{t1}, σ_{t2} – normal circumferential shrink fit stress (if a gear is connected to the shaft by a shrinkfit) [N/mm²];
ε_α – transverse contact ratio;
ε_β – overlap ratio;
ε_γ – total contact ratio.

Note 1: For internal gear pairs diameters d_2, d_{w2}, d_{a2}, d_{f2} and d_{b2} and gear ratio u are negative.

Note 2: The type of prime mover and of driven machinery shall be stated in the documentation.

4.2.2.7 Dimensions and geometrical values

Dimensions and geometrical values of cylindrical gear pairs are calculated in accordance with the following formulae:

$$\alpha_t = \text{arc } \tan\left(\frac{\tan\alpha_n}{\cos\beta}\right)$$

$$\beta_b = \text{arc } \tan(\tan\beta \cdot \cos\alpha_t)$$

$$m_t = m_n / \cos\beta$$

$$d_{1,2} = m_t \cdot z_{1,2}$$

$$d_{b1,2} = d_{1,2} \cdot \cos\alpha_t$$

$$a_d = (d_1 + d_2)/2$$

$$\alpha_{tw} = \text{arc } \cos\left(\frac{a_d}{a} \cdot \cos\alpha_t\right)$$

$$d_{w1} = 2a \cdot \frac{1}{1+u}$$

$$d_{w2} = 2a \cdot \frac{u}{1+u}$$

$$z_{n1,2} = \frac{z_{1,2}}{\cos\beta \cdot \cos^2\beta_b}$$

$$x_1 + x_2 = (z_1 + z_2) \cdot \frac{\tan\alpha_{tw} - \tan\alpha_t - (\alpha_{tw} - \alpha_t)\pi/180^o}{2 \cdot \tan\alpha_n}$$

$$\cos\alpha_{tw} = \frac{m_t(z_1 + z_2)}{2a} \cdot \cos\alpha_t$$

$$k = \frac{a - a_d}{m_n} - (x_1 + x_2)$$

$$d_{a1,2} = d_{1,2} + 2 \cdot (h_{ao} + k + x_{1,2}) \cdot m_n$$

$$\varepsilon_\alpha = \frac{\sqrt{d_{a1}^2 - d_{b1}^2} + \mathrm{sign}(z_2)\sqrt{d_{a2}^2 - d_{b2}^2} - 2a\sin\alpha_{tw}}{2m_t\pi\cos\alpha_t}$$

$$\varepsilon_\alpha = \frac{b\sin\beta}{m_n\pi}$$

$$\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta$$

If the transverse contact ratio $\varepsilon_\alpha \geq 2$, the gear pairs shall be specially considered by *Register*.

The tip diameters $d_{a1,2}$ may be in discordance with the calculated theoretical values, depending on the eventual interference and the least permissible tip clearance. They may be rounded up, when some slight changes in the value of tip clearance and transverse contact ratio ε_α may appear.

4.2.2.8 Nominal tangential load

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:

$$T_{1,2} = \frac{30 \cdot 10^3 P}{\pi \cdot n_{1,2}} \quad (4.2.2.8\text{-}1)$$

$$F_t = 2000 \cdot \frac{T_{1,2}}{d_{1,2}} \quad (4.2.2.8\text{-}2)$$

4.2.2.9 General influence factors

Application factor, K_A

Factor K_A accounts for additional dynamic loads from sources external to the gearing.

For gears designed for infinite life, factor K_A is defined as the ratio between the maximum repetitive cyclic torque applied to the gear set and the nominal rated torque.

The nominal rated torque is defined by the rated power and speed and is the torque used in the rating calculations.

The factor K_A mainly depends on:
- characteristics of driving and driven machines;
- ratio of masses;
- type of couplings;
- operating conditions (overspeeds, changes in propeller load conditions, etc.).

When operating near a critical speed of the drive system, a careful analysis of conditions must be made.

Factor K_A should be determined by measurements or by system analysis (e.g. from the calculation of torsional vibrations, taking into account the possible combinations of various working conditions, or on the basis of the measurement results on similar installations) acceptable to the *Register*. Where a value determined in such a way cannot be supplied, the following values can be taken.

a) Main propulsion:
   - diesel engine with hydraulic or electromagnetic slip coupling, K_A = 1,00
   - diesel engine with high elasticity coupling, K_A = 1,30
   - diesel engine with other couplings, K_A = 1,50

b) Auxiliary gears:
   - electric motor, K_A = 1,00
   - diesel engine with hydraulic or electromagnetic slip coupling, K_A = 1,00
   - diesel engine with high elasticity coupling, K_A = 1,20

   diesel engine with other couplings, K_A = 1,40

- In other cases value of K_A is determined in agreement with the *Register*.

NOTE: Where the vessel, on which the reduction gear is being used, is receiving an Ice Class notation according to the provisions of the *Rules for the classification of ships, Part 29 – Polar class ships and ice class ships*, the application factor or the nominal tangential force should be adjusted to reflect the ice load associated with the requested Ice Class, i.e. applying the design approach in *IACS Unified Requirement I3* when applicable (see also 4.2.3.2).

Load sharing factor, K_γ

Factor K_γ accounts for the unequal distribution of load in multiple-path transmissions (dual tandem, epicyclic, double helix, etc.):

K_γ is defined as the ratio between the maximum load through an actual path and the evenly shared load. The factor mainly depends on accuracy and flexibility of the branches.

The load sharing factor K_γ should be determined by measurements or by system analysis.

Where a value determined in such a way cannot be supplied, the following values can be considered for epicyclic gears with:
- 1 to 3 planetary gears, K_γ=1,00
- 4 planetary gears, K_γ=1,20
- 5 planetary gears, K_γ=1,30
- 6 planetary gears and over, K_γ=1,40

For dual tandem gears: K_γ= 1+0,2/φ

Internal dynamic factor, K_v

Factor K_v accounts for internally generated dynamic loads due to vibrations of pinion and wheel against each other.

This factor is defined as the ratio between the maximum load which dynamically acts on the tooth flanks and the maximum externally applied load ($F_t K_A K_\gamma$).

The factor K_v mainly depends on:

- transmission errors (depending on pitch and profile errors);
- masses of pinion and wheel;
- gear mesh stiffness variation as the gear teeth pass through the meshing cycle;
- transmitted load including application factor;
- pitch line velocity;
- dynamic unbalance of gears and shaft;
- shaft and bearing stiffnesses;
- damping characteristics of the gear system.

Hereafter presented method, as described in a) and b) below, for calculation of the factor K_v may be applied only to cases where all the following conditions are satisfied:

- running velocity in the subcritical range, i.e.:

$$\frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}} < 10 \text{ m/s}$$

- spur gears or helical gears with $\beta \le 30°$
- pinion with relatively low number of teeth, $z_1 < 50$
- solid disc wheels or heavy steel gear rim.

This method may be applied to all types of gears if:

$$\frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}} < 3 \text{ m/s}$$

as well as to helical gears where $\beta > 30°$.

For gears other than the above, reference is made to *Method B* outlined in the reference standard *ISO 6336-1:2019*.

a) For spur gears and for helical gears with overlap ratio $\varepsilon_\beta \ge 1$

$$K_v = 1 + \left(\frac{K_1}{K_A \frac{F_t}{b}} + K_2\right) \cdot \frac{v \cdot z_1}{100} K_3 \sqrt{\frac{u^2}{1+u^2}} \qquad (4.2.2.9\text{-}1)$$

In the formula above, if $K_A F_t/b$ is less than 100 N/mm, this value is assumed to be equal to 100 N/mm.

Factors K_1, and K_2 for spur gears (β =0°) and for helical gears (β>0°) are specified in the following Table.

Table 4.2.2.9-1

Factors K_1 and K_2 for internal dynamic factor K_v calculation

accuracy, Q[1)]	**3**	**4**	**5**	**6**	**7**	**8**
K_1 spur gears	2,1	3,9	7,5	14,9	26,8	39,1
K_1 helical gears	1,9	3,5	6,7	13,3	23,9	34,8
K_2 spur gears	0,0193					
K_2 helical gears	0,0087					

[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 should be used.

Factor K_3 is to be in accordance with the following:

If $\frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}} \le 0{,}2$ then $K_3 = 2{,}0$

If $\frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}} > 0{,}2$ then $K_3 = 2{,}071 - 0{,}357 \cdot \frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}}$

b) For helical gears with overlap ratio ε_β<1 the value K_v is determined by linear interpolation between values determined for spur gears ($K_{v\alpha}$) and helical gears ($K_{v\beta}$) in accordance with:

$$K_v = K_{v\alpha} - \varepsilon_\beta \left(K_{v\alpha} - K_{v\beta}\right) \qquad (4.2.2.9\text{-}2)$$

where:

$K_{v\alpha}$ – K_v value for spur gears (β =0°), in accordance with a);

$K_{v\beta}$ – K_v value for helical gears (β>0°), in accordance with a).

Face load distribution factors, $K_{H\beta}$ and $K_{F\beta}$

Factors $K_{H\beta}$ for contact stress and $K_{F\beta}$ for tooth root bending stress, accounts for the effects of non-uniform distribution of load across the face width.

Factor $K_{H\beta}$ is defined as follows:

$$K_{H\beta} = \frac{\text{max load per unit face width}}{\text{mean load per unit face width}}$$

$K_{F\beta}$ is defined as follows:

$$K_{F\beta} = \frac{\text{max bending stress at tooth root per unit face width}}{\text{mean bending stress at tooth root per unit face width}}$$

The mean bending stress at tooth root relates to the considered face width b_1 respectively b_2.

$K_{F\beta}$ can be expressed as a function of the factor $K_{H\beta}$.

The factors $K_{H\beta}$ and $K_{F\beta}$ mainly depend on:

- gear tooth manufacturing accuracy;
- errors in mounting due to bore errors;
- bearing clearances;
- wheel and pinion shaft alignment errors;
- elastic deflections of gear elements, shafts, bearings, housing and foundations which support the gear elements;
- thermal expansion and distortion due to operating temperature;
- compensating design elements (tooth crowning, end relief, etc.).

The face load distribution factors, $K_{H\beta}$ for contact stress, and $K_{F\beta}$ for tooth root bending stress, are to be determined according to the *Method C* outlined in the reference standard *ISO 6336-1:2019*.

Alternative methods acceptable to the *Register* may also be applied.

a) In case the hardest contact is at the end of the face width $K_{F\beta}$ is given by the following equations:

$$K_{F\beta} = K_{H\beta}^{N}$$

$$N = \frac{(b/h)^2}{1 + (b/h) + (b/h)^2}$$

where:

(b/h) – face width/tooth height ratio, the minimum of b_1/h_1 or b_2/h_2.

For double helical gears, the face width of only one helix is to be used.

When b/h<3 the value b/h=3 is to be used.

b) In case of gears where the ends of the face width are lightly loaded or unloaded (end relief or crowning):

$$K_{F\beta} = K_{H\beta}$$

Transverse load distribution factors, $K_{H\alpha}$ and $K_{F\alpha}$

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 factors $K_{H\alpha}$ *and* $K_{F\alpha}$ mainly depend on:

- total mesh stiffness;
- total tangential load F_t
- factors K_A, K_γ, K_v, $K_{H\beta}$
- base pitch error;
- tip relief;
- running-in allowances.

The transverse load distribution factors, $K_{H\alpha}$ for contact stress and $K_{F\alpha}$ for tooth root bending stress, are to be determined according to *Method B* outlined in the reference standard *ISO 6336-1:2019*.

4.2.2.10 Tooth root bending strength

The criterion for tooth root bending strength is the permissible limit of local tensile strength in the root fillet. The root stress σ_F and the permissible root stress σ_{FP} shall be calculated separately for the pinion and the wheel.

Both gears of a gear pair shall satisfy the following tooth root strength criterion:

$$\sigma_{F1,2} \le \sigma_{FP1,2} \quad (4.2.2.10)$$

where:

$\sigma_{F1,2}$ – tooth root bending stress for pinion, wheel [N/mm²] (see 4.2.2.12-1);

$\sigma_{FP1,2}$ – permissible tooth root stress [N/mm²] (see 4.2.2.13-1).

4.2.2.11 Surface durability (pitting)

Both gears of a gear pair shall satisfy the following surface durability criterion based on the Hertz pressure on the operating pitch circle or at the inner points of single pair contact:

$$\sigma_{H1,2} \le \sigma_{HP1,2} \quad (4.2.2.11)$$

where:

$\sigma_{H1,2}$ – Hertz contact stress for gear flank surface [N/mm²] (see 4.2.2.14-1);

$\sigma_{HP1,2}$ – permissible Hertz contact stress [N/mm²] (see 4.2.2.15-1).

4.2.2.12 Tooth root bending stress

Tooth root bending stress shall be calculated in accordance with the following:

$$\sigma_{F1,2} = \frac{F_t}{b\ m_n} \cdot Y \cdot K_F \ \text{[N/mm²]} \quad (4.2.2.12\text{-}1)$$

where:

F_t – nominal tangential load at reference cylinder (see 4.2.2.8-2) [N]

$$Y = Y_{Fa1,2} \cdot Y_{Sa1,2} \cdot Y_\varepsilon \cdot Y_\beta \quad (4.2.2.12\text{-}2)$$

$$K_F = K_A \cdot K_\gamma \cdot K_v \cdot K_{F\alpha} \cdot K_{F\beta} \quad (4.2.2.12\text{-}3)$$

The following formulae and definitions for the calculation of tooth root bending stress apply to gears having rim thickness greater than $3{,}5m_n$.

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*.

Tooth form factor, Y_F

This factor represents the influence on nominal bending stress of the tooth form with load applied at the outer point of single pair tooth contact. Y_F shall be determined separately for the pinion and the wheel.

In the case of helical gears, the form factors for gearing shall be determined in the normal section, i.e. for the virtual spur gear with virtual number of teeth Z_n.

The tooth form factor, Y_F, is to be calculated as follows:

$$Y_F = \frac{6 \frac{h_F}{m_n} \cos\alpha_{Fen}}{\left(\frac{s_{Fn}}{m_n}\right)^2 \cos\alpha_n} \quad (4.2.2.12\text{-}4)$$

where (see Figure 4.2.2.12-1):

h_F – bending moment arm for tooth root stress for application of load at the outer point of single tooth pair contact [mm];

α_{Fen} – pressure angle at the outer point of single tooth pair contact in the normal section [°];

s_{Fn} – tooth root normal chord in the critical section [mm].

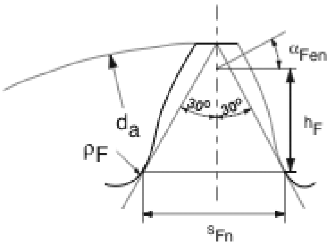


Fig. 4.2.2.12-1
Dimensions of h_F, s_{Fn} and α_{Fen} for external gear

For the calculation of h_F, s_{Fn} and α_{Fen}, the procedure outlined in the reference standard *ISO 6336-3:2019* is to be used.

Stress correction factor, Y_S

This factor is used to convert the nominal bending stress to the local tooth root stress, taking into account the stress concentration due to tooth root fillet and the fact that not only bending stresses arise at the root.

Y_S applies to the load application at the outer point of single tooth pair contact. Y_S shall be determined separately for the pinion and for the wheel.

The stress correction factor, Y_S, is to be determined with the following equation (having range of validity: $1 \le q_s \le 8$):

$$Y_S = (1.2 + 0.13L) q_s^{\left(\frac{1}{1.21+2.3/L}\right)} \quad (4.2.2.12\text{-}5)$$

where:

$$q_s = \frac{s_{Fn}}{2\rho_F} \quad (4.2.2.12\text{-}6)$$

$L =$ s_{Fn}/h_F

q_s– notch parameter

ρ_F – root fillet radius in the critical section [mm]

s_{Fn} – ditto as for factor Y_F

h_F – ditto as for factor Y_F

For the calculation of ρ_F the procedure outlined in the reference standard *ISO 6336-3:2019* is to be used.

Helix angle factor, Y_β

This factor converts the stress calculated for a point loaded cantilever beam representing the substitute gear tooth to the stress induced by a load along an oblique load line into a cantilever plate which represents a helical gear tooth.

The helix angle factor, Y_β is to be calculated as follows:

$$Y_\beta = 1 - \varepsilon_\beta \frac{\beta}{120} \quad (4.2.2.12\text{-}7)$$

The value 1,0 is substituted for ε_β when $\varepsilon_\beta > 1{,}0$ and 30° is substituted for $\beta > 30°$.

Rim thickness factor, Y_B

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:

$Y_B = 1$ for $s_R/h \ge 1.2$

$Y_B = 1{,}6 \cdot \ln\left(2{,}242 \frac{h}{s_R}\right)$ for $0{,}5 < s_R/h < 1{,}2$

where:

s_R – rim thickness of external gears [mm]

h – tooth height [mm]

The case $s_R/h \le 0{,}5$ is to be avoided.

b) for internal gears:

$Y_B = 1$ for $s_R/m_n \ge 3{,}5$

$Y_B = 1{,}15 \cdot \ln\left(8{,}324 \frac{m_n}{s_R}\right)$ for $1{,}75 < s_R/m_n < 3{,}5$

where:

s_R – rim thickness of internal gears [mm]

The case $s_R/m_n \le 1{,}75$ is to be avoided.

Deep tooth factor, Y_{DT}

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 $2{,}05 \le \varepsilon_{\alpha n} \le 2{,}5$, where:

$$\varepsilon_{\alpha n} = \frac{\varepsilon_\alpha}{\cos^2 \beta_b}$$

Factor Y_{DT} is to be determined as follows:

$Y_{DT} = 0{,}7$ for $Q \le 4$ and $\varepsilon_{\alpha n} > 2{,}5$

$Y_{DT} = 2{,}366 - 0{,}666 \cdot \varepsilon_{\alpha n}$ for $Q \le 4$ and $2{,}05 < \varepsilon_{\alpha n} \le 2{,}5$

$Y_{DT} = 1{,}0$ for all other cases

4.2.2.13 Permissible tooth root stress

Permissible tooth root stress σ_{FP} is determined from the formula:

$$\sigma_{FP1,2} = \frac{\sigma_{FE1,2} \cdot \mathrm{Y}_{d1,2} \cdot \mathrm{Y}_N}{S_F} Y_{\delta relT} \cdot Y_{RrelT1,2} \cdot Y_x \quad \text{[N/mm²]}$$

(4.2.2.13-1)

Safety factor for tooth root bending stress, S_F

Safety factor S_F can be assumed by the *Register* taking into account the type of application.

The following guidance values can be adopted:

a) For main propulsion gears:

$S_F = 1{,}55 \dots 2{,}00$

b) For auxiliary gears:

$S_F = 1{,}40 \dots 1{,}45$

For gearing of duplicated independent propulsion or auxiliary machinery, duplicated beyond that required for class, a reduced value can be assumed at the discretion of the *Register*.

Bending endurance limit, σ_{FE}

For a given material, σ_{FE} is the local tooth root stress which can be permanently endured.

According to the reference standard ISO 6336-5:2016 the number of $3 \cdot 10^6$ cycles is regarded as the beginning of the endurance limit.

σ_{FE} is defined as the unidirectional pulsating stress with a minimum stress of zero (disregarding residual stresses due to heat treatment). Other conditions such as alternating stress or prestressing, etc. are covered by the design factor Y_d.

The σ_{FE} values are to correspond to a failure probability 1% or less.

The endurance limit mainly depends on:

- material composition, cleanliness and defects;
- mechanical properties;
- residual stresses;
- hardening process, depth of hardened zone, hardness gradient;
- material structure (forged, rolled bar, cast).

The bending endurance limit, σ_{FE} is to be determined, in general, making reference to values indicated in the reference standard *ISO 6336-5:2016*, for material quality *MQ*.

Design factor, Y_d

This factor takes into account the influence of load reversing and shrink fit prestressing on the tooth root strength, relative to the tooth root strength with unidirectional load as defined for σ_{FE}.

The design factor, Y_d, for load reversing, is to be determined as follows:

Y_d=1,0 in general;

Y_d=0,9 for gears with occasional part load in reversed direction, such as main wheel in reversing gearboxes;

Y_d=0,7 for idler gears

Life factor, Y_N

This factor accounts for the higher tooth root bending stress permissible in case a limited life (number of cycles) is required.

The factor mainly depends on:

- material and heat treatment;
- number of load cycles (service life);
- influence factors $Y_{\delta relT}$,Y_{RrelT} and Y_X.

The life factor, Y_N, is to be determined according to *Method B* outlined in the reference standard *ISO 6336-3:2019*.

Relative notch sensitivity factor, $Y_{\delta relT}$

This factor indicates the extent to which the theoretically concentrated stress lies above the fatigue endurance limit. The factor mainly depends on material and relative stress gradient.

The relative notch sensitivity factor, $Y_{\delta relT}$, is to be determined as follows:

$$Y_{\delta relT} = \frac{1+\sqrt{0{,}2\rho'(1+2q_s)}}{1+\sqrt{1{,}2\rho'}}$$

where:

q_s – notch parameter (see clause 3.4)

ρ' – slip-layer thickness, mm, from the following table

Table 4.2.2.12-1
Slip-layer thickness

Material		ρ' [mm]
case hardened steels, flame or induction hardened 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 yield point R_e not stated above		

Relative surface factor, Y_{RrelT}

This factor takes into account the dependence of the root strength on the surface condition in the tooth root fillet, mainly the dependence on the peak to valley surface roughness.

The relative surface factor, Y_{RrelT} is to be determined from the following Table.

Table 4.2.2.12-2
Relative surface factor depending on the material and approximate height of surface roughness

$R_z < 1$	$1 \le R_z \le 40$	Gear material
1,120	$1{,}674 - 0{,}529(R_z+1)^{0{,}1}$	case hardened steels, through-hardened steels ($\sigma_B < 800$ N/mm^2)
1,070	$5{,}306 - 4{,}203(R_z+1)^{0{,}01}$	normalised steels ($\sigma_B < 800$ N/mm^2)
1,025	$4{,}299 - 3{,}259(R_z+1)^{0{,}00}$	nitrided steels

where:

R_z – mean peak-to-valley roughness of tooth root fillets [μm],

σ_B – tensile strength, [N/mm²]

The method applied here is only valid when scratches or similar defects deeper than $2R_z$ are not present.

If the roughness stated is an arithmetic mean roughness, i.e. R_a value (=*CLA* value) (=*AA* value) the following approximate relationship can be applied:

$$R_a = CLA = AA = R_Z/6$$

Size factor, Y_X

This factor takes into account the decrease of the strength with increasing size.

The factor mainly depends on:

- material and heat treatment;
- tooth and gear dimensions;
- ratio of case depth to tooth size.

The size factor, Y_X, is to be determined as follows:

a) generally:

$Y_x = 1{,}0$ for $m_n \leq 5$

b) normalised and through-hardened steels:

$Y_x = 1{,}03–0{,}006m_n$ for $5< m_n <30$

$Y_x = 0{,}85$ for $m_n \geq 30$

c) for surface hardened steels:

$Y_x = 1{,}05–0{,}01m_n$ for $5\leq m_n <25$

$Y_x = 0{,}80$ for $m_n \geq 25$

4.2.2.14 Hertz contact stress for gear flank surface

Hertz contact stress for gear flank surface σ_H at the operating pitch circle, or at the inner point of single pair contact is calculated from the formula:

$$\sigma_{H1,2} = Z\sqrt{\frac{F_1}{d_1 b}\,\frac{u+1}{u}\,K_H} \quad [\text{N/mm}^2] \qquad (4.2.2.14\text{-}1)$$

where:

$K_H = K_A \cdot K_\gamma \cdot K_v \cdot K_{H\alpha} \cdot K_{H\beta}$

$Z = Z_B \cdot Z_H \cdot Z_E \cdot Z_\varepsilon \cdot Z_\beta$ for pinion,

$Z = Z_B \cdot Z_H \cdot Z_E \cdot Z_\varepsilon \cdot Z_\beta$ for wheel.

Single pair tooth contact factors, Z_B and Z_D

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 factor Z_H.

The factors transform the contact stresses determined at the pitch point to contact stresses considering the flank curvature at the inner point of single pair contact. These factors, Z_B for pinions and Z_D for wheels, are to be determined as follows:

a) For spur gears (β=0°):

$Z_B = 1$ for $M_1 \leq 1$

$Z_B = M_1$ for $M_1 >1$

$Z_D = 1$ for $M_2 \leq 1$

$Z_D = M_2$ for $M_2 >1$

b) For helical gears (β>0°), on condition that ε_β<1:

$Z_B = M_1 - \varepsilon_\beta (M_1 - 1)$

If $Z_B > 1$ then $Z_B = 1$ shall be used further.

$Z_D = M_2 - \varepsilon_\beta (M_2 - 1)$

If $Z_D > 1$ then $Z_D = 1$ shall be used further.

c) For helical gears (β>0°), on condition that $\varepsilon_\beta \geq 1$:

$Z_B = 1$

$Z_D = 1$

In the above formulas M_1, M_2, M_{11}, M_{12}, M_{21} i M_{22} are determined as follows:

$$M_1 = \frac{\tan\alpha_{tw}}{\sqrt{M_{11}M_{12}}}$$

$$M_2 = \frac{\tan\alpha_{tw}}{\sqrt{M_{21}M_{22}}}$$

$$M_{11} = \sqrt{\left(d_{a1}/d_{b1}\right)^2 - 1} - \frac{2\pi}{z_1}$$

$$M_{12} = \sqrt{\left(d_{a2}/d_{b2}\right)^2 - 1} - \left(\varepsilon_\alpha - 1\right)\frac{2\pi}{z_2}$$

$$M_{21} = \sqrt{\left(d_{a1}/d_{b1}\right)^2 - 1} - \left(\varepsilon_\alpha - 1\right)\frac{2\pi}{z_1}$$

$$M_{22} = \sqrt{\left(d_{a2}/d_{b2}\right)^2 - 1} - \frac{2\pi}{z_2}$$

d) For internal gears, Z_D shall be taken as equal to 1.

Zone factor, Z_H

This factor accounts for the influence on the Hertzian pressure of tooth flank curvature at pitch point and transforms the tangential load at the reference cylinder to the normal load at the pitch cylinder. It is calculated as follows:

$$Z_H = \sqrt{\frac{2\cdot\cos\beta_b}{\cos^2\alpha_t\cdot\tan\alpha_{ttw}}}$$

Elasticity factor, Z_E

This factor accounts for the influence of the gear material properties expressed by Young's moduli E_1, E_2 and Poisson's ratios ν_1, ν_2 on the contact stress. It is calculated as follows:

$$Z_E = \frac{1}{\sqrt{\pi\left(\frac{1-\nu_1^2}{E_1}+\frac{1-\nu_2^2}{E_2}\right)}} \quad \left[\sqrt{\text{N/mm}^2}\right]$$

For steel gears with:

$E_1 = E_2 = 206\,000$ N/mm²

$\nu_1 = \nu_2 = 0{,}3$

the value of factor Z_E amounts to $189{,}8\sqrt{\text{N/mm}^2}$

.

Contact ratio factor, Z_ε

Factor Z_ε accounts for the influence of the transverse contact ratio ε_α and the overlap ratio ε_β on the specific surface load of gears. It is calculated as follows:

a) For spur gears (β=0°):

$$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}}$$

b) For helical gears (β>0°):

$$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}\cdot(1-\varepsilon_\beta)+\frac{\varepsilon_\beta}{\varepsilon_\alpha}} \qquad \text{for } \varepsilon_\beta<1$$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}} \qquad \text{for } \varepsilon_\beta \ge 1$$

Helix angle factor, Z_β

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. It is dependent only on the helix angle. It is calculated as follows:

$$Z_\beta = \sqrt{\frac{1}{\cos\beta}}$$

4.2.2.15 Permissible Hertz contact stress

Permissible Hertz contact stress σ_{HP} shall be evaluated according to formula:

$$\sigma_{HP1,2} = \frac{\sigma_{H\lim1,2}\cdot Z_{NT}}{S_{H\min}} \cdot Z_{L1,2}\cdot Z_{v1,2}\cdot Z_{R1,2}\cdot Z_w\cdot Z_{x1,2} \ [\text{N/mm}^2]$$

(4.2.2.15-1)

Safety factor for contact stress, S_H

Safety factor S_H can be assumed by the *Register* taking into account the type of application.

The following guidance values can be adopted:

a) For main propulsion gears:

S_H = 1,20 … 1,40

b) For auxiliary gears:

S_H = 1,15 … 1,20

For gearing of duplicated independent propulsion or auxiliary machinery, duplicated beyond that required for class, a reduced value can be assumed at the discretion of the *Register*.

Endurance limit for contact stress, σ_{Hlim}

For a given material, σ_{Hlim} is the limit of repeated contact stress which can be permanently endured. The value of σ_{Hlim} can be regarded as the level of contact stress which the material will endure without pitting for at least $5\cdot10^7$ load cycles.

For this purpose, pitting is defined by:

a) for not surface hardened gears:

pitted area > 2% of total active flank area

b) for surface hardened gears:

pitted area > 0,5% of total active flank area, or

pitted area > 4% of one particular tooth flank area.

The σ_{Hlim} values are to correspond to a failure probability of 1% or less.

The endurance limit mainly depends on:
- material composition, cleanliness and defects;
- mechanical properties;
- residual stresses;
- hardening process, depth of hardened zone, hardness gradient;
- material structure (forged, rolled bar, cast).

The endurance limit for contact stress σ_{Hlim}, is to be determined, in general, making reference to values indicated in the standard *ISO 6336-5:2016*, for material quality *MQ*.

Life factor, Z_N

This factor accounts for the higher permissible contact stress in case a limited life (number of cycles) is required.

The factor mainly depends on:
- material and heat treatment;
- number of cycles;
- influence factors Z_R, Z_v, Z_L, Z_W and Z_X.

The life factor Z_N is to be determined according to *Method B* outlined in the reference standard *ISO 6336-2:2019*.

Lubrication film influence on contact stress

Influence factors of lubrication film on contact stress Z_L, Z_v and Z_R may be determined for the softer material, where gear pairs are of different hardness.

The factors mainly depend on:
- viscosity of lubricant in the contact zone;
- the sum of the instantaneous velocities of the tooth surfaces;
- load;
- relative radius of curvature at the pitch point;
- surface roughness of teeth flanks;
- hardness of pinion and gear.

Lubricant factor, Z_L

This factor accounts for the influence of the type of lubricant and its viscosity. It is calculated as follows:

$$Z_L = C_{ZL} + \frac{4(1-C_{ZL})}{\left(1{,}2+\frac{134}{v_{40}}\right)^2}$$

In the range 850 N/mm^2 ≤ $\sigma_{H\lim}$ ≤ 1200 N/mm^2, C_{ZL} is to be calculated as follows:

$$C_{ZL} = \left(0{,}08\frac{\sigma_{H\lim}-850}{350}\right)+0{,}83$$

If σ_{Hlim}<850 N/mm^2, then take C_{ZL} = 0,83

If σ_{Hlim}>1200 N/mm^2, then take C_{ZL} = 0,91

where:

v_{40} – nominal kinematic viscosity of the oil at 40°C [mm^2/s]

Velocity factor, Z_v

This factor accounts for the influence of the pitch line velocity. It is calculated as follows:

$$Z_v = C_{ZV} + \frac{2(1-C_{ZV})}{\sqrt{0.8+\frac{32}{v}}}$$

In the range 850 N/mm^2 ≤ σ_{Hlim} ≤ 1200 N/mm^2, C_{ZV} is to be calculated as follows:

$$C_{ZV} = C_{ZL} + 0{,}02$$

Roughness factor, Z_R

This factor accounts for the influence of the surface roughness on the surface endurance capacity. It is calculated as follows:

$$Z_R = \left(\frac{3}{R_{z10}}\right)^{C_{ZR}}$$

where:

$$R_z = \frac{R_{z1} + R_{z2}}{2}$$

The peak-to-valley roughness determined for the pinion R_{z1} and for the wheel R_{z2} are mean values for the peak-to-valley roughness R_z measured on several tooth flanks (R_z as defined in the reference standard *ISO 6336-2:2019*).

$$R_{z10} = R_Z \sqrt[3]{\frac{10}{\rho_{red}}}$$

Relative radius of curvature:

$$\rho_{red} = \frac{\rho_1 \cdot \rho_2}{\rho_1 + \rho_2}$$

wherein:

$$\rho_{1,2} = 0.5 \cdot d_{b1,2} \cdot \tan \alpha_{tw}$$

(also for internal gears, d_b negative sign)

If the roughness stated is an arithmetic mean roughness, i.e. R_a value (=*CLA* value) (=*AA* value) the following approximate relationship can be applied:

$$R_a = CLA = AA = R_z / 6$$

C_{ZR} = 0,150 for σ_{Hlim} <850;

C_{ZR} = 0,32–0,0002·σ_{Hlim}, for 850≤ σ_{Hlim} ≤ 1200;

C_{ZR} = 0,080 for σ_{Hlim} >1200.

Hardness ratio factor, Z_W

This factor accounts for the increase of surface durability of a soft steel gear meshing with a significantly harder gear with a smooth surface in the following cases:

a) Surface-hardened pinion with through-hardened wheel

$$Z_W = 1{,}2 \cdot \left(\frac{3}{R_{zH}}\right)^{0{,}15} \quad \text{for } HB < 130$$

$$Z_W = \left(1{,}2 - \frac{HB - 130}{1700}\right) \cdot \left(\frac{3}{R_{zH}}\right)^{0{,}15} \quad \text{for } 130 \le HB \le 470$$

$$Z_W = \left(\frac{3}{R_{zH}}\right)^{0{,}15} \quad \text{for } HB > 470$$

where:

HB – Brinell hardness of the tooth flanks of the softer gear of the pair

R_{zH} – equivalent roughness [μm]

$$R_{zH} = \frac{R_{z1} \cdot (10/\rho_{red})^{0.33} \cdot (R_{z1}/R_{z2})^{0.66}}{(v \cdot \nu_{40}/1500)^{0.33}}$$

ρ_{red} – relative radius of curvature (the same as for factor Z_R)

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.

$$Z_W = 1$$

for $HB_1/HB_2 < 1{,}2$

$$Z_W = 1 + \left(0{,}00898 \frac{HB_1}{HB_2} - 0{,}00829\right) \cdot (u - 1)$$

for $1{,}2 \le HB_1/HB_2 \le 1{,}7$

$$Z_W = 1 + 0{,}00698 \cdot (u - 1) \quad \text{for } HB_1/HB_2 > 1{,}7$$

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.

Size factor, Z_X

This factor Z_X accounts for the influence of tooth dimensions on permissible contact stress and reflects the non-uniformity of material properties.

The factor mainly depends on:

- material and heat treatment;
- tooth and gear dimensions;
- ratio of case depth to tooth size;
- ratio of case depth to equivalent radius of curvature.

For through-hardened gears and for surface-hardened gears with adequate case depth relative to tooth size and radius of relative curvature Z_X=1. When the case depth is relatively shallow then a smaller value of Z_X should be chosen.

4.2.3 Shafts

4.2.3.1 The shaft diameter of a larger wheel is not to be less than 1,10 times the diameter of the intermediate shafts when the pinions are set at an angle of 120° or more and not less than 1,15 times the diameter of the intermediate shaft, in all other cases. The mechanical properties of material of the wheel shaft and intermediate shafts and their differences shall be taken into consideration.

4.2.3.2 Shafts, pinions and gear wheels of propulsion gears for ships strengthened for navigation in ice shall be designed for a torque exceeding the main engine designed torque, determined by means of the factor K_i (see the *Rules for the classification of ships, Part 7 - Machinery installation*, item 8.7.1).

The requirements of this item do not apply to the installations protected against torque overload.

4.2.4 Lubrication

4.2.4.1 The toothing and sleeve bearings of the main propulsion gears shall be provided with forced lubrication. The possibility of oil pressure governing shall be provided. Provision shall be made for a safety device excluding the oil pressure rise above the permissible value.

4.2.4.2 Lubricating oil shall be delivered to the toothing through sprayers. The sprayers shall provide the oil is fed in form of fanned-out compact jet with the adjacent jets being overlapped.

The sprayers shall be so arranged that, while running ahead or astern, the oil is captured in the toothing.

Oil supply to and withdrawal from the bearings and sprayers shall be so arranged that there is no oil foaming or emulsification.

A possibility of oil entraining by wheel or pinion of the largest diameter from the gear sump under the conditions mentioned in 1.5.1 shall be prevented.

4.3 REVERSIBLE AND FLEXIBLE COUPLINGS

4.3.1 General provisions

4.3.1.1 The requirements of this Chapter are applicable to main and auxiliary engine reversible and flexible couplings.

4.3.1.2 Materials of rigid parts of couplings shall comply with the requirements specified in the *Rules for the classification of ships, Part 7 - Machinery Installation*, 1.14.

4.3.1.3 Flanges and bolts shall comply with the requirements specified in the *Rules for the classification of ships, Part 7 - Machinery Installation*, 2.5. Keyless couplings shall comply with 2.8 of the above Rules.

4.3.1.4 Flexible and reversible couplings intended for the ships with ice strengthening shall comply with the requirements of 4.2.3.2.

4.3.1.5 Couplings for propulsion of single engine ships shall be of such design that in case of their failure, maintain navigation with a speed ensuring easy steering.

4.3.2 Flexible couplings

4.3.2.1 When the flexible couplings fitted with the elastic elements of rubber or suitable synthetic material do not comply with 4.3.1.5 scantlings of such elements shall be calculated at least on the basis of eight-fold design torque.

4.3.2.2 Additional stresses due to torsional vibrations shall be taken in calculation for couplings intended for main propulsion-plants, diesel-generator sets, as well as for drives with asynchronous electrical engines (see the *Rules for the classification of ships, Part 7 - Machinery Installation*, Section 4).

4.3.2.3 Flexible couplings for diesel-generator sets shall be capable to resist short circuit moments. When short circuit moment is unknown, maximum torque shall be calculated at least 4,5 design moment.

4.3.2.4 Loading of flexible couplings intended for main propulsion and for diesel-generator sets with design torque shall be possible at environment temperature of 5°C to 60°C.

4.3.3 Reversible couplings

4.3.3.1 Remote control means of reversible couplings of main propulsion plant shall be located in control stations of main engines. Provision shall be made for local control of couplings in case of emergency.

4.3.3.2 For the propulsion plant with two engines provision shall be made to preclude engaging of couplings simultaneously with the main engines running in opposite directions.

4.4 SHAFT LINE TURNING DEVICES

4.4.1 Mechanical shaft-turning gear shall have an interlocking system to preclude engaging of coupling with shaft-turning gear engaged. The devices shall comply with 2.11.1.4 and also with the *Rules for the classification of ships, Part 7 - Machinery Installation*, 1.7.5.

5 AUXILIARY MACHINERY

5.1 POWER-DRIVEN AIR COMPRESSORS

5.1.1 General requirements

5.1.1.1 The air inlets of compressors shall be fitted with strainers.

5.1.1.2 The compressors shall be so designed that the air temperature at the air cooler outlet is not in excess of 90°C.

5.1.1.3 The compressor cooling water spaces shall be fitted with drain arrangements.

5.1.2 Safety arrangements

5.1.2.1 Each compressor stage shall be fitted with a safety valve preventing the pressure rise in the stage above 1.1 of the rated pressure when the delivery pipe valve is closed.

The safety valve design shall prevent any possibility of its adjustment or disconnection after being fitted on the compressor.

5.1.2.2 The compressor crankcases of more than 0,5 m^3 in volume shall be fitted with safety valves meeting the requirements of 2.3.3.1.

5.1.2.3 On the delivery pipe immediately after the compressor a safety fuse or a signal device shall be fitted operating before the air temperature reaches 120°C.

5.1.2.4 The casings of the intermediate coolers shall be fitted with safety devices providing for a free escape of air in case the pipes are broken.

5.1.3 Crankshaft

5.1.3.1 The calculation method specified in 5.1.3.3 and 5.1.3.4 applies to the steel crankshafts of ship air compressors and refrigerant compressors with in line, V and W shaped arrangements of cylinders and with single-and multi-stage compression.

Cast iron crankshafts as well as departures from the dimensions of steel crankshafts calculated by 5.1.3.3 and 5.1.3.4 may be allowed only in agreement with the *Register*, provided the confirming calculations or test data are submitted.

5.1.3.2 The crankshafts shall be made of steel having a tensile strength from 410 to 780 N/mm².

The use of steel having a tensile strength over 780 N/mm² shall be, in each case, subject to special consideration by the *Register*.

Cast iron crankshafts may be manufactured only of the spheroid graphite cast iron of ferrite-perlite structure according to the *Rules for the classification of ships, Part 25 - Metallic materials*, Table3.13.3.3.

5.1.3.3 Crank pin diameter is not to be less than that determined by the formula:

$$d_k = 0{,}25 \cdot k_1 \cdot 3\sqrt{D_p^2 \cdot p_k \sqrt{0{,}3 \cdot L_p^2 f + s^2 \cdot \varphi_1^2}} \text{ [mm]} \quad (5.1.3.3)$$

where:

- D_p – the calculated diameter of the cylinder, [mm]:
  - = D_c – for single stage compression,
  - = D_v – for two-stage and multi-stage compression in separate cylinders,
  - = $1{,}4D_v$ – for two-stage compression by tandem pistons,
  - = $\sqrt{D_n^2 - D_v^2}$ – for two-stage compression by a differential piston;
- D_c – diameter of the cylinder, [mm];
- D_v – diameter of high pressure cylinder, [mm];
- D_n – diameter of low pressure cylinder, [mm];
- p_k – delivery pressure of high pressure cylinder for air compressors, [MPa]; for refrigerant compressors the value shall be taken in accordance with the *Rules for the classification of ships, Part 11 - Refrigerating installations*, Table 2.2.2
- L_p – calculated span between main bearings, [mm], equal to:
  - = L – when one crank is arranged between two main bearings;
  - = $1{,}1 \cdot L$ – when two cranks are arranged between two main bearings;
- L – actual span between centres of the main bearings, [mm];
- s – piston stroke, [mm];
- k_1, f, φ_1 – coefficients taken in accordance with Tables 5.1.3.3-1,5.1.3.3-2 and 5.1.3.3-3.

Table 5.1.3.3-1
Values of coefficient k_1

Tensile strength R_m [N/mm²]	390	490	590	690	780	900
k_1	1,43	1,35	1,28	1,23	1,2	1,18

Table 5.1.3.3-2
Values of coefficient f

Angle between the cylinder axes	0° (in line)	45°	60°	90°
f	1,0	2,9	1,96	1,21

Table 5.1.3.3-3
Values of coefficient φ_1

Number of cylinders	1	2	4	6	8
φ_l	1,0	1,1	1,2	1,3	1,4

5.1.3.4 Thickness of crank web shall not be less than determined by the formula

$$h_k = 0{,}105 \cdot k \cdot D_p \cdot \sqrt{\frac{(\psi_1\psi_2 + 0{,}4)\ p_k c_1 \cdot f_1}{b}} \quad \text{[mm]} \quad (5.1.3.4)$$

where:

$$k = a\ \sqrt[3]{\frac{R_m}{2R_m - 430}}$$

R_m – tensile strength of material, [N/mm^2]. In case of R_m>780 N/mm^2 the value of R_m=780 N/mm^2 shall be taken for calculation;

a = 0,9 – for shafts with all surface nitrated subjected to other type of hardening approved by the *Register*;

a = 0,95 – for shafts forged by closed die or continuous grain flow method;

a = 1,0 – for shafts not subjected to hardening;

ψ_1, ψ_2 – coefficients taken in accordance with Tables 5.1.3.4-1 and 5.1.3.4-2;

f_1 – coefficient taken in accordance with Table 5.1.3.4-3;

p_k – delivery pressure, [MPa], taken in accordance with 5.1.3.3;

c_1 – distance from the centre of the main bearing to mid-plane of the web, [mm]. For cranks arranged between two main bearings, the distance is taken to the mid-plane of the web most remote from the support,

b – web thickness, [mm].

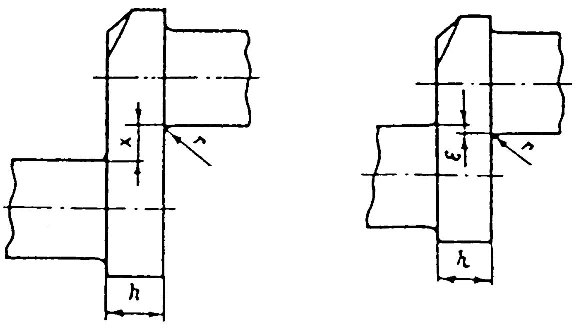


Fig 5.1.3.4

Table 5.1.3.4-1
Values of coefficient ψ_1

r/h	ε/h						
	0	0,2	0,4	0,6	0,8	1,0	1,2
0,07	4,5	4,5	4,28	4,1	3,70	3,30	2,75
0,10	3,5	3,5	3,34	3,18	2,88	2,57	2,18
0,15	2,9	2,9	2,82	2,65	2,40	2,07	1,83
0,20	2,5	2,5	2,41	2,32	2,06	1,79	1,61
0,25	2,3	2,3	2,20	2,10	1,90	1,70	1,40

Remarks:
r – fillet radius, [mm] (figure 5.1.3.4);
ε – absolute amount of overlapping [mm] (figure 5.1.3.4); for crankshafts having no overlapping x between journals and pins (figure 5.1.3.4) the values of coefficient ψ_1 shall be taken valid for ratio ε/h =0.

Table 5.1.3.4-2
Values of coefficient ψ_2

b/d	1,2	1,4	1,5	1,8	2,0	2,2
ψ_2	0,92	0,95	1,00	1,08	1,15	1,27

Remark:
Intermediate value shall be determined by linear interpolation.

Table 5.1.3.4-3
Values of coefficient f_1

Angle between the cylinder axes	0° (in line)	45°	60°	90°
f_1	1,0	1,7	1,4	1,1

5.1.3.5 Shaft designing and manufacturing shall comply with the requirements specified in 2.4.10 and 2.4.11.

5.1.4 Instruments

5.1.4.1 A pressure gauge shall be fitted after each stage of the compressor.

5.1.4.2 Provision shall be made to measure the air temperature at the delivery pipe immediately after the compressor.

5.1.4.3 The instrumentation of the attached compressors shall be subject to special consideration by the *Register* in each case.

5.2 PUMPS

5.2.1 General requirements

5.2.1.1 Provision shall be made to prevent the pumped fluid from penetration to the bearings. However, this does not apply to the pumps, where the pumped fluid is employed also for lubrication of bearings.

5.2.1.2 The pump glands arranged on the suction side are recommended to be fitted with hydraulic seals.

5.2.2 Safety devices

5.2.2.1 If the design of the pump does not preclude the possibility of pressurising above the rated value, a safety valve shall be fitted on the pump casing or on the pipe before first stop valve.

5.2.2.2 In pumps intended for transferring flammable liquids, the by-pass from safety valves shall be effected to the suction side of the pump.

5.2.2.3 Provision shall be made to prevent hydraulic impacts; the use of the by-pass valves for this purpose is not recommended.

5.2.3 Strength test

5.2.3.1 The critical speed of the pump rotor is not to be less than 1,3 of the rated rpm.

5.2.4 Self-priming pumps

5.2.4.1 The pumps provided with self-priming devices shall ensure operation under "dry suction" conditions and shall be fitted generally with arrangements preventing the self-priming device from operating with contaminated water.

5.2.4.2 The self-priming pumps shall have the place for connecting a vacuum-pressure gauge on their suction side.

5.2.5 Additional requirements for pumps that serve for transferring of flammable liquids

5.2.5.1 Shaft-sealing shall be so arranged that leakage occurred will not cause the formation of vapours and gases in such quantities as to create easily flammable mixture of air and gas.

5.2.5.2 The possibility of overheating and ignition in the sealing of rotating parts due to friction shall be excluded.

5.2.5.3 When material of low electrical conductivity (plastic material, rubber, etc.) are used in the pumps structure, provision shall be made for removal of electrostatic charges by means of the conductor situated in the material or by means of charge releasing device.

5.3 FANS AND AIR BLOWERS

5.3.1 General requirements

5.3.1.1 The requirements of this Chapter shall be complied with when designing and manufacturing fans intended to complete the systems specified in *Part 8. - Piping* as well as boiler fans.

5.3.1.2 The rotors of fans and air blowers shall be dynamically balanced together with couplings in compliance with 4.1.2.

5.3.1.3 The suction pipes of fans and air blowers shall be protected against entry of foreign materials.

5.3.1.4 The lubricating oil system of the turbocharger bearings shall be so arranged as to prevent the oil from getting into the supercharging air.

5.3.2 Strength test

5.3.2.1 The impellers shall be so dimensioned that at a speed equal to 1,3 of the rated one, reference stresses at any section are not in excess of 0,95 of yield strength of the material.

By gas turbine compressors another strength security may be allowed in accordance with the *Register*, if calculation including local concentration of stresses and plastic properties of material is applied.

5.3.3 Additional requirements for the pump rooms fans

5.3.3.1 The clearances between the fan casing and the rotating parts shall be such as to exclude any possibility of contact between the rotating parts and the casing even in the case of damage to the bearings. These clearances shall be not less than 0,1 bearings diameter and, in all cases, shall be not less than 2 mm and in general not more than 13 mm.

5.3.3.2 Protection screens of not more than 13 mm square mesh shall be fitted in the inlet and outlet ventilation openings on the open deck to prevent the entrance of objects into the fan housing.

5.3.3.3 To prevent electrostatic charges both in the rotating body and casing they shall be made of antistatic materials. Furthermore, the installation on board of the ventilation units shall be such as to ensure their safe bonding to the ship's hull according to requirements of the *Rules for the classification of ships, Part 12 - Electrical Equipment*.

5.3.3.4 The impeller and the housing (in way of the impeller) shall be made of materials which are recognised as being spark proof:

The following combinations of materials of impeller and housing are considered spark proof:

.1 non-metallic antistatic materials;
.2 non-ferrous-based alloys;
.3 austenitic stainless steel;
.4 impeller is made of aluminium alloy or magnesium alloy and housing is made of cast iron or steel (austenitic stainless steel

included), only if a ring of suitable thickness of non-ferrous materials is fitted inside the housing in way of impeller;

.5 any combination of cast iron and steel impellers and housings (including austenitic stainless steel), provided the tip clearance is not less than 13 mm.

Other combinations of materials of impellers and housings may also be permitted if they are recognised as non-sparking by appropriate tests.

5.3.3.5 The following combinations of materials of impeller and housing are not permitted:

.1 impellers made of aluminium alloy or magnesium alloy and housings made of ferrous-based alloys;

.2 impellers are made of ferrous-based alloys and housings are made of aluminium or magnesium alloys;

.3 impellers and housings are made of ferrous-based alloys with less than 13 mm tip clearance.

5.4 CENTRIFUGAL SEPARATORS

5.4.1 General requirements

5.4.1.1 The separator design shall preclude the leakage of oil products and their vapours thereof under any conditions of the separation.

5.4.1.2 The separator bowls shall be dynamically balanced. The position of the removable parts shall be marked. The design of the disc holder and bowl shall preclude the possibility of miss-assembly thereof.

5.4.1.3 Rotor-stator systems shall be so designed that the critical speed exceeds the operating speed both in empty and in filled condition.

The critical speed being less than the rated speed may be allowed only provided that proofs of continuous safe operation of the separator are submitted.

5.4.1.4 The design of couplings shall preclude the possibility of sparking and impermissible heating under all conditions of the separator operation and shall provide heat elimination from the friction surface.

5.4.2 Strength test

5.4.2.1 The separator rotating parts shall be calculated for strength under the stresses corresponding to 1,3 design rotational speed. In this case, the total stresses in the parts shall not exceed 0,95 of the yield strength of the element material.

5.4.2.2 The separators shall be tested at the manufacturer's test bench with the speed exceeding the operating speed by not less than 30%.

5.4.3 Instrumentation and protection

5.4.3.1 A device for the control over the separation process shall be provided.

5.4.3.2 It is advisable that the separators be provided with a device automatically shutting off the drive and stopping the separator when inadmissible vibration occurs.

6 DECK MACHINERY

6.1 GENERAL REQUIREMENTS

6.1.1 The brake straps and their fastening shall be resistant to sea water and oil products and to be heat-resistant at temperatures up to 250°C.

The permissible heat resistance of connections between the brake strap and the frame shall be such as to endure the temperatures which occur under all possible operating conditions of machinery.

6.1.2 The machinery having both manual and power drives shall be provided with interlocking arrangements preventing their simultaneous operation.

6.1.3 The deck machinery control arrangements shall be so made that heaving-in is performed when the handwheel is turned to the right or when the lever is shifted backwards while veering out is carried on when the handwheel is turned to the left or the lever is shifted forward. Locking of brakes shall be carried out by turning the handwheels to the right while releasing is effected by turning to the left.

6.1.4 The control devices as well as the instrumentation shall be so arranged as to provide the observation of them from the control place.

6.1.5 The machinery with the hydraulic drive or control shall additionally comply with the requirements of Section 7.

6.1.6 Winch drums having the multilayer rope winding with the ropes that can be subjected to the load in several layers shall have flanges protruding above the upper layer of winding by not less than 2,5 times the rope diameter.

6.1.7 Winches and drums of davits, cargo hoisting appliances, appliances for change of davit range, appliances for turning and mooring of cranes and lifts and other deck machinery, if fitted within hazardous zones 0,1 and 2 and if used during cleaning operations of spilled oil, shall be explosively protected and shall be provided with the Certificate on explosive protection, issued by competent organisation (for the definition of explosive zones, see the *Rules for the classification of ships, Part 12 - Electrical Equipment*, 2.9).

6.2 STEERING GEAR

In addition to the requirements contained in SOLAS II-1/29 and SOLAS II-1/30 as well as related Guidelines (see Annex 2 of IMCO document MSC XLV/4) the following requirements apply to new ocean-going vessels of 500 gross tonnage and upwards. These requirements may be applied to other vessels at the discretion of the Register.

6.2.1 General requirements and definitions

6. 6.2.1.1 For the purpose of these Rules, the following definitions and explanations have been adopted:

.1 **Main steering gear** is the machinery, rudder actuator(s), steering gear power units, if any, 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.

.2 **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 to the same purpose.

.3 **Steering gear power unit** is:
- .3.1 in case of electric steering gear an electric motor and its associated electrical equipment;
- .3.2 in case of electrohydraulic steering gear an electric motor and its associated equipment and connected pump;
- .3.3 in case of other hydraulic steering gear a driving engine and connected pump.

.4 **Steering gear control system** is the equipment by which orders are transmitted from the navigating 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”.

.5 **Power actuating system** means 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 to the same purpose.

.6 **Rudder actuator** means the component which converts directly hydraulic pressure into mechanical action to move the rudder.

.7 **Maximum ahead service speed** means the greatest speed which the ship is designed to maintain in service at sea at her deepest sea going draught.

.8 **Redundancy** is the ability of a component or system to maintain or restore its function when one failure has occurred. Redundancy can be achieved for instance by installation of more units or alternative means for performing a function.

9. **Maximum working pressure** means the maximum expected pressure in the system when the steering gear is operated under the operational conditions specified in 6.2.2.1.2.

.10 **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.

6.2.1.2 Unless expressly provided otherwise, every ship shall be provided with a main steering gear and an auxiliary steering gear to the satisfaction of these Rules. The main steering gear and the auxiliary steering gear shall be so arranged that the failure of one of them will not render the other one inoperative.

6.2.1.3 All the steering gear components and the rudder stock shall be of sound and reliable construction to the satisfaction of this part of the Rules. Special consideration shall be given to the suitability of any essential component which is not duplicated. Any such essential component shall, where appropriate, utilise antifriction bearings such as ball-bearings, roller-bearings or sleeve-bearings which shall be permanently lubricated or provided with lubrication fittings.

6.2.1.4 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 6.2.2.1.2, taking into account any pressure which may exist in the low-pressure side of the system. At the discretion of the *Register*, fatigue criteria shall be applied for the design of piping and components, taking into account pulsating pressures due to dynamic loads.

6.2.1.5 Relief valves shall be fitted to any part of the hydraulic systems 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.

6.2.1.6 The electrical power circuits and the steering gear control systems with their associated components, cables and pipes required by these Rules shall be separated as far as practicable throughout their length.

6.2.2 Characteristics and performance of steering gear

6.2.2.1 The main steering gear and rudder stock shall be:

.1 of adequate strength and capable of steering the ship at maximum ahead service speed which shall be demonstrated;

.2 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 28 seconds;
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;

.3 operated by power where necessary to meet the requirement of 6.2.2.1.2 and in any case when these Rules require a rudder stock of over 120 mm diameter in way of the tiller, excluding strengthening for navigation in ice; and

.4 so designed that they will not be damaged at maximum astern speed; however, this design requirement need not to be proved by trials at maximum astern speed and maximum rudder angle.

6.2.2.2 The auxiliary steering gear shall be:

.1 of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency;

.2 capable of putting the rudder over from 15° on one side to 15° on the other side in not more than 60 seconds 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

.3 operated by power where necessary to meet the requirements of .2 and in any case when the Rules require a rudder stock of over 230 mm diameter in way of the tiller, excluding strengthening for navigation in ice.

6.2.3 Steering gear power units

6.2.3.1 Main and auxiliary steering gear power units shall be:

.1 arranged to restart automatically when power is restored after a power failure; and
.2 capable of being brought into operation from a position on the navigating bridge. 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.

6.2.3.2 Where the main steering gear comprises two or more identical power units, an auxiliary steering gear need not to be fitted, provided that:

.1 in a passenger ship, the main steering gear is capable of operating the rudder as required by 6.2.2.1-.2 while any one of the power units is out of operation;
.2 in a cargo ship, the main steering gear is capable of operating the rudder as required by 6.2.2.1-.2 while operating with all power units;
.3 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 shall achieve standards equivalent to the requirements of 6.2.3.2.

6.2.3.3 Means for indicating that the motors of electric and electrohydraulic steering gear are running shall comply with requirements specified in the *Rules for the classification of ships, Part 12 - Electrical Equipment*, 5.5.11.4.

6.2.3.4 Supply of each electric or electrohydraulic steering gear comprising one or more power units shall comply with the requirements specified in the *Rules for the classification of ships, Part 12 - Electrical Equipment*, 5.5.2, and rating for supplying all motors shall comply with the requirements specified in the *Rules for the classification of ships, Part 12 - Electrical Equipment*, 5.5.3.

6.2.3.5 Short circuit protection and an overload alarm shall be provided for such circuits and motors. Protection against excess current, including starting current, if provided, shall be for not less than twice the full load current of the motor or circuit so protected, and shall be arranged to permit the passage of the appropriate starting currents. Where a three-phase supply is used an alarm shall be provided that will indicate failure of any one of the supply phases. The alarms required shall be both audible and visual and shall be situated in a conspicuous position in the main machinery space or control room from which the main machinery is normally controlled.

6.2.3.6 When in a ship of gross tonnage less than 1,600 an auxiliary steering gear, which is required by regulation 6.2.2.2.3 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. Where such an electric motor primarily intended for other services is arranged to power such and auxiliary steering gear, the requirement of 6.2.3.5 may be waived by the *Register* if satisfied with the protection arrangement together with the requirements of 6.2.3.1.1, 6.2.3.1.2 and 6.2.4.1.3 applicable to auxiliary steering gear.

6.2.3.7 Where the rudder stock is required to be over 230 mm diameter in way of the tiller, excluding strengthening for navigation in ice, an alternative power supply, sufficient at least to supply the steering gear power unit which complies with the requirements of 6.2.2.2.2 and also its associated control system and the rudder angle indicator, shall be provided automatically, within 45 sec, either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment. This independent source of power shall be used only for this purpose. In every ship of gross tonnage 10,000 and upwards, the alternative power supply shall have a capacity for at least 30 min of continuous operation and in any other ship for at least 10 min.

6.2.3.8 The steering gear power units shall permit a torque overload of at least 1,5 times the rated torque for a period of 1 min.

The steering gear electric motors shall comply with the requirements of the *Rules for the classification of ships, Part 12 - Electrical Equipment*, 5.5.

6.2.4 Steering gear control systems

Two independent steering gear control systems shall be provided and shall be so arranged that a mechanical or electrical failure in one of them will not render the other one inoperative.

The term “Steering control system” shall be understood to cover “the equipment required to control the steering gear *power actuating system*”.

6.2.4.1 Steering gear control shall be provided:
- .1 for the main steering gear, both on the navigating bridge and in the steering gear compartment;
- .2 where the main steering gear is arranged in accordance with 6.2.3.2, by two independent control systems, both operable from the navigating bridge. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system need not to be fitted, except in a tanker, chemical tanker or gas carrier of gross tonnage 10,000 and upwards;
- .3 for the auxiliary steering gear, in the steering gear compartment and, if power-operated, it shall also be operable from the navigating bridge and shall be independent of the control system for the main steering gear.

6.2.4.2 Any main and auxiliary steering gear control system operable from the navigating bridge shall comply with the following:
- .1 means shall be provided in the steering gear compartment for disconnecting any control system operable from the navigating bridge from the steering gear it serves;
- .2 the system shall be capable of being brought into operation from a position on the navigating bridge;
- .3 in the event of a failure of electrical power supply to the control system, an audible and visual alarm shall be given on the navigating bridge; and
- .4 short circuit protection only shall be provided for steering gear control supply circuits.

6.2.4.3 Hydraulic control components

Hydraulic system components in the power actuating or hydraulic servo systems controlling the power systems of the steering gear (e.g. solenoid valves, magnetic valves) are to be considered as part of the steering gear control system and shall be duplicated and separated.

Hydraulic system components in the steering gear control system that are part of a power unit may be regarded as being duplicated and separated when there are two or more separate power units provided and the piping to each power unit can be isolated.

6.2.5 Comunication between the navigating bridge and the steering geer compartment

6.2.5.1 A means of communication shall be provided between the navigating bridge and the steering gear compartment.

6.2.6 Angular position of the rudder

6.2.6.1 The angular position of the rudder shall:
- .1 if the main steering gear is power-operated, be indicated on the navigating bridge. The rudder angle indication shall be independent of the steering gear control system;
- .2 be recognisable in the steering gear compartment.

6.2.7 Hydraulic system

6.2.7.1 Hydraulic power-operated steering gear shall be provided with the following:
- .1 arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system;
- .2 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 navigating bridge and in the machinery space where they can be readily observed; and
- .3 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.

6.2.8 Steering gear compartment

6.2.8.1 The steering gear compartments shall be:
- .1 readily accessible and, as far as practicable, separated from machinery spaces; and
- .2 provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements shall include handrails and gratings or other nonslip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

6.2.9 Additional requirements for oil tankers, chemical tankers and gas carriers of gross tonnage 10.000 and upwards and for all other ships of gross tonnage 70.000 and upwards

6.2.9.1 In every tanker, chemical tanker or gas carrier of gross tonnage 10.000 and upwards and in every other ship of gross tonnage 70.000 and upwards, the main steering gear shall comprise two or more identical power units complying with the provisions of 6.2.3.2.

6.2.9.2 Every tanker, chemical tanker or gas carrier of gross tonnage 10.000 and upwards shall, subject to paragraph 6.2.9.3, comply with the following:

.1 the main steering gear shall be so arranged that in the event of loss of steering capability due to a single failure in any part of one of the power actuating systems of the main steering gear, excluding the tiller, quadrant or components serving the same purpose, or seizure of the rudder actuators, steering capability shall be regained in not more than 45 sec after the loss of one power actuating system;

.2 the main steering gear shall comprise either:

.2.1 two independent and separate power actuating systems, each capable of meeting the requirements of 6.2.2.1-.2; or

.2.2 at least two identical power actuating systems which, acting simultaneously in normal operation, shall be capable of meeting the requirements of 6.2.2.1-.2.

Where necessary to comply with this requirement, interconnection of hydraulic power actuating systems shall be provided. Loss of hydraulic fluid from one system shall be capable of being detected and the defective system automatically isolated so that the other actuating system or systems shall remain fully operational;

.3 steering gears other than of the hydraulic type shall achieve equivalent standards.

6.2.9.3 For tankers, chemical tankers or gas carriers of gross tonnage 10.000 and upwards, but of less than 100.000 tonnes deadweight, solutions other than those set out in 6.2.9.2, which need not apply the single failure criterion to the rudder actuator or actuators, may be permitted provided that an equivalent safety standard is achieved and that:

.1 following loss of steering capability due to a single failure of any part of the piping system or in one of the power units, steering capability shall be regained within 45 sec; and

.2 where the steering gear includes only a single rudder actuator, special consideration is given to stress analysis for the design including fatigue analysis and fracture mechanics analysis, as appropriate, to the material used, to the installation of sealing arrangements and to testing and inspection and to the provision of effective maintenance.

In consideration of the foregoing, the Register shall adopt regulations which include the provisions of the Guidelines for Acceptance of Non-Duplicated Rudder Actuators for Tankers, Chemical Tankers and Gas Carriers of Gross Tonnage 10.000 and above but less than 100.000 Tonnes Deadweight, adopted by the IMO, specified in 6.2.13.

6.2.9.4 Every tanker, chemical tanker or gas carrier of gross tonnage 10.000 and upwards shall comply with the following:

.1 the requirements of 6.2.4.1.1, 6.2.4.2.2, 6.2.4.2.4, 6.2.5.1, 6.2.6.1, 6.2.7.1.2, 6.2.7.1.3 and 6.2.8.1.2.

.2 two independent steering gear control systems shall be provided each of which can be operated from the navigating bridge. This does not require duplication of the steering wheel or steering lever;

.3 if the steering gear control system in operation fails, the second system shall be capable of being brought into immediate operation from the navigating bridge; and

6.2.9.5 In addition to the requirements of 6.2.9.4, in every tanker, chemical tanker or gas carrier of gross tonnage 40.000 and upwards, the steering gear shall be so arranged that, in the event of a single failure of the piping or of one of the power units, steering capability can be maintained or the rudder movement can be limited so that steering capability can be speedily regained. This shall be achieved by:

.1 an independent means of restraining the rudder; or

.2 fast-acting valves which may be manually operated to isolate the actuator or actuators from the external hydraulic piping together with a means of directly refilling the actuators by a fixed independent power-operated pump and piping system; or

.3 an arrangement such that, where hydraulic power systems are interconnected, loss of hydraulic fluid from one system shall be detected and the defective system isolated either automatically or from the navigating bridge so that the other system remains fully operational.

6.2.10 Contructional characteristies

6.2.10.1 Power piping arrangements

.1 The power piping for hydraulic steering gears shall be arranged so that transfer between units can be readily effected.

.2 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 shall be considered.

.3 For all vessels with non-duplicated actuators, isolating valves shall be fitted at the connection of pipes to the actuator, and shall be directly fitted on the actuator.

.4 Arrangements for bleeding air from the hydraulic system shall be provided where necessary.

.5 Piping, joints, valves, flanges and other fittings shall comply with *Register* requirements for Class I components. The design pressure shall be in accordance with 6.2.10.4.14

6.2.10.2 Rudder angle limiters

.1 Power-operated steering gears shall be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements shall be synchronised with the gear itself and not with the steering gear control.

6.2.10.3 Materials

.1 Ram cylinders; pressure housings of rotary vane type actuators; hydraulic power piping valves, flanges and fittings; and all steering gear components transmitting mechanical forces to the rudder stock (such as tillers, quadrants, of similar components) should be of steel or other approved ductile material, duly tested in accordance with the requirements of the *Register*. In general, such material shall not have an elongation of less than 12% nor a tensile strength in excess of 650 N/mm^2.
Grey cast iron may be accepted for redundant parts with low stress level, excluding cylinders, upon special consideration.

6.2.10.4 Design

.1 The construction shall be such as to minimise local concentrations of stress.

.2 The pumps of hydraulic steering engines shall be provided with protective devices preventing rotation of the inoperative pump in the opposite direction or with an automatic arrangement shutting out the flow of liquid through the inoperative pump

.3 The steering gear shall be fitted with a brake or some other device which provides keeping the rudder steady at any position on when the latter exerts a rated torque without allowing for the efficiency of the rudder stock bearings.

.4 Where the pistons or blades of the hydraulic steering gear can be locked by closing the oil pipeline valves, a special braking device may be omitted.

.5 The connection of the steering engine or gear with the elements rigidly coupled with the rudder stock shall eliminate the possibility of break-down on the steering gear when the rudder stock is shifted in the axial direction.

.6 Connection of the tiller hub or segment rack with the rudderstock shall be designed to transmit double rated torque stated in 6.2.2.1.2.
The height of the hubs of loose segment racks and auxiliary tillers is not to be less than 0,8 of the diameter of the rudder stock head.
The external diameter of the hub is not to be less than 1,6 times the rudder stock head diameter.
In case of press keyless fitted solid hub on the rudder stock the friction coefficient shall be taken no more than 0,13.

.7 The split hubs shall be fastened with at least two bolts on each side and have two keys. The keys shall be arranged at an angle of 90° to the split joints plane.

.8 Welds

.8.1 The welding details and welding procedures shall be approved.

.8.2 All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads shall be full penetration type or of equivalent strength.

.9 Oil seals

.9.1 Oil seals between non-moving parts, forming part of the external pressure boundary, shall be of the metal upon metal type or of an equivalent type.

.9.2 Oil seals between moving parts, forming part of the external pressure boundary, shall 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 at the discretion of the *Register*.

.10 All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, shall have a strength at least equivalent to that of the rudder stock in way of the tiller.

.11 For piping, joints, valves, flanges and other fittings see 6.2.10.1.5

.12 Rudder actuators other than those covered by 6.2.9.3 and relating Guidelines shall be designed in accordance with Class I pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

.13 In application according to 6.2.10.4.12 the permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_B}{A} \text{ or } \frac{\sigma_y}{B}$$

where:

σ_B – specified minimum tensile strength of material at ambient temperature, [N/mm²],

σ_y – specified minimum yield stress or 2 per cent proof stress of the material, at ambient temperature, [N/mm²].

The values of *A* and *B* are given in the Table 6.2.10.4.13

Table 6.2.10.4.13

Values of coefficients *A* and *B*

	Steel	Cast Steel	Nodular Cast Iron
A	3,5	4	5
B	1,7	2	3

.14 The design pressure shall be at least equal to the greater of the following:

.14.1 pressure of 1,25 times the maximum working pressure, to be achieved under the operating conditions required in 6.2.2.1.2,

.14.2 the relief valve setting pressure.

.15 Accumulators, if any shall comply with the *Register* requirements for pressure vessels.

6.2.10.5 Dynamic loads for fatigue and fracture mechanic analysis

The dynamic loading to be assumed in the fatigue and fracture mechanics analysis considering 6.2.1.4 and relating Guidelines, will be established at the discretion of the *Register*.

Both the case of high cycle and cumulative fatigue shall be considered.

6.2.10.6 Hoses

.1 Hose assemblies of type approved by the *Register* may be installed between two points where flexibility is required but shall not be subjected to torsional deflection (twisting) under normal operating conditions. In general, the hose shall be limited to the length necessary to provide for flexibility and for proper operation of machinery.

.2 Hoses shall be high pressure hydraulic hoses according to recognised standards and suitable for the fluids, pressures, temperatures and ambient conditions in question.

.3 Burst pressure of hoses shall not be less than four times the design pressure.

6.2.10.7 Relief valves

Relief valves for protecting any part of the hydraulic system which can be isolated, as required by 6.2.1.5 shall comply with the following:

.1 The setting pressure shall not be less than 1,25 times the maximum working pressure.

.2 The minimum discharge capacity of the relief valve(s) shall not 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 shall not exceed 10% of the setting pressure. In this regard, due consideration shall be given to extreme foreseen ambient conditions in respect of oil viscosity.

The *Register* may require, for the relief valves, discharge capacity tests and/or shock tests.

6.2.10.8 Electrical installations

.1 Electrical installations shall comply with the requirements of the Rules of the *Register*.

6.2.10.9 Alternative source of power

.1 Where the alternative power source required by 6.2.3.7 is a generator, or an engine driven pump, automatic starting arrangements shall comply with the requirements relating to the automatic starting arrangements of emergency generators.

6.2.10.10 Monitoring and alarm systems

.1 Monitoring and alarm systems, including the rudder angle indicators, shall be designed, built and tested to the satisfaction of the *Register*.

.2 Where hydraulic locking, caused by a single failure, may lead to loss of steering, an audible and visual alarm, which identifies the failed system, shall be provided on the navigating bridge.

NOTE:

This alarm shall be activated when e.g.:

– position of the variable displacement pump control system does not correspond with given order; or
– incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.

6.2.10.11 Operating instructions

Where applicable, the following standard signboard shall be fitted at a suitable place on steering control post on the bridge or incorporated into operating instruction on board:

"*CAUTION: In some circumstances when two power units are running simultaneously the rudder may not respond to helm. If this happens stop each pump in turn until control is regained.*"

The above signboard is related to steering gears provided with two identical power units intended for simultaneous operation, and normally provided with either their own control systems or two separate (partly or mutually) control systems.

Where applicable, following standard signboard should be fitted at a suitable place on steering control post on the bridge or incorporated into operating instruction on board.

6.2.10.12 Testing

.1 Testing for Class I pressure vessels shall comply with the requirement specified in the *Rules for the classification of ships, Part 10 - Boiler, Heat Exchangers and Pressure Vessels*, and *Part 8 - Piping*.

.2 A power unit pump shall be subjected to a type test. The type test shall be for a duration of not less than 100 hours, the test arrangements shall be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods shall be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another shall occur at least as quickly as on board. During the whole test no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the pump shall be disassembled and inspected. Type tests may be waived for a power unit which has been proven to be reliable in marine service.

.3 All components transmitting mechanical forces to the rudder stock shall be tested according to the requirements of the *Register*.

.4 After installation on board the vessel the steering gear shall be subjected to the required hydraulic and running tests.

6.2.10.13 Trials

The steering gear shall be tried out on the trial trip in order to demonstrate to the Surveyor's satisfaction that the requirements of the Rules have been met. The trial shall include the operation of the following:

.1 In order for ships to comply with the performance requirements stated in 6.2.2.1.2 and 6.2.2.2.2. they are to have steering gear capable of meeting these performance requirements when at their deepest seagoing draught. In order to demonstrate this ability, the trials may be conducted in accordance with Section 6.1.5.1 of ISO 19019:2005 Sea-going vessels and marine technology – Instructions for planning, carrying out and reporting sea trials. On all occasions when trials are conducted with the vessel not at the deepest seagoing draught the loading condition can be accepted on the conditions that either:

- the rudder is fully submerged (at zero speed waterline) and the vessel is in an acceptable trim condition
- the rudder torque at the trial loading condition have been reliably predicted (based on the system pressure measurement) and extrapolated to the maximum seagoing draught condition using the following method to predict the equivalent torque and actuator pressure at the deepest seagoing draught:

$$Q_F = Q_t \cdot \alpha$$

$$\alpha = 1{,}25 \cdot \left(\frac{A_F}{A_T}\right) \cdot \left(\frac{V_F}{V_T}\right)^2$$

Where:

α is the Extrapolation factor.

Q_F is the rudder stock moment for the deepest service draught and maximum service speed condition.

Q_T is the rudder stock moment for the trial condition.

A_F is the total immersed projected area of the movable part of the rudder in the deepest seagoing condition.

A_T is the total immersed projected area of the movable part of the rudder in the trial condition.

V_F is the contractual design speed of the vessel corresponding to the maximum continuous revolutions of the main engine at the deepest seagoing draught.

V_T is the measured speed of the vessel (considering current) in the trial condition.

Where the rudder actuator system pressure is shown to have a linear relationship to the rudder stock torque the above equation can be taken as:

$$P_F = P_t \cdot \alpha$$

Where:

P_F is the estimated steering actuator hydraulic pressure in the deepest seagoing draught condition.

P_T is the maximum measured actuator hydraulic pressure in the trial condition.

Where constant volume fixed displacement pumps are utilised then the regulations can be deemed satisfied if the estimated steering actuator hydraulic pressure at the deepest draught is less than the specified maximum working pressure of the rudder actuator. Where a variable delivery pump is utilised pump data should be supplied and interpreted to estimate the delivered flow rate corresponds to the deepest seagoing draught in order to calculate the steering time and allow it to be compared to the required time.

Where A_T is greater than $0.95A_F$ there is no need for extrapolation methods to be applied.

- Alternatively the designer or builder may use computational fluid dynamic (CFD) studies or experimental investigations to predict the rudder stock moment at the full sea going draught condition and service speed. These calculations or experimental investigations are to be to the satisfaction of the *Register*.

In any case for the main steering gear trial, the speed of the ship corresponding to the number of maximum continuous revolution of main engine and maximum design pitch applies

.2 the steering gear power units, including transfer between steering gear power units;

.3 the isolation of one power actuating system, checking the time for regaining steering capability;

.4 the hydraulic fluid recharging system;

.5 the emergency power supply required by 6.2.3.7;

.6 the steering gear controls, including transfer of control and local control;

.7 the means of communication between the wheelhouse, engine room, and the steering gear compartment;

.8 the alarms and indicators required by 6.2.3 and 6.2.10.10, these tests may be effected at dockside.

.9 where steering gear is designed to avoid hydraulic locking this feature shall be demonstrated.

6.2.11 Hand-operated steering gear

6.2.11.1 The main hand-operated steering gear shall be of self-breaking design.

The emergency hand operated steering gear shall be either of self-breaking design or to have a locking device provided that it is reliably controlled from the control station.

6.2.11.2 The main hand-operated steering gear shall meet the requirements of 6.2.2.1 when handled by one man with a force of not over 120 N applied to the steering wheel handles and with the number of revolutions not more than $9/R$ during shifting the rudder from hard over to hard over. (R – steering wheel radius, [m]).

6.2.11.3 The emergency hand-operated steering gear shall meet the requirements of 6.2.2.2 when handled by not more than four men with a force of not more than 160 N per helmsman applied to the steering wheel handles.

6.2.12 Lifeboats rudder

6.2.12.1 All lifeboats shall be provided with a rudder and tiller. When a wheel or other remote steering mechanism is also provided, the tiller shall be capable of controlling the rudder in case of failure of the steering mechanism. The rudder shall be permanently attached to the lifeboat. The tiller shall be permanently installed on, or linked to, the rudder stock; however, if the lifeboat has a remote steering mechanism, the tiller may be removable and securely stowed near the rudder stock. The rudder and tiller shall be so arranged as not to be damaged by operation of the release mechanism or the propeller.

6.2.13 Guidelines for acceptance of non-duplicated rudder actuators for tankers, chemical tankers and gas carriers of gros tonnage 10.000 and above but less than 100.000 tonnes deadweight

6.2.13.1 Materials

For materials see 6.2.10.3.

6.2.13.2 Design

Design pressure

.1 For design pressure see 6.2.10.4.14

Analysis

.2 The manufacturers of rudder actuators shall submit detailed calculations showing the suitability of the design for the intended service.

.3 A detailed stress analysis of the pressure retaining parts of the actuator shall be carried out to determine the stresses at the design pressure.

.4 Where considered necessary because of the design complexity or manufacturing procedures, a fatigue analysis and fracture mechanics analysis may be required. In connection with these analyses, all foreseen dynamic loads shall be taken into account. Experimental stress analysis may be required in addition to, or in lieu of, theoretical calculations depending on the complexity of the design.

Allowable stresses

.5 For the purpose of determining the general scantlings of parts of rudder actuators subject to internal hydraulic pressure the allowable stresses shall not exceed:

$$\sigma_{1m} \le f$$
$$\sigma_{1l} \le 1{,}5f$$
$$\sigma_b \le 1{,}5f$$
$$\sigma_{1l} + \sigma_b \le 1{,}5f$$
$$\sigma_{1m} + \sigma_b \le 1{,}5f$$

where:

σ_{1m} – equivalent primary general membrane stress, [N/mm²];

σ_{1l} – equivalent primary local membrane stress, [N/mm²];

σ_b – equivalent primary bending stress, [N/mm²];

f = $\min\left(\frac{\sigma_B}{A}, \frac{\sigma_y}{B}\right)$

σ_B – specified minimum tensile strength of material at ambient temperature, [N/mm²];

σ_y – specified minimum yield stress or 0,2 per cent proof stress of material at ambient temperature, [N/mm²].

A, B – given by the Table 6.2.13.2-5

Table 6.2.13.2-5
Values of coefficients A and B

	Steel	Cast steel	Nodular cast iron
A	4	4,6	5,8
B	2	2,3	3,5

Burst test

.6 Pressure retaining parts not requiring fatigue analysis and fracture mechanics analysis may be accepted on the basis of a certified burst test at the discretion of the *Register* and the detailed stress analysis required by 6.2.13.2.3 need not to be provided.

.7 The minimum bursting pressure shall be calculated as follows:

$$P_b = P \cdot A \, \frac{\sigma_{Ba}}{\sigma_B}$$

where;

P_b – minimum bursting pressure,

P – design pressure as defined in 6.2.13.2.1,

A – as from Table in 6.2.13.2-5,

σ_{Ba} – actual tensile strength,

σ_B – tensile strength as defined in 6.2.13.2.5.

6.2.13.3 Construction details

General

.1 For the construction see 6.2.10.4.1

Welds

.2 For the welding details and welding procedure see 6.2.10.4.8.1

.3 For the welded joints see 6.2.10.4.8.2

Oil seals

.4 For oil seals between non-moving parts see 6.2.10.4.9.1
.5 For oil seals between moving parts see 6.2.10.4.9.2

Isolating valves

.6 Isolating valves shall be fitted at the connection of pipes to the actuator, and shall be directly mounted on the actuator.

Relief valves

.7 For relief valves see 6.2.10.7.1
  .1 For setting pressure see 6.2.10.7.1.1
  .2 For minimum discharge capacity see 6.2.10.7.1.2

6.2.13.4 Non-destructive testing

The rudder actuator shall be subjected to suitable and complete non-destructive testing to detect both surface flaws and volumetric flaws. The procedure and acceptance criteria for non-destructive testing shall be in accordance with requirements of recognised standards. If found necessary, fracture mechanics analysis may be used for fracture determining maximum allowable flaw size.

6.2.13.5 Testing

.1 For tests of all pressure parts see 6.2.10.12.1.
.2 For running test see 6.2.10.12.4.

6.2.14 Arrangements for steering capability and function on ships fitted with propulsion and steering systems other than traditional arrangements for a ship's directional control

6.2.14.1 Application

The requirements of this item are applicable for ships fitted with alternative propulsion and steering arrangements, such as but not limited to, azimuthing propulsors or water jet propulsion systems.

6.2.14.2 The stopping times, ship headings and distances recorded on trials, together with the results of trials to determine the ability of ships having multiple propulsion/steering arrangements to navigate and manoeuvre with one or more of these devices inoperative, shall be available on board for the use of the master or designated personnel.

6.2.14.3 For a ship fitted with multiple steering propulsion units, such as but not limited to azimuthing propulsors or water jet propulsion systems each of the steering-propulsion units shall be provided with a main steering gear and an auxiliary steering gear or with two or more identical steering actuating systems in compliance with 6.2.14.7. The main steering gear and the auxiliary steering gear shall be so arranged that the failure of one of them will not render the other one inoperative.

For a ship fitted with a single steering-propulsion unit, the requirement in 6.2.1.2 is considered satisfied if the steering gear is provided with two or more steering actuating systems and is in compliance with 6.2.14.8. A detailed risk assessment is to be submitted in order to demonstrate that in the case of any single failure in the steering gear, control system and power supply the ship steering is maintained.

6.2.14.4 All components used in steering arrangements for ship directional control are to be of sound reliable construction to the satisfaction of the *Register*. Special consideration shall be given to the suitability of any essential component which is not duplicated. Any such essential component shall, where appropriate, utilize anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which shall be permanently lubricated or provided with lubrication fittings.

6.2.14.5 The main steering arrangements for ship directional control shall be:

.1 of adequate strength and capable of steering the ship at maximum ahead service speed which shall be demonstrated;
.2 capable of changing direction of the steering-propulsion unit from one side to the other at declared steering angle limits at an average turning speed of not less than 2.3°/s with the ship running ahead at maximum ahead service speed;
.3 for all ships, operated by power; and
.4 so designed that they will not be damaged at maximum astern speed; this design requirement need not be proved by trials at maximum astern speed and declared steering angle limits. Ship manoeuvrability tests, such as according to Resolution MSC.137(76) on Standards for ship manoeuvrability, are to be carried out with steering angles not exceeding the declared steering angle limits.

NOTE: **Declared steering angle limits** – limits are the operational limits in terms of maximum steering angle, or equivalent, according to manufacturers' guidelines for safe operation, also taking into account the ship's speed or propeller torque/speed or other limitation; the "declared steering angle limits" are to be declared by the directional control system manufacturer for each ship specific non-traditional steering mean; ship manoeuvrability tests, such as those in the Standards for ship manoeuvrability (resolution MSC.137(76)) are to be carried out with steering angles not exceeding the declared steering angle limits.

6.2.14.6 The auxiliary steering arrangements for ship directional control shall be:

.1 of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency;
.2 capable of changing direction of the ship's directional control system from one side to the other at declared steering angle limits at an average turning speed of not less than 0.5 °/s with the ship running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater; and
.3 for all ships, operated by power where necessary to meet the requirements of 6.2.2.2.2 and in any ship having power of more than

2,500 kW propulsion power per steering-propulsion unit.

Ship manoeuvrability tests, such as according to Resolution MSC.137(76), are to be carried out with steering angles not exceeding the declared steering angle limits.

NOTE: **Declared steering angle limits** – limits are the operational limits in terms of maximum steering angle, or equivalent, according to manufacturers' guidelines for safe operation, also taking into account the ship's speed or propeller torque/speed or other limitation; the "declared steering angle limits" are to be declared by the directional control system manufacturer for each ship specific non-traditional steering mean; ship manoeuvrability tests, such as those in the Standards for ship manoeuvrability (Resolution MSC.137(76)) are to be carried out with steering angles not exceeding the declared steering angle limits.

6.2.14.7 For a ship fitted with a single steering-propulsion unit where the main steering gear comprises two or more identical power units and two or more identical steering actuators, an auxiliary steering gear need not be fitted provided that the steering gear:

.1 in a passenger ship is capable of satisfying the requirements in 6.2.14.5 while any one of the power units is out of operation;

.2 in a cargo ship, is capable of satisfying the requirements in 6.2.14.5 while operating with all power units; and

.3 is arranged so that after a single failure in its piping system or in one of the power units' steering capability can be maintained or speedily regained.

6.2.14.8 For a ship fitted with multiple steering propulsion units, where each main steering system comprises two or more identical steering actuating systems, an auxiliary steering gear need not be fitted provided that each steering gear:

.1 in a passenger ship, is capable of satisfying the requirements in 6.2.14.5 while any one of the steering gear steering actuating systems is out of operation;

.2 in a cargo ship, is capable of satisfying the requirements in 6.2.14.5 while operating with all steering gear steering actuating systems;

.3 is arranged so that after a single failure in its piping or in one of the steering actuating systems, steering capability can be maintained or speedily regained the above capacity requirements apply regardless whether the steering systems are arranged with common or dedicated power units.

NOTE: **Steering gear power unit** – For the purposes of alternative steering arrangements, the steering gear power unit is to be considered as defined in SOLAS regulation II-1/3. For electric steering gears, refer to SOLAS regulation II-1/3; electric steering motors are to be considered as part of the power unit and actuator.

6.2.14.9 Where the propulsion power exceeds 2500 kW per thruster unit, an alternative power supply, sufficient at least to supply the steering arrangements which complies with the requirements of 6.2.2.2.-.2 and also its associated control system and the steering gear response indicator, shall be provided automatically, within 45 s, either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment. This independent source of power shall be used only for this purpose. In every ship of 10,000 gross tonnage and upwards, the alternative power supply shall have a capacity for at least 30 min of continuous operation and in any other ship for at least 10 min.

The above is also valid to the steering propulsion units having a certain proven steering capability due to ship speed also in case propulsion power has failed.

6.2.14.10 Each electric or electrohydraulic steering gear comprising one or more power units shall 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. An auxiliary electric or electrohydraulic steering gear associated with a main electric or electrohydraulic steering gear may be connected to one of the circuits supplying this main steering gear. The circuits supplying an electric or electro hydraulic steering gear shall have adequate rating for supplying all motors which can be simultaneously connected to them and may be required to operate simultaneously.

For a ship fitted with multiple steering systems, this requirements are to be applied to each of the steering systems.

6.2.14.11 For ships having multiple propulsion/steering arrangements to navigate and manoeuvre with one or more of these devices inoperative see the *Rules for the classification of ships, Part 7 - Machinery Installation*, item 1.4.3.

6.3 ANCHOR MACHINERY

6.3.1 General

6.3.1.1 Application

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.

6.3.1.2 Standards of Compliance

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.

The following are examples of standards 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 - Sea-going vessels - Windlasses and anchor capstans
- JIS F6714:1995 Windlasses

6.3.1.3 Plans and Particulars to be Submitted

The following plans showing the design specifications, the standard of compliance, engineering analyses and details of construction, as applicable, are to be submitted for evaluation:

.1 Windlass design specifications; anchor and chain cable particulars; anchorage depth; performance criteria; standard of compliance.

.2 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.

.3 Dimensions, materials, welding details, as applicable, of all torque-transmitting (shafts, gears, clutches, couplings, coupling bolts, etc.) and all load bearing (shaft bearings, cable lifter, sheaves, drums, bedframes, etc.) components of the windlass and of the winch, where applicable, including brakes, chain stopper (if fitted) and foundation.

.4 Hydraulic system, to include:
- piping diagram along with system design pressure,
- safety valves arrangement and settings,
- material specifications for pipes and equipment,
- typical pipe joints, as applicable, and
- technical data and details for hydraulic motors.

.5 Electric one line diagram along with cable specification and size; motor controller; protective device rating or setting, as applicable.

.6 Control, monitoring and instrumentation arrangements.

.7 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.

.8 Plans and data for windlass electric motors including associated gears rated 100 kW and over.

.9 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 6.3.4).

.10 Operation and maintenance procedures for the anchor windlass are to be incorporated in the vessel operations manual.

6.3.2. Materials and Fabrication

6.3.2.1 Materials

Materials used in the construction of torque-transmitting and load-bearing parts of windlasses are to comply with Rules of the *Register* 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.

6.3.2.2 Welded Fabrication

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 the class society. Welding consumables are to be approved by the class society in the case their type and grade fall within the scope of IACS UR W17 and UR W23; when their type and grade fall outside the scope of IACS UR W17 and UR W23, the welding consumables are to comply with the applicable Rules of acting class society, if any, 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.

6.3.3 Design

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.

6.3.3.1 Mechanical Design

.1 Design Loads

(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.

.2 Continuous Duty Pull; 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), Z_{cont1}, corresponding to the grade and diameter, d, of the chain cables as follows:

	Z_{cont1}

Grade of chain	*N*	*kgf*
1	*$37.5d^2$*	*$3.82d^2$*
2	*$42.5d^2$*	*$4.33d^2$*
3	*$47.5d^2$*	*$4.84d^2$*
Unit of d	*mm*	*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 Z_{cont2} is:

$Z_{cont2}[N] = Z_{cont1}[N] + (D – 82.5) \times 0.27d_2$

or

$Z_{cont2}[kgf] = Z_{cont1}[kgf] + (D – 82.5) \times 0.0275d_2$

Where D is the anchor depth, in metres.

The anchor masses are assumed to be the masses as given in the *Rules for the classification of ships, Part 3 – Hull equipment, 3.3*. Also, the value of Z_{cont} 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 Overload Capability; The windlass prime mover is to be able to provide the necessary temporary overload capacity for breaking out the anchor. This temporary overload capacity or "short term pull" is to be at least 1.5 times the continuous duty pull applied for at least 2 minutes. The speed in this period may be lower than normal.

.4 Hoisting Speed; The mean speed of the chain cable during hoisting of the anchor and cable is to be at least 9 m/min. 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 or 45 fathoms in length) and the anchor submerged and hanging free.

.5 Brake Capacity; 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.

.6 Chain Cable Stopper; 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.

.7 Support Structure; For hull supporting structures of windlass and chain cable stoppers, refer to the *Rules for the classification of ships, Part 3 – Hull equipment,* 3.5.8.

6.3.3.2 Hydraulic Systems

Hydraulic systems where employed for driving windlasses are to comply with the provisions of the requirements stated in the Section 7 of these Rules and in the *Rules for the classification of ships, Part 8 – Piping*, 14.

6.3.3.3 Electrical Systems

.1 Electric Motors; Electric motors are to meet the requirements of the *Register* 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 the *Register*. Where gears are fitted, they are to meet the requirements of the class society and those rated 100 kW and over are to be certified.

.2 Electrical Circuits; Motor branch circuits are to be protected in accordance with the provisions of the *Register* and cable sizing is to be in accordance with the requirements of the *Register*. Electrical cables installed in locations subjected to the sea are to be provided with effective mechanical protection.

6.3.3.4 Protection of Mechanical Components

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 over speed in the event of uncontrolled rendering of the cable, particularly when an axial piston type hydraulic motor forms the prime mover.

6.3.3.5 Couplings

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.

6.3.4 Shop Inspection and Testing

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 following tests, as a minimum.

.1 No-load test. 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.

.2 Load test. The windlass is to be tested to verify that the continuous duty pull, overload capacity and hoisting speed as specified in 6.3.3.1 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.

.3 Brake capacity test. The holding power of the brake is to be verified either through testing or by calculation.

6.3.5. On-board Tests

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. 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 6.3.3.1.4, 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 will be specially considered.

6.3.6 Marking

Windlass shall be permanently marked with the following information:

.1 Nominal size of the windlass (e.g. 100/3/45 is the size designation of a windlass for 100 mm diameter chain cable of IACS Grade 3, with a holding load of 45 % of the breaking load of the chain cable);

.2 Maximum anchorage depth, in metres.

6.3.7 Additional requirements

6.3.7.1 The anchor machinery intended for handling with mooring operations shall comply also with the requirements of 6.4.

6.3.7.2 If the provision is made for remote control of paying out the chain cable with the sprocket disconnected from the anchor machinery drive, a device shall be fitted ensuring an automatic braking by the band brake in order that the maximum speed of paying out will not exceed 180 m/min and the minimum speed will not be less than 80 m/min without regard to the initial acceleration. In ships with equipment number of 400 and less it is permissible not to install a device for an automatic braking by the band brake.

6.3.7.3 The chain sprocket brake shall provide for smooth stopping of the chain cable when paying it out for a period of not more than 5 s and not less than 2 s from the moment of initiation of the signal from the control station.

6.3.7.4 Provision shall be made at the remote control station for an indicator of the length of the chain cable paid out and the indicator of the paying out speed of the cable with the mark of 180 m/min of the maximum permissible speed.

6.3.7.5 Machinery and machinery elements for which the remote control is provided shall be manually operated form the local position. The failure of any element or the whole remote control system is not to affect adversely the normal operation of the anchor machinery and equipment manually operated from the local position (see also the *Rules for the classification of ships, Part 12 - Electrical Equipment*, 5).

6.3.7.6 The hand-operated drive shall provide for a heaving speed of at least 2,5 m/min with a pull F on the sprocket complying with 6.3.3.1, the force applied to the handle being not over 150 N per operator.

6.4 MOORING MACHINERY

6.4.1 Drive

6.4.1.1 The mooring machinery drive shall provide for an uninterrupted heaving-in of a mooring line at a rated pull with the rated speed for a period of not less than 30 min.

The speed of heaving-in a mooring line on the first rope winding layer on the drum shall not be less than:

- 0,25 m/s at the pull up to 80 kN;
- 0,20 m/s at the pull from 81 to 160 kN;
- 0,16 m/s at the pull from 161 to 250 kN;
- 0,13 m/s at the pull over 250 kN

The speed of heaving-in of a mooring line by the use of a warping drum both at the rated pull and without load shall not exceed 0,3 m/s.

6.4.1.2 The mooring machinery drive shall be capable to provide for force of at least 1,5 times the nominal force when winding up the first rope winding layer on the drum under nominal working conditions (see 6.4.1.1) for two minutes.

6.4.2 Overload protection

6.4.2.1 If the maximum torque of the drive may bring about a larger load on the mooring machinery elements than that specified in 6.4.4, an overload protection shall be provided.

6.4.3 Brakes

6.4.3.1 The mooring machinery shall be provided with an automatic normally closed brake. The brake shall ensure holding of an outside effort affecting the drum equal to 1,5 times the rated pull.

6.4.3.2 The mooring machinery drum shall be provided with a brake which should ensure keeping the mooring rope from unreeling at a pull in the line equal to 0,8 times the breaking load of the line on the first rope winding layer on the drum.

If the drum is fitted with another safety device it shall be capable of disengaging the drum when the mooring rope is under the load.

The force applied to the brake drive handle is not to exceed 740 N.

6.4.4 Strength test

6.4.4.1 The mooring machinery elements situated in lines of force flow shall be tested for strength under the rated pull on the mooring drum. In this case, the reference stresses in the elements shall not exceed 0,4 of the yield point of the element material

6.4.4.2 Elements of holding down bolts and fastening elements of mooring winches to the foundation shall be checked for stresses caused by the maximum torsional moment of prime mover when the drum is effected by one effort equal to breaking load of the mooring rope.

Besides, the strength of the warping drum shaft under the load applied in the middle of his length, equal to the breaking force of the mooring rope shall be checked.

In all cases, the stress in the elements shall not exceed 0,95 of the yield point of the element material.

The strength of the elements shall allow for all possible directions of loads that may arise during operation.

The strength of the mooring rope shall be indicated on the machinery.

6.4.5 Automatic mooring winches

6.4.5.1 The performance and durability of the automatic mooring winches are not to be inferior to the similar-purpose non-automatic machinery.

6.4.5.2 Automatic winches shall be equipped with the manual control to provide the possibility of non-automatic operation.

6.4.5.3 The following shall be provided:

- sound warning alarm operating with the maximum permissible length of the mooring rope veered out;
- an indicator of the actual pull in the mooring rope under the automatic operation.

6.5 TOWING WINCHES

6.5.1 Where automatic devices are used for governing the tension of the towline, provision shall be made to enable checking the value of tension at every moment. The tension indicators shall be installed at the towing winch and on the bridge.

6.5.2 Sound warning alarm operating when the maximum permissible length of the towline is veered out shall be provided.

6.5.3 The drums of the towing winches shall comply with the requirements of 6.1.6 and shall be provided with fairleads.

If two or more drums are provided, the fairleads shall be independent. Rope drum shall be fitted with a coupling to ensure its disconnection from the driving machinery.

Geometrical dimensions of the winch heads shall provide the possibility for paying out of the towline.

6.5.4 The design of the winch shall provide for quick releasing of the drum in order to ensure free paying-out of the towing line.

6.5.5 Brakes

.1 The towing winches shall be provided with an automatic brake ensuring holding of a line at a pull equal to at least 1,25 times the rated one when the driving energy disappears or is switched off.

.2 The rope drum of the winch shall be provided with the brake capable of holding the drum, when the effort in the rope is not less than the breaking load of the towline without slipping and when the drum is disconnected from the drive. The drum brake controlled by any type of energy shall be provided with manual control as well.
The brake design shall ensure the possibility of quick releasing for the purpose of loosening of the towline.

6.5.6 The towing winch elements situated in lines of force flow shall be checked for strength under the rated rope pull applied to the middle layer of winding. The reference stresses in the elements shall not exceed 0,4 of the yield point of the element material in this case.

6.5.7 The elements shall be checked for strength when the drum is affected by efforts corresponding to the maximum torque of the drive, as well as when the drum is affected by an effort equal to the towline breaking force on the upper layer of winding. The reference stresses in elements which may be subjected to efforts caused by the above-mentioned loads shall not exceed 0,95 of the yield point of the element material.

6.5.8 Towing winch emergency release systems

6.5.8.1 This requirements defines minimum safety standards for winch emergency release systems provided on towing winches that are used on towing ships within close quarters, ports or terminals, including those ships normally not intended for towing operation in transverse direction. This requirements is not intended to cover towing winches on board ships used solely for long distance ocean towage, anchor handling or similar offshore activities.

The purpose of this requirement is to provide requirements to prevent the capsize of a tug when in the act of towage as a result of the towline force acting transversely to the tug (in beam direction) as a consequence of an unexpected event (could be loss of propulsion/steering or otherwise), whereby the resulting couple generated by offset and opposing transverse forces (towline force is opposed by thrust or hull resistance force) causes the tug to heel and, ultimately, to capsize. This capsize may be referred to as “girting”, “girthing”, “girding” or “tripping”. See Figure 6.5.8.1a which shows the forces acting during towage operations.

‘**Emergency release system**’ refers to the mechanism and associated control arrangements that are used to release the load on the towline in a controlled manner under both normal and black out conditions.

‘Maximum design load’ is the maximum load that can be held by the winch as defined by the manufacturer (the manufacturer’s rating).

‘Fleet angle’ is the angle between the applied load (towline force) and the towline as it is wound onto the winch drum, see Figure 6.5.8.1b.

6.5.8.2 General requirements

The in-board end of the towline is to be attached to the winch drum with a weak link or similar arrangement that is designed to release the towline at low load.

All towing winches are to be fitted with an emergency release system.

6.5.8.3 Emergency release system performance requirements

The emergency release system is to operate across the full range of towline load, fleet angle and ship heel angle under all normal and reasonably foreseeable abnormal conditions (these may include, but are not limited to, the following: vessel electrical failure, variable towline load (for example due to heavy weather), etc.).

The emergency release system shall be capable of operating with towline loads up to at least 100 per cent of the maximum design load.

The emergency release system is to function as quickly as is reasonably practicable and within a maximum of three seconds after activation.

The emergency release system is to allow the winch drum to rotate and the towline to pay out in a controlled manner such that, when the emergency release system is activated, there is sufficient resistance to rotation to avoid uncontrolled unwinding of the towline from the drum. Spinning (free, uncontrolled rotation) of the winch drum is to be avoided, as this could cause the towline to get stuck and disable the release function of the winch.

Once the emergency release is activated, the towline load required to rotate the winch drum is to be no greater than:

- the lesser of five tonnes or five per cent of the maximum design load when two layers of towline are on the drum, or
- 15 per cent of the maximum design load where it is demonstrated that this resistance to rotation does not exceed 25 per cent of the force that will result in listing sufficient for the immersion of the lowest unprotected opening.

Emergency release of the towline is to be possible in the event of a blackout. For this purpose, where additional sources of energy are required, such sources are to be sufficient to achieve the most onerous of the following conditions (as applicable):

- sufficient for at least three attempts to release the towline (i.e. three activations of the emergency release system). Where the system provides energy for more than one winch it is to be sufficient for three activations of the most demanding winch connected to it.
- Where the winch design is such that the drum release mechanism requires continuous application of power (e.g. where the brake is applied by spring tension and released using hydraulic or pneumatic power), sufficient power is to be provided to operate the emergency release system (e.g. hold the brake open and allow release of the towline) in the event of a blackout for a minimum of five minutes. This may be reduced to the time required for the full length of the towline to feed off the winch drum at the load specified above if this is less than five minutes.

6.5.8.4 Emergency release system operational requirements

Emergency release operation must be possible from the bridge and from the winch control station on deck. The winch control station on deck is to be in a safe location. A position in close proximity to the winch is not regarded as "safe location", unless it is documented that the position is at least protected against towline break or winch failure.

The emergency release control is to be located close to an emergency stop button for winch operation, if provided, and shall be clearly identifiable, clearly visible, easily accessible and positioned to allow safe operability.

The emergency release function is to take priority over any emergency stop function. Activation of the winch emergency stop from any location is not to inhibit operation of the emergency release system from any location.

Emergency release system control buttons are to require positive action to cancel, the positive action may be made at a different control position from the one where the emergency release was activated. It must always be possible to cancel the emergency release from the bridge regardless of the activation location and without manual intervention on the working deck.

Controls for emergency use are to be protected against accidental use.

Indications are to be provided on the bridge for all power supply and/or pressure levels related to the normal operation of the emergency release system. Alarms are to activate automatically if any level falls outside of the limits within which the emergency release system is fully operational.

Wherever practicable, control of the emergency release system is to be provided by a hard-wired system, fully independent of programmable electronic systems.

Computer based systems that operate or may affect the control of emergency release systems are to meet the requirements for Category III systems of IACS UR E22.

Components critical for the safe operation of the emergency release system are to be identified by the manufacturer.

6.5.8.4 Emergency release system test requirements

All testing defined within item 6.5.8.4 is to be witnessed by the Surveyor of the *Register*.

For each emergency release system or type thereof, the performance requirements of 6.5.8.3 are to be verified either at the manufacturer's works or as part of the commissioning of the towing winch when it is installed on board. Where verification solely through testing is impracticable (e.g. due to health and safety), testing may be combined with inspection, analysis or demonstration in agreement with the *Register*.

The performance capabilities, as well as instructions for operation, of the emergency release system are to be documented by the manufacturer and made available on board the ship on which the winch has been installed.

Instructions for surveys of the emergency release system are to be documented by the manufacturer, agreed by the *Register* and made available on board the ship on which the winch has been installed.

Where necessary for conducting the annual and special surveys of the winch, adequately sized strong points are to be provided on deck.

6.5.8.5 Installation trials

The full functionality of the emergency release system is to be tested as part of the shipboard commissioning trials to the satisfaction of the surveyor. Testing may be conducted either during a bollard pull test or by applying the towline load against a strong point on the deck of the tug that is certified to the appropriate load.

Where the performance of the winch in accordance with Section 3.1 has previously been verified, the load applied for the installation trials is to be at least the lesser of 30% of the maximum design load or 80% of vessel bollard pull.

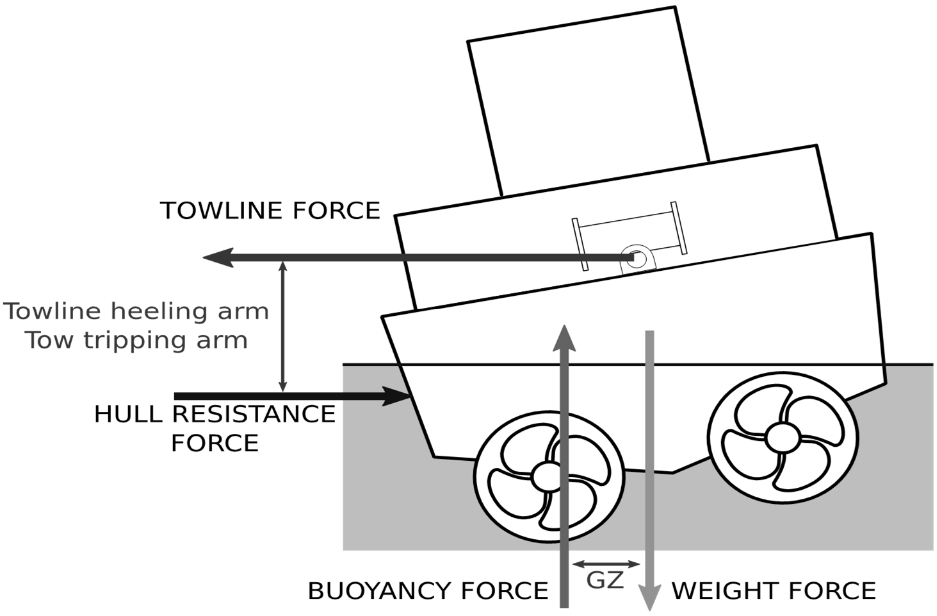


Fig. 2.4.4.1a
Forces during towing

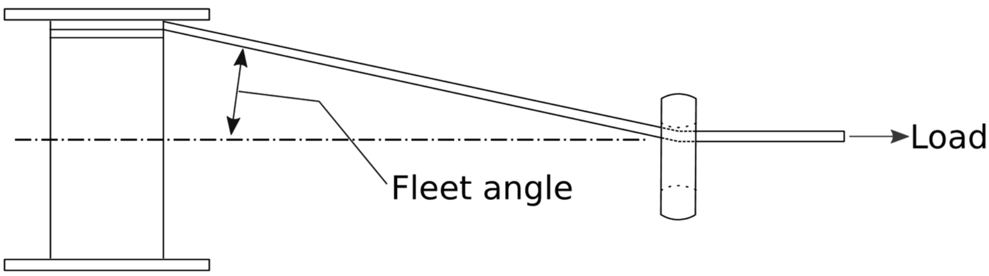


Fig. 2.4.4.1b
Towline “fleet angle”

7 HYDRAULIC MACHINERY

7.1 GENERAL REQUIREMENTS

7.1.1 The connection of the pipeline system of the hydraulic steering engines to other hydraulic systems is not permitted.

7.1.2 Where the pipeline servicing the hydraulic anchor machinery is connected to other hydraulic system pipeline, the latter shall be served by two separate pump units, each of them to be capable to assure work of anchor machinery in accordance with 6.3.1.1.

7.1.3 The hydraulic system failure is not to cause the failure of machinery or arrangement.

7.2 STRENGTH TEST

7.2.1 The hydraulic machinery elements situated in lines of force flow shall be checked under the stresses corresponding to the working pressure. In this case, the reference stresses in elements shall not exceed 0,4 of the yield point of the element material.

7.2.2 In cases specified in 6.2.10.7, 6.3.4 and 6.4.2 the elements shall be checked for strength under the stresses corresponding to the opening pressure of the safety valves. In this case, the reduced stresses in elements shall not exceed 0,95 of the yield point of the element material.

7.2.3 The pipelines and fittings of the hydraulic systems shall comply with the requirements specified in the *Rules for the classification of ships, Part 8 - Piping*, 1.3, 1.4 and 1.6.

7.3 SAFETY AND OTHER ARRANGEMENTS

7.3.1 The hydraulic machinery shall be protected by safety valves which operating pressure is not to exceed 1,1 times the maximum rated pressure, except for the cases specified in 6.2.10.7, 6.3.4 and 6.4.2.

7.3.2 The working fluid from the safety valve shall be led to the drain pipeline or to the oil tank.

7.3.3 Arrangements for complete air expulsion when filling, replenishing or draining the machinery and the pipeline with the working fluid, shall be provided.

7.3.4 The hydraulic systems shall be provided with the filters of appropriate capacity and filtration purity of the working fluid.

For continuously operating hydraulic systems (hydraulic steering gear, hydraulic couplings, etc.) provision shall be made for filter cleaning without interruption of the system operation.

7.3.5 All parts of hydraulic working cylinders which are exposed to excessive heat or to freezing shall be suitably protected.

8 GAS TURBINES

8.1 GENERAL REQUIREMENTS

8.1.1 The requirements of the present Section are applicable to the main and auxiliary marine gas turbines with combustion chambers.

8.1.2 The design output refers to the design conditions, i.e. the specified values of temperatures of ambient air and water, of air humidity, of atmospheric pressure and of resistance of exhaust and suction adopted when designing gas turbines.

8.1.3 When one gas turbine is employed in ships of unrestricted service, the necessity of application of the emergency device ensuring the ship movement shall be agreed upon with the *Register* in each case.

8.1.4 The gas turbine with air intercooling shall develop an output not less than 20% of the design one, when water supply to the air cooler is completely shut off.

8.1.5 The gas turbine installation with a reversing device shall provide reversing from full ahead to full astern and vice versa.

The gas turbine installation without a reversing device may be installed provided the ship is equipped with other means and devices ensuring the reverse.

When the astern turbine is employed, the requirements of 3.1.2 and 3.6.2 shall be complied with; when the reverse-reduction gearing is used the requirements of 4.1.1 of this Part of the Rules and in case of controllable pitch propeller the requirements of 3.5.4 of the *Rules for the classification of ships, Part 7 - Machinery Installation* shall be met.

When using the compressed air for the reverse system, its store shall provide at least 25 re-settings of the reverse. Refuelling of compressed air store shall be automatic from at least two sources of compressed air.

Connection of other consumers to the high pressure compressed air systems providing the operation of the reverse system, protection of gas turbines, bridge control shall not be permitted.

8.1.6 The steady operation of the gas turbines without stalling and surging under all possible operating conditions, manoeuvring included, as well as at the permissible deposits on gas turbines and under ambient conditions stated in 1.6 of the *Rules for the classification of ships, Part 7 - Machinery Installation* shall be proved by calculations and experiments.

Increases and drops of load shall be performed at the speed specified for the gas turbine bridge control system throughout the operating range.

The program of the operation stability control for the gas turbine shall be agreed with the *Register* the control shall be performed at the test bench and on board.

8.1.7 Throughout the operating and starting ranges shall be no zones restricting the operation of the gas turbine due to vibration.

The vibration shall be determined by a vibration of the gas turbine casing in way of bearings and shall not exceed the values stated in the standards.

8.1.8 For the gas turbines for ships with ice strengthening of category 1 AS, 1 A and 1 B the requirements of 1.4.2 of the *Rules for the classification of ships, Part 7 - Machinery Installation* shall be complied with; if these requirements cannot be fulfilled, the loads on units transmitting the power from the gas turbine to propeller shall be agreed upon with the *Register*.

8.1.9 The starting device of each gas turbine shall be operated from at least two sources of power.

A change over from one source of power to the other for starting up the gas turbine shall be performed in not more than 60 sec. Provision shall be made for starting up the gas turbine to the full stop of the rotor.

Hydrofoil ships and air-cushion vehicles need not to be provided with two sources of power.

The provision shall be made for ensuring at least four successive starts of the gas turbine.

8.1.10 Provision shall be made for cleaning the blading of gas turbine under the ship's service conditions without stopping the gas turbine.

For hydrofoil ships and air-cushion vehicles, the cleaning of gas turbines may be carried out by means of shore appliances.

8.1.11 The air suction inlets of the gas turbines shall be fitted with filters to preclude entering of particles including sea salt into compressor, dangerous for the normal operation of the gas turbine. The provisions shall be made for closing air suction inlets when gas turbines are out of operation.

The air suction inlets shall be fitted with quick-closing devices. The location of the air suction inlets shall prevent the entry of water, vapours or blow-out from a fan into compressor.

Provisions shall be made for preventing the suction duct from icing if the risk of icing exists in the ship's operating conditions. The reserve intake of 60% of air volume shall be provided in case of icing of the main suction inlet.

In agreement with *Register* measures against icing and the reserve intake need not to be provided for the hydrofoil ships and air-cushion vessels.

Drainage shall be provided through hydraulic valves.

8.1.12 Gas exhaust systems shall be provided with arrangements distance controlled to prevent air circulation through the gas turbine in case of fire and when in port.

If one air duct or exhaust manifold are intended for two or more engines, it is necessary to exclude the recirculation of air and gas through a non-operating engine.

8.1.13 Air suction and gas exhaust trunks, fuel, refrigeration and other piping shall be so connected to the engine that no expansion stresses are transmitted to the place of connection.

8.1.14 In air ducts and trunks of air supply to compressors all inner components shall be manufactured from materials resistant to corrosion in sea conditions. Dimensions of components and fastenings shall exclude the possibility of their penetration through the protective gratings before compressor. All inner mountings shall be fixed. Trunks and ducts shall provide the possibility of periodical checking the condition of inner surfaces.

8.1.15 All turbocompressors, gas turbines shall be fitted with a shaft turning gear. Provision shall be made for interlocking a shaft turning gear with a gas turbine starting device or for an automatic disconnection of the shaft-turning gear.

Quick-disconnecting couplings shall be provided with a device for interlocking the starting up of gas turbine with a reduction gear being disconnected.

8.1.16 Gas turbines for driving the emergency generator and fire pump shall be fitted with independent fuel, lubricating oil and cooling systems. In addition to automatic starting, manual starting shall be provided.

8.1.17 Automatic or interlocked means shall be provided for clearing all parts of the main gas turbine of the accumulation of liquid fuel or for purging gaseous fuel, before ignition commences on starting or recommences after failure to start.

Each main gas turbine shall be provided with a fire extinguishing system independent of the fire extinguishing systems of a machinery space.

When there are several gas turbines in a ship, provision shall be made for supply of fire extinguishing agent from a fire extinguishing system of one gas turbine to another.

8.1.18 Starting devices shall be so arranged that firing operation is discontinued and main fuel valve is closed within pre-determined time, when ignition is failed.

8.2 ROTORS

8.2.1 The strength calculation of the rotating parts of the gas turbines shall be performed for the condition of the rated output and for conditions when the stresses can reach their maximum values. The check calculation is carried out for the number of revolutions exceeding the design number by 20%.

8.2.2 The calculation for the enlarged torque corresponding to the operation of gas turbines at the outside air temperature reduced by 20°C as compared to the design temperature shall be performed for the rotating parts of the gas turbine.

8.2.3 The strength calculation of the rotating parts of the astern gas turbines shall be performed to the maximum torque corresponding to the crush stop from full ahead to full astern at the maximum output of astern turbine.

8.2.4 The strength calculation of the units transmitting the gas turbine power for driving the electric generators shall be performed according to the torque for the condition of the short circuit if the system engine-generator does not use the special sliding couplings.

8.2.5 The rotating blades which dimensions do not permit the safety of casings or special sheaths shall have the increased factors of the static and dynamic strength.

8.2.6 The critical speed of the rotor shall be determined with regard for brackets and meet the requirements of 3.2.2. For overhanging rotors the precession calculation and calculation of the additional loads from the gyroscopic moment shall be carried out.

8.2.7 The requirements of 3.2.3 to 3.2.5 of the this Part of the Rules shall be complied with as well.

8.2.8 The dynamic stresses in the compressors blades shall be experimentally determined throughout all operating range, the starting ranges included, and blading shall be set so that the dangerous vibrations do not occur. Factor of fatigue strength of the blades shall be not less than 3 for the operational ranges and 2,5 for the transient ranges. If the corroding medium effect is taken into account, this factor may be reduced to 1,2.

8.3 CASING

8.3.1 Special sight holes for the inspection of the blading shall be provided in the casing of gas turbines and compressors, and gas turbines proper shall be equipped with special instruments for the inspection.

8.3.2 The casing of the gas turbine shall be in conformity with the requirements of 3.3.4 and 3.3.7 of the present Part; in this case, requirements of 3.3.7 are applicable only to the constructions of gas turbines with sleeve bearings.

8.3.3 When the internal lagging of the gas turbine casing is applied, its safe fastening and covering with a sheath shall be provided excluding its local stripping and entering of the lagging into the blading.

8.3.4 The oil sealing shall prevent lubricating oil and its vapours from entering into the blading of the turbines and compressors and blow out of oil and vapours outside.

8.3.5 Each turbine and compressor shall have drain holes in the lower points of the casing.

Provision shall be made for blowing down the turbine casing for removing the unburned fuel from the combustion chambers and gas piping.

8.4 BEARINGS

8.4.1 The sleeve bearings of the gas turbines shall comply with the requirement of 3.4.

8.4.2 The use of the ball and roller bearings is allowed for all types of ship gas turbines.

8.5 COMBUSTION CHAMBERS

8.5.1 The arrangement of the combustion chambers of the gas turbines shall provide the convenience of servicing and the possibility of replacement of burners and flame tubes by ship's means.

8.5.2 The possibility of inspection of the flame tubes of the combustion chambers without disassembling shall be provided.

8.5.3 The entering of the fuel into the combustion chambers of the gas turbine, while the engine is out of function, shall be excluded.

8.5.4 To remove unburned fuel, provision shall be made for blowing out combustion chamber and gas pipelines.

8.6 HEAT EXCHANGERS

8.6.1 The possibility of detection of the leakage and the location of the damaged member by means of a pressure test shall be provided in the heat exchangers of the gas turbines (regenerators and air coolers).

The regenerators shall be tested for tightness on the gas side, as well as on the air side. The procedure and the method of detecting the leakage and the location of the damaged components, as well as disconnection thereof shall be set forth in special instructions.

8.6.2 The dangerous resonance vibrations and self-excited vibrations of the components of the heat exchangers shall be excluded.

8.6.3 The regenerator shall be provided with a fire extinguishing system in conformity with the *Rules for the classification of ships, Part 17 - Fire Protection*.

8.6.4 The air coolers shall comply with the requirements of 1.5.6.

8.6.5 The air coolers shall provide for the possibility of the inspection and cleaning of the tube plates and for muffling of any tubes without removing the covers.

8.6.6 The air coolers shall be provided with arrangements for continuous removal of moisture falling out of the air during the operation of the gas turbines.

8.6.7 The heat exchangers shall also be in compliance with the requirements of the *Rules for the classification of ships, Part 10 - Boilers, Heat Exchangers and Pressure Vessels*, 1.2 and 6 with the exception of 6.3.1 to 6.3.4, 6.3.6 and 6.4.2.

8.7 CONTROL, PROTECTION AND REGULATION

8.7.1 The main gas turbine shall be provided with the automatic regulation and remote control systems ensuring the following:

.1 setting of the necessary rates and steady maintaining thereof throughout the whole range of operating speeds;
.2 starting and stopping under any operating conditions;
.3 maintaining of steady operation of the compressors and combustion chambers in the manoeuvring mode of operation;
.4 prevention of the sudden increase of gas temperatures;
.5 unified control of the gas turbine and propeller by the single lever or hand wheel; however, provision shall be made for separate control;
.6 restriction of torque at the power take off shaft, if necessary;

The following turbine services shall be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the main gas turbine:

.7 lubricating oil supply;
.8 oil fuel supply (or automatic control of oil fuel viscosity as alternative);
.9 exhaust gas.

8.7.2 Each propulsion turbine shall be provided with an overspeed device directly connected to the turbine shaft. The oil switch receiving the impulse from the impeller directly driven by the turbine shaft can be used as an overspeed device.

Main gas turbines are to be provided with over speed protective devices to prevent the turbine speed from exceeding more than 15% of the maximum continuous speed.

The overspeed device shall operate so that racing the turbine above 15 percent of rated speed is not allowed. Control system which stops the turbine from the overspeed device shall be executed with the minimum number of power sources so that in the case of deenergizing in the control system, the number of revolutions of the gas turbine will not be increased.

Where a main gas turbine incorporates a reverse gear, electric transmission, controllable pitch propeller or other free-coupling arrangement, a speed governor independent of the over speed protective device is to be fitted and is to be capable of controlling the speed of the unloaded gas turbine without bringing the over speed protective device into action.

8.7.3 In cases specified in 3.6, the gas turbines shall be fitted, in addition to the overspeed device, with a speed governor and the speed governor itself shall comply with the requirements contained in that chapter.

When reducing the fuel supply by the governor, stopping of the gas turbines is not allowed.

8.7.4 The main gas turbine shall, after at least 60 min stand by "Propeller-stop" condition, provide the ship's movement immediately after receiving the command. In the “Propeller-stop” condition, the propeller shaft speed is permitted of not more than 3 rpm.

After unlimited out of action the gas turbine shall be prepared for the immediate loading within 20 min what ensure the heating of the gas turbine, its starting and the bearing of ship's movement.

8.7.5 The requirements stated in the *Rules for the classification of ships, Part 13 - Automation*, Section 2 shall be met.

8.7.6 Main and auxiliary gas turbines shall be fitted with an arrangement for emergency stopping of the gas turbine under any operation conditions by at least two independent means.

When operating from the bridge control of the wheel house provision shall be made for emergency stopping of the gas turbine from the control station of engine room.

8.7.7 The manoeuvring arrangement of the gas turbine installation with an astern turbine shall comply with the requirements of 3.6.1 and 3.6.2.

The manoeuvring ahead and astern valves shall be interlocked. Adequate stall safety factor of gas turbine compressors shall be provided in any position of the manoeuvring valves.

8.7.8 Miscellaneous automatic safety devices

8.7.8.1 Details of the manufacturer’s proposed automatic safety devices to safeguard against hazardous conditions arising in the event of malfunctions in the gas turbine installation are to be submitted to the *Register* together with the failure mode and effect analysis (FMEA). Unless the FMEA proves otherwise, the shutdown functions for gas turbines are to be provided in accordance with Table 8.9.1 in addition to the general monitoring and safety system functions.

8.7.8.2 Main gas turbines are to be equipped with a quick closing device (shut-down device) which automatically shuts off the fuel supply to the turbines at least in case of:

a) Over speed
b) Unacceptable lubricating oil pressure drop
c) Loss of flame during operation
d) Excessive vibration
e) Excessive axial displacement of each rotor (Except for gas turbines with rolling bearings)
f) Excessive high temperature of exhaust gas
g) Unacceptable lubricating oil pressure drop of reduction gear
h) Excessive high vacuum pressure at the compressor inlet

8.7.8.3 The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the main gas turbine:

a) Lubricating oil supply
b) Oil fuel supply (or automatic control of oil fuel viscosity as alternative)
c) Exhaust gas

8.7.8.4 Automatic or interlocked means are to be provided for clearing all parts of the main gas turbine of the accumulation of liquid fuel or for purging gaseous fuel, before ignition commences on starting or recommences after failure to start.

8.7.8.5 Hand trip gear for shutting off the fuel in an emergency is to be provided at the manoeuvring station.

8.7.8.6 Starting devices are to be so arranged that firing operation is discontinued and main fuel valve is closed within pre-determined time, when ignition is failed.

8.7.9 The main gas turbine shall be provided with alarm system in accordance with the *Rules for the classification of ships, Part 13 – Automation.*

8.7.10 The control system of gas turbines shall comply with the requirements of the *Rules for the classification of ships, Part 7 - Machinery Installation*, 1.7, 1.8, 1.9 and 1.10.

8.7.11 The working medium for the control system shall not become viscous at low temperatures and shall not be readily flammable.

The system of filters and heat exchangers shall provide the necessary temperature and purity of the working medium.

8.7.12 Provision shall be made for checking the tachometer readings for main gas turbines.

8.7.13 The control systems of the auxiliary gas turbines intended for driving generators shall comply with the requirements of 2.11.3 and 2.11.4.

8.8 INSTRUMENTS

8.8.1 The control station of the main gas turbine shall be provided with instruments for measuring the parameters in accordance with 8.7.9 and devices specified in 3.7.2.2 to 3.7.2.4, as well as instruments necessary to carry out thermal check of the gas turbine operation.

8.8.2 The control station for the auxiliary gas turbines shall be provided with instruments for measuring:

1. rotor revolutions,
2. lubricating oil pressure before the gas turbine,
3. fuel pressure before the gas turbine,
4. lubricating oil temperature before the turbine,
5. gas temperature before or after the turbine.

8.9 ALARMING DEVICES

8.9.1 Although in principle alarming devices listed in Table 8.9-1 are to be provided, they can be added or omitted, taking into account the result of FMEA specified in item 2.1.

8.9.2 Alarms marked with "*" in Table 8.9-1 shall be activated at the suitable setting points prior to arriving the critical condition for the activation of shutdown devices.

8.9.3 Suitable alarms shall be operated by the activation of shutdown devices.

Table 8.9-1
List of alarms and shutdowns

Monitoring parameter	**Alarm**	**Shutdown**
Turbine speed	high	x
Lubricating oil pressure	Low *	x
Lubricating oil pressure of reduction gear	Low *	x
Differential pressure across lubricating oil filter	high	
Lubricating oil temperature	high	
Oil fuel supply pressure	low	
Oil fuel temperature	high	
Cooling medium temperature	high	
Bearing temperature	high	
Flame and ignition Failure	x	x
Automatic starting Failure	x	
Vibration	high*	x
Axial displacement of rotor	high	x
Exhaust gas temperature	High *	x
Vacuum pressure at the compressor inlet	High *	x
Loss of control system	x	

9 REQUIREMENTS FOR AC GENERATING SETS [1)]

9.1 GENERAL

9.1.1 This section provides requirements for AC Generating sets (i.e. Reciprocating Internal Combustion engines, alternators and couplings) in addition to requirements stated in 2.4, 2.11, 2.14.10, and IACS UR E13.

Reciprocating Internal Combustion engines are to comply with the requirements in 2.14 and 2.14.10.

The Reciprocating Internal Combustion engine speed governor and overspeed protective device are to comply with the requirements of 2.11.

Alternators are to comply with the requirements in IACS UR E13.

9.1.2 The requirements are applicable to AC generating sets subject to certification 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).

9.2 GENERATING SETS - REQUIREMENTS

9.2.1 The generating set shall show torsional vibration levels which are compatible with the allowable limits for the alternator, shafts, coupling and damper.

9.2.2 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. The torsional vibration calculations are to be submitted to the *Register* for approval when the engine power is 110 kW or above.

9.2.3 The rated power shall be appropriate for the actual use of the generator set.

9.2.4 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);
(viii) the set rated current (A);
(ix) the mass (kg).

[1)] 1. This requirement is to be implemented for AC generating sets:
i) when an application for certification of the generating set is dated on or after 1 July 2020; or
ii) which are installed in new ships contracted for construction on or after 1 July 2020.
2. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and shipbuilder. For further details regarding the date of "contract for construction", refer the 5.14 of the *Rules for the classification of ships, Part 1 – General requirements, Chapter 1 - General information*.
3. The "date of application for certification of the generating set" is the date of whatever document the Classification Society requires/accepts as an application or request for certification of an individual generating set.

ANNEX A - DOCUMENTS FOR THE APPROVAL OF DIESEL ENGINES

1 SCOPE

The documents necessary to approve a diesel engine design for conformance to the Rules of the *Register* and for use during manufacture and installation are listed.

The requirements of Annex A are to be implemented for engines for which date of an application for type approval certification is dated on or after 1 July 2016. Engines with an existing type approval on 1 July 2016 are not required to be re-type approved in accordance with this Annex A until the current type approval becomes invalid. For the purpose of certification of these engines, the current type approval and related submitted documentation will be accepted in place of that required by this Annex A until the current type approval expires or the engine type has undergone substantive modifications.

2 DEFINITIONS

2.1 The following definitions apply in the present chapter (see also IACS UR M44).

Certificate - A formal document attesting to the compliance of a design, product, service or process with acceptance criteria.

Certification - A procedure whereby a design, product, service or process is approved in accordance with acceptance criteria.

Component - Part, member of equipment or system.

Conformity - Where a design, product, process or service demonstrates compliance with its specific requirements.

Contract - Agreement between two or more parties relating to the scope of service.

Contractor / Supplier - One who contracts to furnish materials or design, products, service or components to a customer or user.

Customer - Party who purchases or receives goods or services from another.

Design - All relevant plans, documents, calculations described in the performance, installation and manufacturing of a product.

Design appraisal - Evaluation of all relevant plans, calculations and documents related to the design.

Design review - Part of the appraisal process to evaluate specific aspects of the design.

Drawings approval/ plan approval - Part of the design approval process which relates to the evaluation of drawings and plans.

Equipment - Part of a system assembled from components.

Equivalent - An acceptable, no less effective alternative to specified criteria.

Evaluation - Systematic examination of the extent to which a design, product, service or process satisfies specific criteria.

Examination - Assessment by a competent person to determine compliance with requirements.

Inspection - Examination of a design, product service or process by an Inspector.

Inspection plan - List of tasks of inspection to be performed by the Inspector.

Installation - The assembling and final placement of components, equipment and subsystems to permit operation of the system.

Manufacturer/Producer - Party responsible for the manufacturing and quality of the product.

Manufacturing process - Systematic series of actions directed towards manufacturing a product.

Manufacturing process approval - Approval of the manufacturing process adopted by the manufacturer during production of a specific product.

Material - Goods supplied by one manufacturer to another manufacturer that will require further forming or manufacturing before becoming a new product.

Modification - A limited change that does not affect the current approval.

Modification notice - Information about a design modification with new modification index or new drawing number replacing the earlier drawing.

Performance test - Technical operation where a specific performance characteristic is determined.

Prototype test - Investigations on the first or one of the first new engines with regard to optimization, fine tuning of engine parameters and verification of the expected running behaviour.

Quality assurance − All the planned and systematic activities implemented within the quality system, and demonstrated as needed to provide adequate confidence that an entity will fulfil requirements for quality. Refer to 9001:2015.

Information - Additional technical data or details supplementing the drawings requiring approval.

Revision - Means to record changes in one or more particulars of design drawings or specifications.

Specification - Technical data or particulars which are used to establish the suitability of materials, products, components or systems for their intended use.

Substantive modifications or major modifications or major changes - Design modifications, which lead to alterations in the stress levels, operational behaviour, fatigue life or an effect on other components or characteristics of importance such as emissions.

Subsupplier/subcontractor - One who contracts to supply material to another supplier.

Supplier - One who contracts to furnish materials or design, products, service or components to a customer or user.

Test - A technical operation that consists of the determination of one or more characteristics or performance of a given product, material, equipment, organism, physical phenomenon, process or service according to a specified procedure. A technical operation to determine if one or more characteristic(s) or performance of a product, process or service satisfies specific requirements.

Traceability - Ability to follow back through the design and manufacturing process to the origin.

Date of application for type approval - is the date of documents accepted by the Register as request for type approval certification of a new engine type or of an engine type that has undergone substantive modifications in respect of the one previously type approved.

2.2 The document flow between engine designer, *Register* Head Office, engine builder/licensee and *Register* Branch Office Surveyors are to be in accordance with IACS UR M44.

3 GENERAL

3.1 APPROVAL PROCESS

3.1.1 Type approval certificate

For each type of engine that is required to be approved, a type approval certificate is to be obtained by the engine designer. The process details for obtaining a type approval certificate are given in Section 4. This process consists of the engine designer obtaining:

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

3.1.2 Engine certificate

Each diesel engine manufactured for a shipboard application is to have an engine certificate. The certification process details for obtaining the engine certificate are in Section 5. This process consists of the engine builder/licensee obtaining design approval of the engine application specific documents, submitting a comparison list of the production drawings to the previously approved engine design drawings referenced in 3.1.1, forwarding the relevant production drawings and comparison list for the use of the Surveyors at the manufacturing plant and shipyard if necessary, engine testing and upon satisfactorily meeting the Rule requirements, the issuance of an engine certificate.

3.2 DOCUMENT FLOW FOR DIESEL ENGINES

3.2.1 Document flow for obtaining a type approval certificate

3.2.1.1 For the initial engine type, the engine designer prepares the documentation in accordance with requirements in Tables 1 and 2 and forwards to the Register according to the agreed procedure for review.

3.2.1.2 Upon review and approval of the submitted documentation (evidence of approval), it is returned to the engine designer.

3.2.1.3 The engine designer arranges for a Surveyor to attend an engine type test and upon satisfactory testing the Register issues a type approval certificate.

3.2.1.4 Document flow process for obtaining a type approval certificate shall be in accordance with IACS UR M44.

3.2.2 Document flow for engine certificate

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

3.2.2.2 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 Table 3.

3.2.2.3 The engine builder/licensee develops a comparison list of the production documentation to the documentation listed in Tables 1 and 2. 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 licensor.

If the designer acceptance 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.

3.2.2.4 The engine builder/licensee submits the comparison list and the production documentation to the Register according to the agreed procedure for review/approval.

3.2.2.5 The Register returns documentation to the engine builder/licensee with confirmation that the design has been approved. This documentation is intended to be used by the engine builder/licensee and their subcontractors and attending Register Surveyors. As the attending Register Surveyors may request the engine builder/licensee or their subcontractors to provide the actual documents indicated in the list, the documents are necessary to be prepared and available for the *Register* Surveyors.

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

3.2.2.7 The engine builder/licensee assembles the engine, tests the engine with a *Register* Surveyor present. An engine certificate is issued by the register Surveyor upon satisfactory completion of assembly and tests.

3.2.2.8 Document flow process for obtaining an engine certificate shall be in accordance with IACS UR M44.

3.3 APPROVAL OF DIESEL ENGINE COMPONENTS

Components of engine designer's design which are covered by the type approval certificate of the relevant engine type are regarded as approved whether manufactured by the engine manufacturer or sub-supplied. For components of subcontractor's design, necessary approvals are to be obtained by the relevant suppliers (e.g. exhaust gas turbochargers, charge air coolers, etc.).

3.4 SUBMISSION FORMAT OF DOCUMENTATION

The *Register* determines the documentation format (electronic or paper) and number of copies in case of paper format documentation.

4 TYPE APPROVAL PROCESS

4.1 DOCUMENTS FOR INFORMATION TABLE 1

4.1.1 Table 1 lists basic descriptive information to provide the Register an overview of the engine's design, engine characteristics and performance. Additionally, there are requirements related to auxiliary systems for the engine's design including installation arrangements, list of capacities, technical specifications and requirements, along with information needed for maintenance and operation of the engine.

4.1.2 The documentation listed in Tables 1, as far as applicable to the type of engine, shall be submitted by the engine designer/licensor to the *Register*.

4.2 DOCUMENTS FOR APPROVAL OR RECALCULATION TABLE 2

4.2.1 Table 2 lists the documents and drawings, which are to be approved by the *Register*.

4.2.2 The documentation listed in Tables 2, as far as applicable to the type of engine, shall be submitted by the engine designer/licensor to the *Register*.

4.3 DESIGN APPROVAL/APPRAISAL (DA)

Design approval/appraisal are valid as long as no substantial modifications have been implemented. Where substantial modifications have been made the validity of the design approval/appraisal 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.

4.4 TYPE APPROVAL TEST

A type approval test is to be carried out in accordance with IACS UR M71 and is to be witnessed by the Register. The manufacturing facility of the engine presented for the type approval test is to be assessed in accordance with IACS UR M72.

4.5 TYPE APPROVAL CERTIFICATE

After the requirements in 4.1 through 4.4 have been satisfactorily completed the *Register* issues a type approval certificate (TAC).

4.6 DESIGN MODIFICATIONS

After the *Register* 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 *Register*.

4.7 TYPE APPROVAL CERTIFICATE RENEWALS

A renewal of type approval certificates will be granted upon:

4.7.1 Submission of information in either 4.7.1.1 or 4.7.1.2.

4.7.1.1 The submission of modified documents or new documents with substantial modifications replacing former documents compared to the previous submission(s) for Design approval/appraisal (DA).

4.7.1.2 A declaration that no substantial modifications have been applied since the last Design approval/appraisal (DA) issued.

4.8 VALIDITY OF TYPE APPROVAL CERTIFICATE

The *Register* 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 *Register*.

4.9 DOCUMENT REVIEW AND APPROVAL

4.9.1 The assignment of documents to Table 1 for information does not preclude possible comments by the *Register*.

4.9.2 Where considered necessary, the *Register* may request further documents to be submitted. This may include details or evidence of existing type approval or proposals for a type testing programme in accordance with IACS UR M71.

5 CERTIFICATION PROCESS

The certification process consists of the steps in 5.1 to 5.5.

Document flow process for obtaining an engine certificate shall be in accordance with IACS UR M44 and determinate the document flows between the:

- engine designer/licensor,
- engine builder/licensee,
- component manufacturers,
- Head Office of the *Register*, and
- Branch Office of the *Register*.

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 Table 3 may be submitted by:

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

5.1 DOCUMENT DEVELOPMENT FOR PRODUCTION

Prior to the start of the engine certification process, a design approval is to be obtained per 4.1 through 4.3 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 Tables 1 and 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 *Register* as per 4.6.

5.2 DOCUMENTS TO BE SUBMITTED FOR INSPECTION AND TESTING

Table 3 lists the production documents, which are to be submitted by the engine builder/licensee to the *Register* following acceptance by the engine designer/licensor. The *Register's* Surveyor uses the information for inspection purposes during manufacture and testing of the engine and its components. See 3.2.2.3 through 3.2.2.6.

5.3 ALTERNATIVE EXECUTION

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 *Register's* approval centre 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.

5.4 MANUFACTURER APPROVAL

The *Register* assesses conformity of production with the *Register's* requirements for production facilities comprising manufacturing facilities and processes, machining tools, quality assurance, testing facilities, etc. See IACS UR M72. Satisfactory conformance results in the issue of a Register approval document.

5.5 DOCUMENT AVAILABILITY

In addition to the documents listed in Table 3, the engine builder/licensee is to be able to provide to the *Register's* 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.

5.6 ENGINE ASSEMBLY AND TESTING

Each engine assembly and testing procedure required according to relevant Rules and IACS URs are to be witnessed by the *Register* unless an Alternative Certification Scheme meeting the requirements of IACS UR Z26 is agreed between manufacturer and the *Register*.

Table 1 - Documentation to be submitted for information, as applicable

No.	Item
1	Engine particulars (e.g. Data sheet with general engine information (see IACS UR M44 Appendix 3), 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[3]
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	Quality requirements for engine production
29	Type approval certification for environmental tests, control components[6]

FOOTNOTES:
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 UR E10.

Table 2 Documentation to be submitted for approval, as applicable

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[1]
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 data sheet stated in UR M44 Appendix 3 and UR M53
9	Thrust shaft or intermediate shaft (if integral with engine)
10	Shaft coupling bolts
11	Material specifications of main parts with information on non-destructive material tests and pressure tests[3]
	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 (see UR M9)[5]
23	Calculation results for crankcase explosion relief valves (see UR M9)
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 (see UR M10)
27	Details of mechanical joints of piping systems (see UR P2)
28	Documentation verifying compliance with inclination limits (see UR M46)
29	Documents as required in UR E22, as applicable

FOOTNOTES:
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 *Register* 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

- Special consideration will be given to engines of identical design and application
- For engine applications refer to IACS UR M72

No.	Item
1	Engine particulars as per data sheet in IACS UR M 44, Appendix 3
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:[3]
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 IACS UR M9)[6]
24	Oil mist detection and/or alternative alarm arrangements (see IACS UR M10)
25	Cylinder head
26	Cylinder block, engine block
27	Cylinder liner
28	Counterweights (if not integral with crankshaft), including fastening
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

FOOTNOTES:

1. For comparison with *Register* 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 register for information or approval, as applicable. See 3.2.2.2, and IACS UR M44 Appendix 4 and Appendix 5.

ANNEX B - STORAGE AND USE OF SCR REDUCTANTS

1 GENERAL

The NOx Technical Code, in 2.2.5 and elsewhere, provides for the use of NOx Reducing Devices of which Selective Catalytic Reduction (SCR) is one option. SCR requires the use of a reductant which may be a urea/water solution or, in exceptional cases, aqueous ammonia or even anhydrous ammonia. These requirements apply to the arrangements for the storage and use of SCR reductants.

The requirements for SCR reductants tanks with volume below of 500 L are left to the discretion of *Register*. This discretion is only applicable to Section 2 of the Annex B.

2 REDUCTANT USING UREA BASED AMMONIA (e.g. 40 % / 60 % UREA/WATER SOLUTION)

2.1 Where urea-based ammonia (e.g. AUS 40 – aqueous urea solution specified in ISO 18611-1:2014) is introduced, 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.

2.2 The storage tank may be located within the engine room.

2.3 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.

2.4 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.

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.

2.5 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.

2.6 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.

2.7 The requirements specified in item 2.4 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.

2.8 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.

2.9 Reductant tanks are to be of steel or other equivalent material with a melting point above 925 degrees C.

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.

NOTE:
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.

2.10 For the protection of crew members, the ship is to have on board suitable personnel protective equipment. Eye-wash are to be provided, the location and number of these eye-wash stations are to be derived from the detailed installation arrangements.

2.11 Urea storage tanks are to be arranged so that they can be emptied of urea and ventilated by means of portable or permanent systems.

3 REDUCTANT USING AQUEOUS AMMONIA (28 % OR LESS CONCENTRATION OF AMMONIA)

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.

4 REDUCTANT USING ANHYDROUS AMMONIA (99.5 % OR GREATER CONCENTRATION OF AMMONIA BY WEIGHT)

Anhydrous 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.

ANNEX C - SAFETY MEASURES AGAINST CHEMICAL TREATMENT FLUIDS USED FOR EXHAUST GAS CLEANING SYSTEMS AND THE RESIDUES WHICH HAVE HAZARDOUS PROPERTIES

1 GENERAL

1.1 With regard to regulation 14 of MARPOL Annex VI requiring ships to use fuel oil with a sulphur content not exceeding that stipulated in regulations 14.1 or 14.4, regulation 4 allows, with the approval of the Administration, the use of an alternative compliance method at least as effective in terms of emission reductions as that required by the MARPOL Annex VI, including the standards set forth in regulation 14.

1.2 As some types of exhaust gas cleaning systems to be approved by the Administration as "alternative compliance method" consume chemicals which are typically carried on board in bulk quantities, the prescriptive requirements contained in this UR related safety measures against chemical treatment fluids apply to exhaust gas cleaning systems using such fluids. 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 section 2 of this Annex).

1.3 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 analyse 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 requirements stated in section 2 of this Annex.

2 REQUIREMENTS FOR EXHAUST GAS CLEANING SYSTEMS USING AQUEOUS SOLUTION OF NAOH OR $CA(OH)_2$ FOR CHEMICAL TREATMENT FLUID

2.1 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.

2.2 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.

2.3 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 shall be provided outside the compartment adjacent to each point of entry.

2.4 The storage tank may be located within the engine room. In this case, the requirements of 2.3 shall 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.

2.5 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.

2.6 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.

2.7 Where chemical treatment fluid 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 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.
- 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.

2.8 The requirements specified in item 2.3 of this Annex also apply to closed compartments normally entered by persons:

- 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
- 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.

2.9 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.

2.10 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.

2.11 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 anti-corrosion coating.

NOTE: Several metals are incompatible with the chemical treatment fluids, e.g. NaOH is incompatible with zinc, aluminium, etc.

2.12 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.

2.13 The following connections are to be screened and fitted with drip trays to prevent the spread of any spillage where they are installed:

- Detachable connections between pipes (flanged connections and mechanical joints, etc.);
- Detachable connections between pipes and equipment such as pumps, strainers, heaters, valves; and
- Detachable connections between equipment mentioned in the above sub-paragraph.

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, item 2.7.1 and 2.7.2 of this Annex are to be applied to the tank.

2.14 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.

2.15 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:

- 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.
- 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.
- 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.

2.16 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.

3 REQUIREMENT FOR EXHAUST GAS CLEANING SYSTEMS DISCHARGE WATER PIPELINE

3.1 Overboard discharges from exhaust gas cleaning system (EGCS) are not to be interconnected to other systems.

3.2 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.

3.3 The piping material for the EGCS discharge water pipeline system is to be selected based on the corrosive nature of the liquid media.

3.4 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.

3.5 In case distance piece is fitted between the outboard discharge valve and the shell plating, it shall 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 shall be at least the minimum values specified in .1 and .2 as below; otherwise Sch. 160 thickness specified in piping standards shall, as far as practicable, 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.

4 MISCELLANEOUS

4.1 Tanks for residues generated from the exhaust gas cleaning process are to satisfy the following requirements:

- The tanks are to be independent from other tanks, except in cases where these tanks are also used as the overflow tanks for chemical treatment fluids storage tank.

- 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.
- 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.

ANNEX D - BALLAST WATER MANAGEMENT SYSTEMS

1 APPLICATION

In addition to the requirements contained in BWM Convention (2004), the following requirements are applied to the installation of Ballast Water Management Systems.

This UR is not applied to ship's ballast water systems including piping valves, pumps, etc., where the BWMS is not fitted.

This UR is to be read in conjunction with IACS UR F45 - Installation of BWMS on board ships.

2 DEFINITIONS

2.1 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 Table 1. Applicability of the requirements for each BWMS technology is in accordance with Table 2.

2.2 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.

2.3 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 (O_2), carbon dioxide (CO_2), carbon monoxide (CO), ozone (O_3), chlorine (Cl_2) and chlorine dioxide (ClO_2), etc.

2.4 Dangerous liquid means any liquid that is identified as hazardous in the Material Safety Data Sheet or other documentation relating to this liquid.

2.5 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.

2.6 Non-hazardous area means an area which is not a hazardous area as defined in above 2.5.

Table 1 - Categorization of BWMS technologies

BWMS's Technology category (as defined in UR M74 informative Annex II)		**1**	**2**	**3a**	**3b**	**3c**	**4**	**5**	**6**	**7a**	**7b**	**8**
Characteristics ↓		In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO_2 or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N_2 from a N_2 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	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
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 2.3			(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

Note:

(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 1 by identifying their characteristics in the same manner as for the above BWMS categories 1, 2, 3a, 3b, 3c, 4, 5, 6, 7a, 7b and 8.

Table 2 - Applicability of the requirements for each BWMS technology

BWMS's Technology category (as defined in UR M74 informative Annex II)	**1**	**2**	**3a**	**3b**	**3c**	**4**	**5**	**6**	**7a**	**7b**	**8**
Requirement ↓	In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO_2 or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N_2 from a N_2 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	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
3.2.1.1				x	x				x	x	
3.2.1.2						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	
3.3.1.1		x	x			x	x	x	x	x	x
3.3.1.2			x	x	x				x	x	x
3.3.1.3									x	x	
3.3.1.4						x	x	x	x	x	
3.3.1.5						x	x	x			
3.3.1.6			x	x	x				x	x	x
3.3.2.1 to 3.3.2.4		x	x	x	x	x	x	x	x	x	x
3.3.2.5			x			x	x	x	x	x	x
3.3.2.6			x						x	x	x
3.3.2.7			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 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 *Register*.

3.1.2 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 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 shall not exceed the maximum TRC of the BWMS.

3.1.4 BWMS should be subject to design review by the *Register* to verify the compliance of the BWMS's manufacturer package with the Rules of the *Register*. 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 the UR E22 Rev. 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 *Register* at the manufactory (Society Certificate (SC) as defined in UR M72) including pressure vessels, piping class I or II, filters, switchboards, etc.

3.1.5 Where a vacuum or overpressure may occur in the ballast piping or 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 on the open deck.

NOTES:

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**: 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**: 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.*

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 shall be followed in order to:

- Define hazardous areas and acceptable electrical equipment, and

- Design ventilation systems.

3.1.6 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 Inert gas systems installed for de-oxygenation BWMS (categories 3a, 3b, 3c and 8) are to be designed in accordance with the following requirements:

3.1.7.1 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.

3.1.7.2 IACS UR F20 requirements F20.1.1.1, F20.1.1.3, F20.3.1, F20.3.3, F20.3.7, F20.3.8, F20.4.4, F20.4.5 and F20.4.6. In applying F20.4.6, 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 3.1.7.1 prevail.

3.1.8 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 When it is required to have an automatic shutdown of the BWMS for safety reasons, this must be initiated by a safety system independent of the BWM control system.

3.2 ADDITIONAL REQUIREMENTS FOR TANKERS

3.2.1 Hazardous area classification is to be in accordance with IEC 60092-502:1999 with due consideration of IACS UI SC274.

.1 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:
- *This requirement does not apply to inert gas generators for which FSS Code Ch 15/2.4.1 and IACS UR F20.3 and F20.4 apply.*

.2 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.

NOTES:
- *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.*
- *For submerged cargo pumps, the room containing the hydraulic power unit or electric motors is not to be considered as the “cargo pump room”.*
- *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 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 Annex I.

NOTE:

- *When the Fore Peak Tank is ballasted with the piping system serving the other ballast tanks within the cargo area in accordance with IACS UR F44, 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 Isolation between ballast piping serving the ballast tanks inside and outside of the cargo area is to be in accordance with the following requirements:

3.2.3.1 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 Annex I is applied.

NOTES:

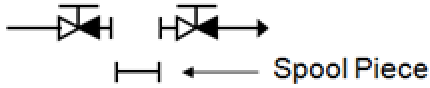
- *The means of appropriate isolation described in Paragraph 3.2.3.1 is necessary for the interconnection specified in said Paragraph regardless of the diameter of the piping.*
- *As indicated in Annex I, the means of appropriate isolation described in Paragraph 3.2.3.1 is necessary for the interconnection 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 Register 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.*
- *The means of appropriate isolation described in this Paragraph 3.2.3.1 for the interconnection specified in said Paragraph need not be applied to the sampling lines described in Paragraph 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 dis-connection" in Annex I), or

NOTE:

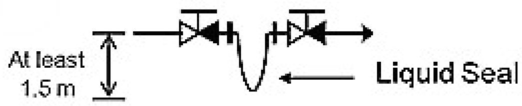
- *As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the spool piece.*



.2 Two non-return valves with positive means of closing in series with a liquid seal at least 1.5 m in depth, or

NOTES:

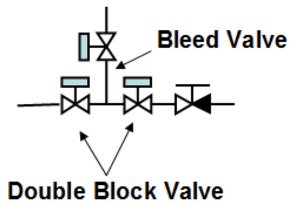
- *As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the liquid seal.*
- *For ships operating in cold weather conditions, freeze protection should be provided in the water seal. A portable heating system can be accepted for this purpose.*



.3 Automatic double block and bleed valves and a non-return valve with positive means of closing.

NOTE:

- *As an alternative to positive means of closure, an additional valve having such means of closure may be provided after the non-return valve.*



3.2.3.2 The above-mentioned means of appropriate isolation is to be provided on the open deck in the cargo area.

NOTE:

- *When the Fore Peak Tank is ballasted with the piping system serving the other ballast tanks within the cargo area in accordance with IACS UR F44, the means of appropriate isolation described in Paragraphs 3.2.3.1 and 3.2.3.2 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 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:

.1 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 i) through iv) are to be complied.

i) In the cabinet, a stop valve is to be installed on each sampling line.

ii) Gas detection equipment is to be installed in the cabinet and the valves specified in i) above are to be automatically closed upon activation of the gas detection equipment.

iii) 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:

- *When the electrical equipment is of a certified safety type, the automatic disconnection of power supply is not required.*

iv) 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.

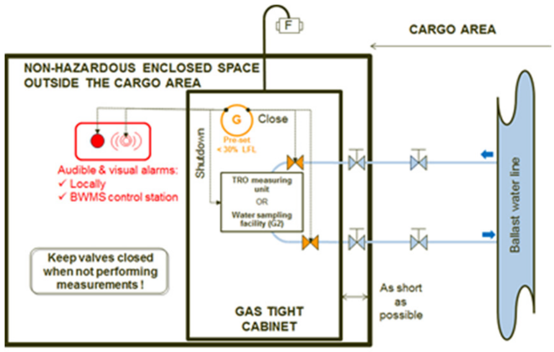
.2 The standard internal diameter of sampling pipes is to be the minimum necessary in order to achieve the functional requirements of the sampling system.

.3 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.

.4 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.

.5 A stop valve is to be installed on the cargo area for each sampling line (i.e. both the suction and return lines).

.6 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.



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 Where the operating principle of the BWMS involves the generation of a dangerous gas, the following requirements are to be satisfied:

.1 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 H2, 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.

.2 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 shall 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 shall be both audible and visual and shall 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 shall 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 shall be both audible and visual and shall 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.

.3 For BWMS categories 7a and 7b, at least one ozone sensor shall be provided at the vicinity of the discharge outlet to the open deck from the ozone destructors addressed in 3.3.2.3 to alarm when the ozone concentration level raises above 0.1 ppm. The alarms shall be both audible and visual and shall be activated in the BWMS control room.

In addition, at least two ozone sensors shall 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 shall be both audible and visual and shall 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.

.4 Inside double walled spaces or pipe ducts constructed for the purpose of 3.3.2.1 Note 1), sensors are to be provided for the detection of H2 leakages (BWMS categories 4, 5 and 6 when relevant) or O2 leakages (BWMS categories 7a and 7b) or O3 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 3.3.1.1 to 3.3.1.3.

NOTE:

- *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.*

.5 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 shall be certified explosion proof and have spark arrestor to avoid ignition sources to enter the ventilation systems whereas remaining H2 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 H2 concentration. The open end of the hydrogen by-product enriched gas relieving device is to be led to a safe location as specified in 3.3.2.3. on open deck.

.6 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 as specified in 3.1.5 on open deck.

3.3.2 Where the piping is conveying active substances, by-products or neutralizers that are containing dangerous gas or dangerous liquids as defined respectively in 2.3 and 2.4, the following requirements are to be satisfied:

NOTES:

- *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.*
- *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.*

.1 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 IACS UR P2 table 1. 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 IACS UR P2. Mechanical joints, where allowed, are to be selected in accordance with IACS UR P2 Table 8.

NOTES:

- *For piping class II with special safeguards conveying dangerous gas like hydrogen (H_2), oxygen (O_2) or ozone (O_3), the special safeguards are to be either double walled pipes or pipe duct.*
- *For piping class II with special safeguards conveying dangerous liquids, other special safeguards could be considered like shielding, screening, etc.*
- *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 UR P4 apply.*

.2 The length of pipe and the number of connections are to be minimised.

.3 Inside double walled space or pipe ducts constructed as the special safeguard for the purpose of 3.3.2.1 Note 1) are to be equipped with mechanical exhaust ventilation leading to a safe location as specified below in notes on open deck.

NOTES:

Safe location: *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: *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.*

.4 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.

.5 Pipes carrying acids are to be arranged so as to avoid any projection on crew in case of a leakage.

.6 H2 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) shall not be routed through accommodation spaces, services spaces and control stations.

.7 O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) shall not 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 3.3.2.1 Note 1) and provided with suitable gas detection as described in 3.3.1.4 and mechanical exhaust ventilation as described in 3.3.2.3.

.8 The routing of H2 by-product enriched air vent pipes (BWMS categories 4, 5 and 6) or O2 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 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:

.1 The materials, inside coating used for the chemical storage tanks, piping and fittings are to be resistant to such chemicals substances.

.2 Chemical substances (even if they are not defined as dangerous liquid in the sense of 2.4) 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 (e.g. sulfuric acid H_2SO_4) or dangerous gas (e.g. oxygen O_2): the *Register'* Rules as applicable to pressure vessels,
- for independent tanks permanently fixed onboard not containing dangerous liquid (e.g. sodium sulphite, sodium biosulphite or sodium thiosulfphate neutralizers) and not containing dangerous

gas (e.g. nitrogen N2): the Rules or other industry standard recognized by the *Register*,
- for portable tanks: the IMDG Code or other industry standard recognized by the *Register*.

.3 When the chemical substances are stored inside integral tanks, the ship's shell plating shall not form any boundary of the tank.

.4 Dangerous liquids and dangerous gas storage tank air pipes are to be led to a safe location as specified in 3.1.5 on open deck.

.5 An operation manual containing chemical injection procedures, alarm systems, measures in case of emergency, etc. is to be kept onboard.

.6 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 2.3 and 2.4.

NOTE:
- *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 A risk assessment is to be conducted in a generic manner during the design review mentioned in 3.1.4 and submitted to the *Register* 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:
- *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.*

.1 The recommended risk assessment techniques for BWMS and other guidance are listed below but not limited to:
- FMEA, FMECA, HAZID, HAZOP, etc.,
- ISO 31010 – Risk Assessment Techniques,
- IACS Recommendation Rec. 146,
- the Rules of the *Register* for risk assessment techniques.

.2 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.

Installation of one single BWMS on tankers

Table 1: In-line BWMS's technologies categorization

NOTE: This Annex does not cover In-tank technologies categories 3c and 8.

BWMS's Technology category → / Characteristics ↓		1	2	3a	3b	4	5	6	7a	7b
		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 (3)	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 2.3			(1)	O_2 N_2	CO_2, CO	H_2, Cl_2	H_2, Cl_2	(1)	O_2, O_3, N_2	
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 3.2.3.1 are to be applied.

(3) In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or de-ballasting)

(4) For details regarding Case 1.2, 1.3a, 1.3b, 1.4, 1.5, 1.6, 1.7a and 1.7b see UR M74 Annex I