PART 5 Machinery

Contents

CHAPTER 1 General

Contents

SECTION 1 General

1.1 Application

1.1.1 The requirements of Part 5, Chapter 1, Part 5, Chapter 2, Part 5, Chapter 3 and Part 5, Chapter 4 are applicable to main propulsion and essential auxiliary machinery where the total input power to each propeller shaft is not grater than 500 kW. Craft fitted with oil engines where the total input power to each propeller shaft exceeds 500 kW are to comply with the relevant requirements of the *Rules and Regulations for the Classification and Construction of Steel Ships*..

1.1.2 The requirements of this Part are not applicable to petrol engines. Such engines, normally, are not acceptable. Where their installation is proposed, special consideration is required.

1.1.3 Supplementary to paragraph 1.1.1, yachts with the notation "COMMERCIAL YACHTS" shall additionally meet the minimum requirements of Section 8 of this Chapter.

1.2 Classification survey

1.2.1 Workmanship and materials should be examined by the Surveyors from the beginning of work until the final test of the machinery under full load. After this, the Surveyors will submit a report and if this is found to be satisfactory by the Society a certificate will be granted, and an appropriate notation will be assigned in accordance with Part 1.

1.3 System of inspection of mass produced machinery items

1.3.1 The Society will be prepared to adopt a survey procedure of mass produced machinery items based on quality assurance concepts utilizing regular and systematic audits of the approved manufacturing and quality control processes and procedures as an alternative to the direct survey of individual items.

1.3.2 In order to obtain approval, the requirements of SECTION 7 are to be complied with.

1.4 Deviation from the Rules

1.4.1 Requests for departure from the requirements of the Rules, due to special circumstances, will be subject to special consideration.

SECTION 2 Documents for approval

2.1 Plans

2.1.1 Plans in triplicate (and/or zelectronically), of all machinery items, as detailed in the Chapters giving the requirements for individual systems, are to be submitted for consideration, before the commencement of the work. The particulars of the machinery, including power ratings and design calculations, where applicable, necessary to verify the design, are also to be submitted. Any subsequent modifications or alterations to initial design, materials or manufacturing procedure are to be re-submitted for consideration. A plan showing the arrangement of the machinery is also to be submitted.

2.2 Materials

2.2.1 The requirements for the materials used in the construction of all machinery items are those described in Part 2 of the present Rules. Materials for which provision is not made therein may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary.

SECTION 3 Operating conditions

3.1 Ambient reference conditions (IACS UR M28 (1978), UR M40 (1981))

3.1.1 For the purpose of determining the power of main and auxiliary reciprocating internal combustion engines, the following ambient reference conditions apply for ships of unrestricted service:

(a) Total barometric pressure 1000 mbar

(b) Air temperature +45°C

(c) Relative humidity 60%

(d) Sea water temperature 32°C (charge air coolant-inlet)

NOTE:

1. The engine manufacturer shall not be expected to provide simulated ambient reference conditions at a test bed.

3.1.2 The ambient conditions specified in Table 1.3.1 are to be applied to the layout, selection and arrangement of all shipboard machinery, equipment and appliances as to ensure proper operation.

Table 1.3.1: Temperatures

(a) Air

Installations, components	Location, arrangement	Temperature range (°C)
Machinery and electrical installations (1)	In enclosed spaces	0 to +45 (2)
	On machinery components, boilers. In spaces subject to higher and lower temperature	According to specific local conditions
	On the open deck	-25 to +45 (2)

(b) Water

Coolant	Temperature (°C)
Seawater	+32 (2)
Charge air coolant inlet to charge air cooler	+32 (2)

NOTES:

1. Electronic appliances are to be suitable for proper operation even with an air temperature of +55°C
2. The Society may approve other temperatures in the case of ships not intended for unrestricted service.

3.2 Ambient conditions - Inclinations (IACS UR M46 (2018))

3.2.1 The ambient conditions specified in Table 1.3.2 are to be applied to the layout, selection and arrangement of all shipboard machinery, equipment and appliances to ensure proper operation.

3.2.2 Any proposal to deviate from the angles given in Table 1.3.2 will be specially considered taking into account the type, size and service conditions of the ship.

3.3 Vibrations

3.3.1 Machinery, equipment and hull structures are normally subjected to vibration stresses. Design, construction and installation must in every case take account of these stresses.

Table 1.3.2: Inclinations

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

NOTES:

1. No undesired switching operations or operational changes are to occur.
2. Athwartships and fore-and-aft inclinations may occur simultaneously.
3. In ships for the carriage of liquefied gases and of chemicals the emergency power supply must also remain operable with the ship flooded to a final athwartships inclination up to a maximum of 30°.
4. Where the length of the ship exceeds 100m, the fore-and-aft static angle of inclination may be taken as 500/L degrees where L = length of the ship, in metres, as defined in PART 3CHAPTER 1SECTION 1, 1.1.2

3.4 Definitions

3.4.1 Units and formulae included in the Rules are shown in SI units.

3.4.2 Where the metric version of shaft power, i.e. (shp), appears in the Rules, 1 shp is equivalent to 75 kgf m/s or 0,735 kW.

3.4.3 Pressure gauges may be calibrated in bar, where:

$$1 \text{ bar} = 0{,}1 \text{ N/mm}^2 = 1{,}02 \text{ kgf/cm}^2$$

3.5 Fuels

3.5.1 The flash point (closed cup test) of fuel oil for use is, in general, to be not less than 60°C.

3.5.2 Fuels with flash points lower than 60°C require special consideration.

3.6 Power ratings

3.6.1 In the Chapters where the dimensions of any particular component are determined from shaft power, P, in kW, and revolutions per minute, n, the values to be used are to be derived from the following:

(a) for main propelling machinery, the maximum shaft power and corresponding revolutions per minute giving the maximum torque for which the machinery is to be classed,

(b) for auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service.

3.7 Starting arrangements of internal combustion engines (IACS UR M61 (2022))

3.7.1 Mechanical starting arrangements

3.7.1.1 The arrangement for air starting is to be such that the necessary air for the first charge can be produced on board without external aid.

3.7.1.2 Where the main engine is arranged for starting by compressed air, two or more air compressors are to be fitted. At least one of the compressors is to be driven independent of the main propulsion unit and is to have the capacity not less than 50 % of the total required.

3.7.1.3 The total capacity of air compressors is to be sufficient to supply within one hour the quantity of air needed to satisfy 3.7.1.5 by charging the receivers from atmospheric pressure. The capacity is to be approximately equally divided between the number of compressors fitted, excluding an emergency compressor which may be installed to satisfy 3.7.1.1.

3.7.1.4 Where the main engine is arranged for starting by compressed air, at least two starting air receivers of about equal capacity are to be fitted which may be used independently.

3.7.1.5 The total capacity of air receivers is to be sufficient to provide, without their being replenished, not less than 12 consecutive starts alternating between Ahead and Astern of each main engine of the reversible type, and not less than six starts of each main non-reversible type engine connected to a controllable pitch propeller or other device enabling the start without opposite torque. When other consumers such as auxiliary engines starting systems, control systems, whistle, etc., are to be connected to starting air receivers, their air consumption is also to be taken into account.

Regardless of the above, for multi-engine installations the number of starts required for each engine may be reduced upon the agreement with the Classification Society depending upon the arrangement of the engines and the transmission of their output to the propellers.

3.7.2 Electrical starting

3.7.2.1 Where the main engine is arranged for electric starting, two separate batteries are to be fitted. The arrangement is to be such that the batteries cannot be connected in parallel. Each battery is to be capable of starting the main engine when in cold and ready to start conditions. The combined capacity of the batteries is to be sufficient without recharging to provide within 30 minutes the number of starts of main engines are required above in case of air starting.

3.7.2.2 Electric starting arrangements for auxiliary engines are to have two separate batteries or may be supplied by separate circuits from the main engine batteries when such are provided. In the case of a single auxiliary engine only one battery may be required. The capacity of the batteries for starting the auxiliary engines is to be sufficient for at least three starts for each engine.

3.7.2.3 The starting batteries are to be used for starting and the engine's own monitoring purposes only. Provisions are to be made to maintain continuously the stored energy at all times.

SECTION 4 Machinery space arrangements

4.1 Accessibility

4.1.1 Equipment are to be so arranged in the engine space that all the erection holes and inspection parts provided by the engine manufacturer for inspections and repairs are accessible.

4.2 Machinery fastenings

4.2.1 All fastenings are to be of robust construction. The machinery is to be securely fixed to the ship's structure to the Surveyor's satisfaction.

4.3 Flexible mountings

4.3.1 The Shipbuilder is to ensure that the vibration levels of flexible pipe connections, shaft couplings and mounts remain always within the limits specified by the component manufacturer. The vibration levels are to be checked in the following conditions:

(a) Condition of maximum dynamic inclinations to be expected during service.

(b) Start-stop operation.

(c) Operation on the natural frequencies of the system.

Due account is to be taken of any creep that may be inherent in the mount.

4.3.2 Anti-collision chocks are to be used to ensure that manufacturers limits are not exceeded. Suitable means are to be provided to accommodate the propeller thrust.

4.4 Ventilation

4.4.1 In spaces where the presence of flammable or toxic gases or vapours is probable adequate ventilation is required.

4.5 Fire protection

4.5.1 All surfaces of machinery where the surface temperature may exceed 220^{o}C and where impingement of flammable liquids may occur are to be properly shielded and insulated.

SECTION 5 Astern power for main propulsion (IACS UR M25 (2017))

5.1 General requirements

5.1.1 In order to maintain sufficient manoeuvrability and secure control of the ship in all normal circumstances, the main propulsion machinery is to be capable of reversing the direction of thrust so as to bring the ship to rest from the maximum service speed. The main propulsion machinery is to be capable of maintaining in free route astern at least 70% of the ahead revolutions[2].

5.1.2 Where steam turbines are used for main propulsion, they are to be capable of maintaining in free route astern at least 70% of the ahead revolutions[2] for a period of at least 15 minutes. The astern trial is to be limited to 30 minutes or in accordance with manufacturer’s recommendation to avoid overheating of the turbine due to the effects of “windage” and friction.

5.1.3 For the main propulsion systems with reversing gears, controllable pitch propellers or electric propeller drive, running astern should not lead to the overload of propulsion machinery.

5.1.4 Main propulsion systems are to undergo tests to demonstrate the astern response characteristics.

The tests are to be carried out at least over the manoeuvring range of the propulsion system and from all control positions. A test plan is to be provided by the yard and accepted by the surveyor. If specific operational characteristics have been defined by the manufacturer these shall be included in the test plan.

5.1.5 The ahead revolutions as mentioned above are understood as those corresponding to the maximum continuous ahead power for which the vessel is classed. The reversing characteristics of the propulsion plant, including the blade pitch control system of controllable pitch propellers, are to be demonstrated and recorded during trials.

SECTION 6 Trials

6.1 Tests

6.1.1 All tests of particular components and trials of machinery are to be carried out to the satisfaction of the Surveyors, according to the Chapters giving the individual requirements for each part.

6.2 Sea trials

6.2.1 For the sake of reliability, due attention is required to the duration of all sea trials. Sea trials for all types of installation are to be carried out under normal manoeuvring conditions, to verify the machinery under power. During the trials and within the operating speed range any generated vibration is not to exceed the manufacturers values.

6.2.2 Diesel engines for main propulsion are to undergo trials as specified in Part 5, Chapter 2, SECTION 4. In case of controllable pitch propellers, the free route astern trial is to be carried out with the propeller blades set in the full pitch astern position. Where emergency manual pitch setting facilities are provided, their operation is to be demonstrated to the satisfaction of the Surveyors.

6.2.3 Before the full power sea trials, in geared installations, the gear teeth are to be suitably coated to demonstrate the contact markings, and on conclusion of the sea trials all gears are to be opened up in

[2] The ahead revolutions as mentioned above are understood as those corresponding to the maximum continuous ahead power for which the vessel is classed.

order to permit the Surveyors to make an inspection of the teeth. The marking is to indicate freedom from hard bearing, particularly at the ends of the teeth, including both ends of each helix where applicable

6.2.4 The stopping time, ship headings and distances recorded on trials, together with the results of trials to determine the ability of ships having multiple propellers to navigate and manoeuvre with one or more propellers inoperative, are to be available on board for the use of the master or designated personnel.

SECTION 7 Quality assurance scheme for machinery

7.1 General

7.1.1 The proposed certification scheme is applicable to mass produced items manufactured under controlled conditions and will be restricted to works where the use of quality control procedures is well established. The Society will have to be satisfied that the practices employed will ensure that the quality level of the finished products is equivalent to the standards which would be required from the use of traditional survey methods.

7.1.2 An extensive survey is to be made by the Surveyors of the actual operation of the quality control programme including workmanship. The Committee is to consider proposed alternative designs for compliance with the Society's Rules, or other relevant requirements.

7.1.3 The procedures and practices of manufacturers which have been granted approval will be kept under review.

7.1.4 Approval by another organization will normally not be accepted as sufficient evidence that a manufacture's arrangements comply with the Society's requirements.

7.2 Quality systems requirements

7.2.1 A quality management system in accordance with requirements of the ISO 9001 Standard may be considered as meeting the requirements of the Society. Other quality systems will be subject to special consideration.

SECTION 8 Additional requirements for commercial yachts

8.1 General

8.1.1 Supplementary to paragraph 1.1.1 the requirements of this section shall apply **additionally** to yachts with the notation “COMMERCIAL YACHT”.

8.2 Yachts of less than 500 gross tons

8.2.1 For existing and new yachts which operate with periodically unattended machinery spaces, the machinery and its installation shall meet the standards of SOLAS II-1/Part E -“Additional requirements for periodically unattended machinery spaces”, so far as is reasonable and practicable to do so.

8.2.2 The requirements for main propulsion are based upon the installation of diesel powered units. When other types of main propulsion are proposed, the arrangements and installation shall be specially considered. Where gas turbines are fitted, attention shall be paid to the guidance contained within the IMO

High Speed Craft Code, and installation shall be to the satisfaction of L.H.R..

8.2.3 Notwithstanding the requirements referred to paragraphs 8.2.1 and 8.2.2, the machinery, fuel tanks and associated piping systems and fittings shall be of a design and construction adequate for the service for which they are intended, and shall be so installed and protected as to reduce to a minimum any danger to persons during normal movement about the vessel, with due regard being made to moving parts, hot surfaces, and other hazards.

8.3 Yachts of 500 gross tons and over

8.3.1 The requirements of this paragraph shall be met even if the machinery is not considered the primary means of propulsion.

8.3.2 For existing and new vessels, the machinery and its installation shall meet the requirements of a Recognised Organisation and of SOLAS II-1/Part C Machinery installations and II-1/Part E -Additional requirements for periodically unattended machinery spaces, so far as is reasonable and practicable to do so.

8.3.3 In any case the intention shall be to achieve a standard of safety which is at least equivalent to the standard of SOLAS. Equivalence may be achieved by incorporating increased requirements to balance deficiencies and thereby achieve the required overall standard.

8.3.4 Where gas turbines are fitted, attention shall be paid to the guidance contained within the IMO High Speed Craft Code, and installation shall be to the satisfaction of L.H.R..

8.3.5 For vessels installed with high powered engines designed for short sprint speeds, on a case by case basis the L.H.R. may relax SOLAS II-1/26.11 to accommodate day tanks sized for maximum continuous rating, and use the vessel’s cruising speed.

8.4 Alternative design and arrangements (all yachts)

8.4.1 Vessels may follow Part 1, Chapter 2, Section 1.9 on Alternative Design and Arrangements for this chapter as allowed by SOLAS II-1/55.

8.4.2 The engineering analysis required by Part 1, Chapter 2, Section 1.9, Paragraph 1.9.3 shall be prepared and submitted to L.H.R. based on the guidelines (SOLAS chapters II-1 and III (MSC.1/Circ.1212)) and shall include, as a minimum, the following engineering analysis elements:

- a) determination of the ship type, machinery, electrical installations and space(s) concerned;
- b) identification of the prescriptive requirement(s) with which the machinery and electrical installations will not comply;
- c) identification of the reason the proposed design will not meet the prescriptive requirements supported by compliance with other recognized engineering or industry standards;
- d) determination of the performance criteria for the ship, machinery, electrical installation or the space(s) concerned addressed by the relevant prescriptive requirement(s):
    - i. performance criteria shall provide a level of safety not inferior to the relevant prescriptive requirements contained in SOLAS II-1 parts C, D and E; and
    - ii. performance criteria shall be quantifiable and measurable;
- e) detailed description of the alternative design and arrangements, including a list of the assumptions used in the design and any proposed operational restrictions or conditions;
- f) technical justification demonstrating that the alternative design and arrangements meet the safety performance criteria; and
- g) risk assessment based on identification of the potential faults and hazards associated with the proposal.

CHAPTER 2 Piston Engines

Contents

SECTION 1 General

1.1 Application

1.1.1 The Rules of this Chapter apply to mass-produced internal combustion engines used as main propulsion units or auxiliary units. For the purpose of these Rules, internal combustion engines are diesel engines.

1.1.2 In case of non mass-produced engines, special consideration is required, after taking into account the relevant applicable requirements of Part 5, Chapter 2 of the "Rules and Regulations for the Classification and Construction of Steel Ships".

1.2 Definition of diesel engine type (IACS M71(2016))

1.2.1 Engines are of the same type if they don't vary in any detail included in the definition 1.2.2. When two engines are to be considered of the same type it is assumed that they do not substantially differ in design and their design details, crankshaft, e.t.c., and the materials used meet Rule requirements and are approved by the Society.

1.2.2 The type of internal combustion engine expressed by the Engine Builder's designation is defined by:

(a) the bore,

(b) the stroke,

(c) the method of injection (direct or indirect injection),

(d) valve and injection operation (by cams or electronically controlled)

(e) the kind of fuel (liquid, dual-fuel, gaseous),

(f) the working cycle (4-stroke, 2-stroke)

(g) the maximum continuous power per cylinder at maximum continuous speed and /or maximum continuous brake mean effective pressure, 2

(h) the method of pressure charging (pulsating system, constant pressure system),

(i) the charging cooling system (with or without intercooler, number of stages),

(j) cylinder arrangement (in-line or V). 1

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 Societie's discretion, separate type tests may be required for the V-version. On the other hand, a type test of a V-engine covers the in-line engines, unless the bmep is higher. Items such as axial crankshaft vibration, torsional vibration in camshaft drives, and crankshafts, etc. may vary considerably with the number of cylinders and may influence the choice of engine to be selected for type testing.

2. One type test suffices for the whole range of engines having different numbers of cylinders. The engine is type approved up to the tested ratings and pressures (100% corresponding to MCR). Provided documentary evidence of successful service experience with the classified rating of 100% is submitted, an increase (if design approved*) may be permitted without a new type test if the increase from the type tested engine is within:

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

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

* Only crankshaft calculation and crankshaft drawings, if modified.

De-rated engine

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

- Test at over speed (only if nominal speed has increased)
- Rated power, i.e. 100% output at 100% torque and 100% speed corresponding to load point 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

Integration Test

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

1.3 Documents for the approval of diesel engines (IACS M44(2022))

1.3.1 Scope

The documents necessary to approve a diesel engine design for conformance to the Rules and for use during manufacture and installation are listed. The document flow between engine designer, Society approval centre, engine builder/licensee and Society's Surveyors is provided.

1.3.2 Overview

1.3.2.1 Approval process

1.3.2.1.1 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 in 1.3.3. 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.

1.3.2.1.2 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 1.3.4. 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 1.3.2.1.1, 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.

1.3.2.2 Documents flow for diesel engines

1.3.2.2.1 Document flow for obtaining a type approval certificate

(a) For the initial engine type, the engine designer prepares the documentation in accordance with requirements in Table 2.1.1 and Table 2.1.2 and forwards to the Society according to the agreed procedure for review.
(b) Upon review and approval of the submitted documentation (evidence of approval), it is returned to the engine designer.
(c) The engine designer arranges for a Surveyor to attend an engine type test and upon satisfactory testing the Society issues a type approval certificate.

1.3.2.2.2 Document flow for engine certificate

(a) 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 (ECP) may be performed simultaneously.
(b) Engines to be installed in specific applications may require the engine designer/licensor to modify the design or performance requirements. The modified drawings are forwarded by the engine designer to the engine builder/licensee to develop production documentation for use in the engine manufacture in accordance with Table 2.1.3. The engine builder/licensee develops a comparison list of the production documentation to the documentation listed in Table 2.1.1 and Table 2.1.2.

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.

(c) The engine builder/licensee submits the comparison list and the production documentation to the Society according to the agreed procedure for review/approval.
(d) The Society 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 Surveyors. As the attending 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 Surveyors.

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

(f) The engine builder/licensee assembles the engine, tests the engine with a Surveyor present. An engine certificate is issued by the Surveyor upon satisfactory completion of assembly and tests.

(g) For a representative document flow process for obtaining an engine certificate refer to IACS UR M44.

1.3.2.3 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.).

1.3.2.4 Submission format of documentation

The Society determines the documentation format: electronic or paper. If documentation is to be submitted in paper format, the number of copies is determined by the Society.

1.3.3 Type approval process

The type approval process consists of the steps in 1.3.4.1 to 1.3.4.4.

The documentation, as far as applicable to the type of engine, to be submitted by the engine designer/licensor to the Society is listed in Table 2.1.1 and Table 2.1.2.

1.3.4.1 Documents for information Table 1

Table 2.1.1 lists basic descriptive information to provide the Society 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.

1.3.4.2 Documents for approval or recalculation Table 2

Table 2.1.2 lists the documents and drawings, which are to be approved by the Society.

1.3.4.3 Design approval/appraisal (DA)

DA's are valid as long as no substantial modifications have been implemented. Where substantial modifications have been made the validity of the DA's may be renewed based on evidence that the design is in conformance with all current Rules and statutory regulations (e.g. SOLAS, MARPOL). See also 1.3.4.6.

1.3.4.4 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 Society.

The manufacturing facility of the engine presented for the type approval test is to be assessed in accordance with IACS UR M72.

1.3.4.5 Type approval certificate

After the requirements in 1.3.4.1 through 1.3.4.4 have been satisfactorily completed the Society issues a type approval certificate (TAC).

1.3.4.6 Design modifications

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

1.3.4.7 Type approval certificate renewals

A renewal of type approval certificates will be granted upon:

1.3.4.7.1 Submission of information in either (a) or (b)

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

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

1.3.4.8 Validity of type approval certificate

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

1.3.4.9 Document review and approval

1.3.4.9.1 The assignment of documents to Table 2.1.1 for information does not preclude possible comments by LHR.

1.3.4.9.2 Where considered necessary, the Society may request further documents to be submitted. This may include details or evidence of existing type approval or proposals for a type testing programme in accordance with IACS UR M71.

1.3.4 Certification process

The certification process consists of the steps in 1.3.5.1 to 1.3.5.5. This process showing the document flows between the:

- engine designer/licensor,
- engine builder/licensee,
- component manufacturers,
- Society approval centre, and
- Society site offices.

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 2.1.3 may be submitted by:

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

1.3.5.1 Document development for production

Prior to the start of the engine certification process, a design approval is to be obtained per 1.3.4.1 through 1.3.4.3 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 Table 2.1.1 and Table 2.1.2 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 Society as per 1.3.4.6.

1.3.5.2 Documents to be submitted for inspection and testing

Table 2.1.3 lists the production documents, which are to be submitted by the engine builder/licensee to the Classification Society following acceptance by the engine designer/licensor. The Surveyor uses the information for inspection purposes during manufacture and testing of the engine and its components. See (b) through (e).

1.3.5.3 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 Society 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.

1.3.5.4 Manufacturer approval

The Society assesses conformity of production with the Society'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 class approval document.

1.3.5.5 Document availability

In addition to the documents listed in Table 2.1.3, the engine builder/licensee is to be able to provide to the Surveyor performing the inspection upon request the relevant detail drawings, production quality control specifications and acceptance criteria. These documents are for supplemental purposes to the survey only.

1.3.5.6 Engine assembly and testing

Each engine assembly and testing procedure required according to relevant IACS URs are to be witnessed by the Society unless an Alternative Certification Scheme meeting the requirements of IACS UR Z26 is agreed between manufacturer and the Society.

Table 2.1.1: Documentation to be submitted for information, as applicable

No.	Item
1	Engine particulars (e.g. Data sheet with general engine information, 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 IACS UR E10.

Table 2.1.2: Documentation to be submitted for approval, as applicable

No.	Item
1	Bedplate and crankcase of welded design, with welding details and welding Instruction (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 drawing (1), (2)
6	Crankshaft, details, each cylinder No.
7	Crankshaft, assembly, each cylinder No.
8	Crankshaft calculations (for each cylinder configuration) according to the attached data sheet and IACS 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 IACS UR M9) (5)
23	Calculation results for crankcase explosion relief valves (see IACS 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 IACS UR M10)
27	Details of mechanical joints of piping systems (see IACS UR P2)
28	Documentation verifying compliance with inclination limits (see IACS UR M46)
29	Documents as required in IACS 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 Society requirements for material, NDT and pressure testing as applicable.

(4) All engines.

(5) Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0,6 m^3 or more.

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

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

Table 2.1.3: 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
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 Society requirements for material, NDT and pressure testing as applicable.

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

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

(4) All engines.

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

(6) Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0,6 m^3 or more.

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

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

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

(10) Documents modified for a specific application are to be submitted to the Society for information or approval, as applicable. See (b).

SECTION 2 Rated power

2.1 General

2.1.1 Diesel engines are to be capable to deliver their rated power when running at rated speed as a continuous net brake power. Diesel engines are to be capable of continuous operation within power range A in Figure 2.2.1 and of short-period operation in power range B. The extent of the power ranges are to be stated by the engine manufacturer.

2.1.2 For the purposes of this Chapter, continuous power means the net brake power which an engine is capable of delivering continuously, provided that the maintenance prescribed by the engine manufacturer is carried out, between the maintenance intervals stated by the engine manufacturer.

2.1.3 To verify that an engine is rated at its continuous power, it is to be demonstrated that the engine can run at an overload power corresponding to 110% of its rated power at corresponding speed for an uninterrupted period of 1 hour. Deviations from the overload power value require the agreement of the Society.

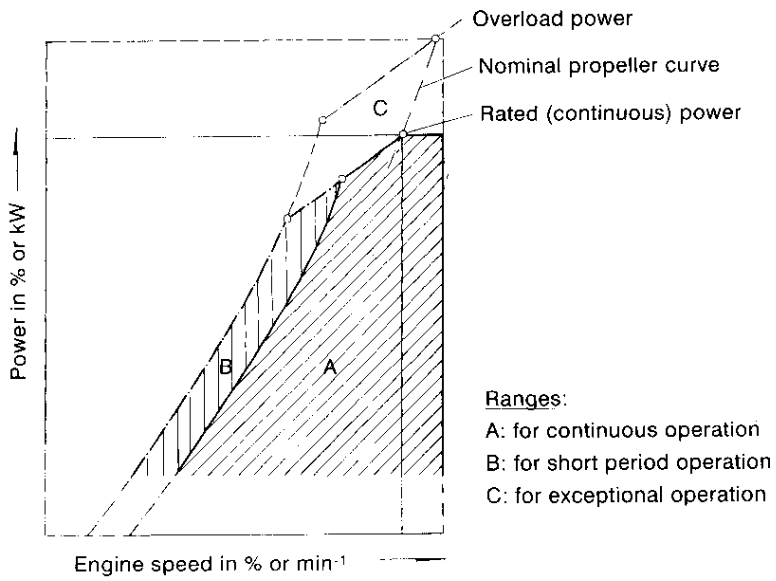
2.1.4 After running on the test bed, the fuel delivery system of main engines is normally to be so adjusted that overload power cannot be given in service.

2.1.5 Subject to the prescribed conditions, diesel engines driving electric generators must be capable of overload operation even after installation on board.

2.1.6 Subject to the approval of the Society, diesel engines for special vessels and special applications may be designed for a continuous power (fuel stop power) which cannot be exceeded.

2.1.7 For main engines, a power diagram (Figure 2.2.1) is to be prepared showing the power ranges within which the engine is able to operate continuously and for short periods under service conditions.

Figure 2.2.1: Example of a power diagram



SECTION 3 Piping

3.1 Lubricating oil filters

3.1.1 Suitable lubricating oil filters should be used in lubricating oil lines located in the main oil flow on the delivery side of the pumps.

3.1.2 The arrangement of that main flow filters should be such that to ensure easy cleaning or substitution, without interrupting operation.

3.1.3 With automatic filters, by-pass systems can be approved by the Society if simplex filters in accordance with 3.1.4 are fitted downstream. By-pass systems are not permitted for switch-over duplex filters.

3.1.4 Where simplex filters are used after the main filters the simplex filters are normally to be provided with a by-pass and a differential pressure alarm.

3.1.5 On main engines the lubricating oil for which is supplied from the engine oil sump and which have rated power less than 220 kW the use of simplex filters is permitted only if the latter are equipped with a pressure alarm and can be substituted during operation.

3.2 Exhaust systems

3.2.1 Exhaust gas lines are to be fitted with expansion compensators.

3.2.2 The exhaust gas lines of main and auxiliary engines are to be fitted with suitable silencers.

3.2.3 The surface temperature of the exhaust gas lines should normally not to exceed 220°C. This may be obtained by using proper insulation or cooling means.

3.2.4 Where lagging covering the exhaust piping system including flanges is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent.

3.2.5 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the engine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard.

3.2.6 Where the exhausts of two or more engines are led to a common silencer or exhaust gas- heated boiler or economizer, an isolating device is to be provided in each exhaust pipe.

3.2.7 In two stroke engines with exhaust gas turbo-blowers operating on the impulse systems, due care is to be taken for preventing broken piston rings entering the turbine casing.

SECTION 4 Tests and trials

4.1 Alternative Certification Scheme (ACS) (4.1.1:IACS UR Z26 (2015), 4.1.2-4.1.5: IACS UR Z26 (2015)), Type Testing of I.C. Engines(4.1.6-4.1.13:IACS UR M71 (1974)), Turbochargers (4.1.14-:IACS UR M73 (2022))

4.1.1 Definitions (Alternative Certification Scheme)

(a) ACS is a certification scheme involving a manufacturer (and associated sub-suppliers, if needed) in the inspection, testing and certification of the manufacturer's products.

(b) An ACS will clarify:

- The extent of the required inspection and testing.
- To which extent and under which conditions the manufacturer may perform all or parts of the required inspection and testing without the presence of a Surveyor from the Society when a Society Certificate is required.

(c) The extent to which the manufacturer is given permission to carry out inspections and testing without the presence of a Surveyor is to be agreed on a case by case basis, e.g. for a specific product production line or for specific parts.

4.1.2 Scope

(a) An ACS may be arranged with product manufacturers and/or sub-suppliers.

(b) An ACS with a manufacturer must define the handling of subcontracted parts (those that require Society or work certificates or in any other way are addressed in the Society's Rules). The sub-supplier may be included in the ACS of the manufacturer or have his own ACS or deliver parts that are inspected and certified by the Society.

(c) An ACS that permits the manufacturer to carry out all or parts of required inspection and testing without the presence of a Surveyor may be arranged in two versions with regard to traceability:

– The ACS describes inspection, testing and certification additional to the manufacturer's standard quality control in order to meet the Rules. The components are to be stamped with a special stamp supplied by the Society or identified as required by the Society.
– The manufacturer has a standard quality control that covers all required inspection, testing and certification in compliance with the Rules. Traceability and the required type of product document for components or products will be defined in the ACS.

4.1.3 Conditions

.1 The conditions for the manufacturer to be granted the permission to carry out inspection and testing without the presence of a Surveyor are that:

- The manufacturer has an implemented Quality System according to a national or international standard approved by an accredited certification body or recognised by the Society.
- The manufacturer has a quality control system, current drawings, and Rules and standards that cover the product to be certified.
- The inspection and testing required by the Rules are either standard procedures in the Quality System and recognized by the Society or specified in detail in the ACS.
- The Society initially ascertains the manufacturer's compliance with the ACS requirements by verifying the required product and process approvals and performing an initial audit. Follow-up and renewal audits are conducted by the Society on a regular basis to verify that conditions of the ACS are continuously maintained by the manufacturer.
- If work certificates (W) or test reports (TR) are found not to fulfil the standards agreed with the Society, the component may not be accepted.
- The agreed ACS may be suspended or cancelled when / if found justified by the Society.
- The Society may carry out unscheduled inspections at the manufacturer and/or subcontractor at its own discretion.
- The manufacturers (and designers, if producing under license) commit themselves to involve the Society

when changes to the design, manufacturing process or testing are made as well as when any major production problems or any major product delivery problems have occurred.

- The validity of an ACS is to be a maximum of 5 years. The ACS may be renewed subject to an audit. The scope of the renewal audit shall:

  .1 verify the conditions of the ACS are still met

  .2 verify that the current products and processes are appropriately controlled

4.1.4 Information to be submitted

(a) For admission to an alternative certification scheme for a product, the manufacturer is to submit an application enclosing the following documentation:

  - Product details.
  - Existing class approvals of the manufacturer's products as far as required.
  - The procedures relevant to the manufacturing process.
  - A list of material suppliers with an indication of their class approval (as far as required by the Rules) and the type of material certification in each case.
  - Quality control plans relevant to the products and relevant components to be certified through the alternative certification scheme. Said plans are to detail the inspections and tests required by the Rules with an indication of which inspections and tests are delegated to the manufacturer and which are to be done in the presence of a Society representative.
  - The procedures relevant to the quality control and inspections, their methods, frequency and certification.
  - The list of suppliers of materials and main components of the product, including certificates.
  - The quality system details.
  - List of nominated personnel for:

    .1 Marking/stamping of products

    .2 Tests and Inspection (responsible)

    .3 Provision of data and information (e.g. declaration of conformity, test reports etc.)

  - Any other additional documents that the Society may require in order to evaluate the manufacturing processes and product quality control.

4.1.5 Information to be submitted

(a) Upon satisfactory examination of the complete documentation for application an initial audit shall be carried out at the manufacturer's works. This audit is to verify that the manufacture of the product and the relevant controls are performed in accordance with the documents submitted and are in compliance with the requirements laid down in the ACS documentation and the Society Rules.

(b) Upon satisfactory outcome of the audits, the extent, duration and conditions of the ACS are documented.

(c) At least one intermediate audit during the period of validity of the ACS is to be carried out. Additional audits may be required at the discretion of the Society.

4.1.6 General (Type Testing of I.C. Engines)

(a) Type approval of I.C. 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 maximum period of validity of a Type Approval Certificate is 5 years. The requirements for drawing approval and specification approval of engines and components are specified in separate URs.

(b) For the purpose of this UR, 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.

4.1.7 Objectives

(a) The type testing, documented in this UR, 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.

(b) 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.

4.1.8 Safety precautions

(a) Before any test run is carried out, all relevant equipment for the safety of attending personnel is to functioning is to be verified.

(b) This applies especially to crankcase explosive conditions protection, but also overspeed protection and any other shut down function.

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

(d) Interlock test of turning gear is to be performed when installed.

4.1.9 Test programme

(a) 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 Society or stipulated by the designer are to be presented to the Society before starting stage B.

- Stage B - witnessed tests.

This is the testing made in the presence of Classification Society personnel.

- Stage C - component inspection.

This is the inspection of engine parts to the extent as required by the Society.

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

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

(d) Upon completion of complete type testing (stage A through C), a type test report is to be submitted to the Society for review. The type test report is to contain:

- overall description of tests performed during stage A. Records are to be kept by the builders QA management for presentation to the Classification Society.
- detailed description of the load and functional tests conducted during stage B.
- inspection results from stage C.

(e) As required in 4.1.7 the type testing is to substantiate the capability of the design and its suitability for the intended operation. Special testing such as LCF and endurance testing will normally be conducted during stage A.

(f) 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 1.2.

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.

4.1.10 Measurements and recordings

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

(b) 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.

4.1.11 Stage A - internal tests

(a) 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.

(b) At least the following conditions are to be tested:

- Normal case:

The load points 25%, 50%, 75%, 100% and 110% of the maximum rated power for continuous operation, to be made along the normal (theoretical) propeller curve and at constant speed for propulsion engines (if applicable mode of operation i.e. driving controllable pitch propellers), and at constant speed for engines intended for generator sets including a test at no load and rated speed.

- The limit points of the permissible operating range. These limit points are to be defined by the engine manufacturer.
- For high speed engines, the 100 hr full load test and the low cycle fatigue test apply as required in connection with the design assessment.
- Specific tests of parts of the engine, required by the Society or stipulated by the designer.

4.1.12 Stage B - witnessed tests

(a) 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.

(b) 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.

(c) Load points

The engine is to be operated according to the power and speed diagram (see

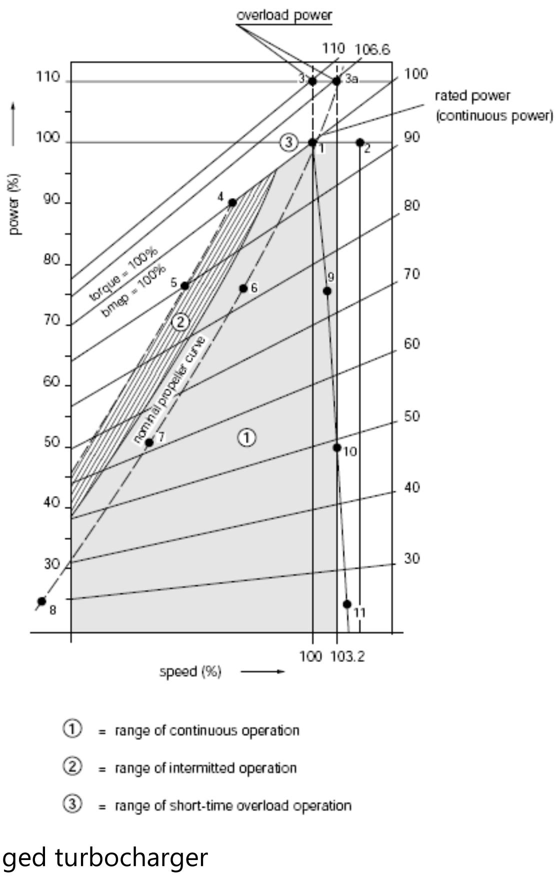
Figure 2.4.1). The data to be measured and recorded when testing the engine at the various load points have to include all engine parameters listed in 4.1.10. The operating time per load point depends on the engine size (achievement of steady state condition) and on the time for collection of the operating 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.

(d) 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.

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

Figure 2.4.1: Load points



(f) 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.)

(g) 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 waterbrake). 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.

(h) 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 Society for selected cases based on the FMEA required in IACS UR M44 (see 1.3).

(i) 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 Society. Readings obtained are to be randomly verified by use of contact thermometers.

4.1.13 Stage C - Opening up for Inspections

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

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

(c) 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.)

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

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

4.1.14 Scope (Turbochargers)

(a) 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.

(b) 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).

(c) 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

4.1.15 Documentation to be submitted

(a) Category A:

On request

- Containment test report.
- Cross sectional drawing with principal dimensions and names of components.
- Test program.

(b) 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 (b).
- Operational data and limitations as:
- Maximum permissible operating speed (rpm)
- Alarm level for over-speed
- Maximum permissible exhaust gas temperature before turbine
- Alarm level for exhaust gas temperature before turbine

- Minimum lubrication oil inlet pressure
- Lubrication oil inlet pressure low alarm set point
- Maximum lubrication oil outlet temperature
- Lubrication oil outlet temperature high alarm set point
- Maximum permissible vibration levels, i.e. self- and externally generated vibration

(Alarm levels may be equal to permissible limits but shall not be reached when operating the engine at 110% power or at any approved intermittent overload beyond the 110%.)

- Arrangement of lubrication system, all variants within a range.
- Type test reports.
- Test program.
- 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 (c).
- Information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue.
- Operation and maintenance manuals*.

  * Applicable to two sizes in a generic range of turbochargers.

4.1.16 Design requirements and corresponding type testing

(a) General

- The turbochargers shall be designed to operate under conditions given in IACS UR M46 (see CHAPTER 13.2) and IACS UR M28 (see CHAPTER 13.1). The component lifetime and the alarm level for speed shall be based on 45° C air inlet temperature.
- The air inlet of turbochargers shall be fitted with a filter.

(b) Containment

- 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.
- For category B and C, containment shall be documented by testing. Fulfilment of this requirement can be awarded to a generic range** of turbochargers based on testing of one specific unit. Testing of a large unit is preferred as this is considered conservative for all smaller units in the generic range. In any case, it must be documented (e.g. by calculation) that the selected test unit really is representative for the whole generic range.

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

- 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.

- Containment tests shall be performed at working temperature.
- A numerical analysis (simulation) of sufficient containment integrity of the casing based on calculations by means of a simulation model may be accepted in lieu of the practical containment test, provided that:
  - The numerical simulation model has been tested and its suitability/accuracy has been proven by direct comparison between calculation results and the practical containment test for a reference application (reference containment test). This test shall be performed at least once by the manufacturer for acceptance of the numerical simulation method in lieu of tests.
  - The corresponding numerical simulation for the containment is performed for the same speeds as specified for the containment test.
  - Material properties for high-speed deformations are to be applied in the numeric simulation. The correlation between normal properties and the properties at the pertinent deformation speed are to be substantiated.
  - The design of the turbocharger regarding geometry and kinematics is 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.

(c) Disc-shaft shrinkage fit

- Applicable to Category C
- 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.

(d) Type testing

- Applicable to Categories B and C
- 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.
- Turbochargers 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 IACS UR M71.
- The suitability of the turbocharger for such kind of operation is to be preliminarily stated by the manufacturer.
- The rotor vibration characteristics shall be measured and recorded in order to identify possible sub-synchronous vibrations and resonances.
- 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.
- The extent of the surveyor’s presence during the various parts of the type tests is left to the discretion of the Society.

4.1.17 Certification

(a) 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.

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

(c) 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.

(d) Turbochargers shall be delivered with:

- For category C, a society certificate, which at a minimum cites the applicable type approval and the ACS, when ACS applies.
- For category B, a work's certificate, which at a minimum cites the applicable type approval, which includes production assessment.

(e) The same applies to replacement of rotating parts and casing.

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

4.1.18 Alarms & Monitoring

(a) For all turbochargers of Categories B and C, indications and alarms as listed in Table 2.4.1 are required.

(b) Indications may be provided at either local or remote locations.

Table 2.4.1:

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	high (1)	X (1)	high	X	High temp. alarms for

	each turbocharger inlet, temperature					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 turbocharger(s) being activated last in the sequence, provided all turbochargers share the same intake air filter and they are not fitted with waste gates.

4.2 Programme for trials of internal combustion engines (IACS UR M51 (2018))

4.2.1 Safety precautions

4.2.1.1 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.

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

4.2.1.3 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.

4.2.2 General

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

4.2.2.2 Adequate test bed facilities for loads as required in 4.2.3.3 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.

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

4.2.2.4 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 Society may request temperature measurements as required by (i).

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

4.2.3 Works trials (Factory Acceptance Test)

4.2.3.1 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.

4.2.3.2 Records

4.2.3.2.1 The following environmental test conditions are to be recorded:

- Ambient air temperature
- Ambient air pressure
- Atmospheric humidity

4.2.3.2.2 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)

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

4.2.3.2.4 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.

4.2.3.2.5 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.

4.2.3.3 Test loads

4.2.3.3.1 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 Society when the overall scope of tests is found to be equivalent.

(a) Propulsion engines driving propeller or impeller only.

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

.2 110% power at engine speed n = 1,032·n_0: Records to be taken after 15minutes or after steady conditions have been reached, whichever is shorter.

NOTE:

Only required once for each different engine/turbocharger configuration.

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

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

.5 Reversing manoeuvres (if applicable).

Note:

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

(b) Engines driving generators for electric propulsion

The test is to be performed at rated speed with a constant governor setting under conditions of:

.1 100% power (MCR) at corresponding speed: at least 60 min, - after having reached steady conditions

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

.3 Governor tests for compliance with IACS UR M3.1 and M3.2 are to be carried out.

.4 75%, 50% and 25% power and idle run, 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.

(c) Engines driving generators for auxiliary purposes.

Test to be performed in accordance with (b).

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

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

.2 110% power at engine speed n_0: Records to be taken after 15minutes after having reached steady conditions.

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

.4 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve or at constant speed n_o, 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.

(e) Engines driving auxiliaries.

.1 100% power (MCR) at corresponding speed n_0: at least 30 min.

.2 110% power at engine speed n_0: 15minutes after steady conditions have been reached.

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

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

Note:

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.

4.2.3.4 Turbocharger matching with engine

4.2.3.4.1 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.

4.2.3.4.2 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:

1. 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).
2. 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.
   - The engine load corresponding to a charge air pressure of about 0.6 bar (but without auxiliary blowers running).
3. No continuous surging and the turbocharger shall be stabilised at the new load within 20 seconds when the power is abruptly reduced from 100% to 50% of the maximum continuous power.

4.2.3.5 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 Society for selected cases based on the FMEA required in IACS UR M44 (see 1.3).

4.2.3.6 Component inspections

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

4.2.4 Shipboard trials

4.2.4.1 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).

4.2.4.2 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.

4.2.4.3 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.

4.2.4.4 Test loads

4.2.4.4.1 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.

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

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).

4.2.4.4.3 Propulsion engines driving fixed pitch propeller or impeller.

.1 At rated engine speed n0: at least 4 hours.
.2 At engine speed 1,032·n0 (if engine adjustment permits, see 4.2.4.4.1): 30 min.
.3 At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
.4 Minimum engine speed to be determined.
.5 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 4.2.5.1 for additional requirements in the case of a barred speed range.

4.2.4.4.4 Propulsion engines driving controllable pitch propellers

.1 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.
.2 At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
.3 With reverse pitch suitable for manoeuvring, see 4.2.5.1 for additional requirements in the case of a barred speed range.

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

.1 At 100% power (rated electrical power of generator): at least 60 min.
.2 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.

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

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

.1 100% engine power (MCR) at corresponding speed n0: at least 4 hours.
.2 100% propeller branch power at engine speed n_0 (unless already covered in .1: 2 hours.
.3 100% PTO branch power at engine speed n_0: at least 1 hour.

4.2.4.4.7 Engines driving auxiliaries.

.1 100% power (MCR) at corresponding speed n_0: at least 30 min.
.2 Approved intermittent overload: testing for duration as approved.

4.2.5 Torsional vibrations

4.2.5.1 Barred speed range

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).

SECTION 5 Engine alignment

5.1 General

5.1.1 The crankshaft alignment is to be checked every time an engine has been aligned on its foundation by measurement of the crank web deflections.

Note is to be taken of:

(a) The loading condition of the ship, and

(b) The condition of the engine (whether hot or cold).

CHAPTER 3 Main Propulsion Shafting

Contents

SECTION 1 General

1.1 Scope

1.1.1 The requirements of this Chapter are applicable to normal and accepted types of main shafting. In the present Chapter formulas for determining the diameters for shafting for main propulsion installations are included along with requirements for the design of sternbushes, keys, keyways, couplings, coupling bolts and other relevant parts. Any modification to the diameters determined from the formulas of the present Chapter due to alignment requirements is acceptable.

1.2 Documents for approval

1.2.1 The following plans are to be submitted to the Society for consideration before the commencement of the work:

(a) general arrangement of the entire shafting from main engine coupling to propeller,

(b) detail drawing of the final gear shaft,

(c) detail drawing of the thrust shaft,

(d) detail drawing of the internmediate shafting,

(e) drawing of the tube shaft, where applicable,

(f) drawings of the screwshaft and screwshaft oil gland,

(g) drawing of the sternbursh.

1.2.2 The following data are also to be submitted for approval:

(a) material specifications,

(b) strength calculations,

(c) vibration calculations.

1.2.3 The Society reserves the right to ask for any additional information.

SECTION 2 Materials

2.1 Materials for shafts

2.1.1 In the design calculations of shafting, the minimum tensile strength of forgings for shafts is to be taken within the following limits

(a) Carbon and carbon-manganesse steel: 400 to 600 N/mm^2.

(b) Alloy steel: not exceeding 800 N/mm^2.

2.1.2 Where it is proposed to use alloy steel, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

2.2 Ultrasonic tests

2.2.1 Ultrasonic tests are required on shaft forgings where the diameter is 250 mm or greater.

SECTION 3 Design

3.1 Dimensions of propulsion shafts and their permissible torsional vibration stresses (IACS M68 (2021))

3.1.1 Scope

This UR applies to propulsion shafts such as intermediate and propeller shafts of traditional straight forged design and which are driven by rotating machines such as diesel engines, turbines or electric motors.

For shafts that are integral to equipment, such as for gear boxes, podded drives, electrical motors and/or generators, thrusters, turbines and which in general incorporate particular design features, additional criteria in relation to acceptable dimensions have to be taken into account. For the shafts in such equipment, the requirements of this UR may only be applied for shafts subject mainly to torsion and having traditional design features. Other limitations, such as design for stiffness, high temperature, etc. are to be addressed by specific rules of the Society.

Explicitly the following applications are not covered by this UR:

- additional strengthening for shafts in ships classed for navigation in ice
- gearing shafts
- electric motor shafts
- generator rotor shafts
- turbine rotor shafts
- diesel engine crankshafts (see IACS M53)
- unprotected shafts exposed to sea water

3.1.2 Alternative calculation methods

Alternative calculation methods may be considered by the classification society. Any alternative calculation method is to include all relevant loads on the complete dynamic shafting system under all permissible operating conditions. Consideration is to be given to the dimensions and arrangements of all shaft connections.

Moreover, an alternative calculation method is to take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and for peak operating loads (dimensioning for yield strength). The fatigue strength analysis may be carried out separately for different load assumptions, for example as given in 3.1.7.1.

3.1.3 Material limitations

Where shafts may experience vibratory stresses close to the permissible stresses for transient operation, the materials are to have a specified minimum ultimate tensile strength (σ_B) of 500 N/mm^2. Otherwise materials having a specified minimum ultimate tensile strength (σ_B) of 400 N/mm^2 may be used.

For use in the following formulae in this UR, σ_B is limited as follows:

- For carbon and carbon manganese steels, a minimum specified tensile strength not exceeding 600 N/mm^2 for use in 3.1.5 and not exceeding 760 N/mm^2 in 3.1.4.
- For alloy steels, a minimum specified tensile strength not exceeding 800 N/mm^2.

- For propeller shafts in general a minimum specified tensile strength not exceeding 600 N/mm^2 (for carbon, carbon manganese and alloy steels).

Where materials with greater specified or actual tensile strengths than the limitations given above are used, reduced shaft dimensions or higher permissible vibration stresses are not acceptable when derived from the formulae in this UR unless the Society verifies that the materials exhibit similar fatigue life as conventional steels (see Appendix I

3.1.4 Shaft diameters

Shaft diameters are not to be less than that determined from the following formula:

$$d = F \times k \times \sqrt[3]{\frac{P}{n_0} \times \frac{1}{1 - \left(\frac{d_i}{d_o}\right)^4} \times \frac{560}{\sigma_B + 160}}$$

where:

d = minimum diameter, mm,

d_i = actual diameter of shaft bore, mm,

d_o = actual outside diameter of shaft, mm. If the bore in the shaft is ≤ 0,4d_o the expression

$1 - \left(\frac{d_i}{d_o}\right)^4$ = 1,0 may be taken

k = factor for the particular shaft design features, see 3.1.6

n_0 = rated speed of intermediate shaft, rpm,

F= factor for type of propulsion installation

= 95 for intermediate shafts in turbine installation, diesel installations with hydraulic (slip type) couplings, electric propulsion installations

= 100 for all other diesel installations and all propeller shafts

P = rated power in kW transmitted through the shaft (losses in gearboxes and bearings are to be disregarded)
σ_B = specified minimum tensile strength in N/mm2 of the shaft material, see 3.1.3

The diameter of the propeller shaft located forward of the inboard stern tube seal may be gradually reduced to the corresponding diameter required for the intermediate shaft using theminimum specified tensile strength of the propeller shaft in the formula and recognising anylimitations given in M68.3.

3.1.5 Permissible torsional vibration stresses

The alternating torsional stress amplitude is understood as (τ_{max} - τ_{min}) / 2 as can be measured on a shaft in a relevant condition over a repetitive cycle.

Torsional vibration calculations are to include normal operation and operation with any one cylinder misfiring (i.e. no injection but with compression) giving rise to the highest torsional vibration stresses in the shafting.

For continuous operation the permissible stresses due to alternating torsional vibration are not to exceed the values given by the following formulae:

$$\pm\tau_c = \frac{\sigma_B + 160}{18} \times C_K \times C_D \times (3 - 2 \times \lambda^2)\ for\ \lambda < 0{,}9$$

$$\pm\tau_c = \frac{\sigma_B + 160}{18} \times C_K \times C_D \times 1{,}38\ \ for\ 0{,}9 \le \lambda < 1{,}05$$

Where:

τ_c = permissible stress amplitude in N/mm^2 due to torsional vibration for continuous operation

σ_B = specified minimum ultimate tensile strength in N/mm^2 of the shaft material, see also 3.1.3

c_K = factor for the particular shaft design features, see 3.1.6

c_D = size factor

= $0{,}35 + 0{,}93 \times d_0^{-0.2}$

d_0 = shaft outside diameter in mm

λ = speed ratio = n/n_0

n= speed in revolutions per minute under consideration

n_0 = speed in revolutions per minute of shaft at rated power

Where the stress amplitudes exceed the limiting values of τ_c for continuous operation, including one cylinder misfiring conditions if intended to be continuously operated under such conditions, restricted speed ranges are to be imposed which are to be passed through rapidly.
Restricted speed ranges in normal operating conditions are not acceptable above λ = 0,8.
Restricted speed ranges in one-cylinder misfiring conditions of single propulsion engine ships are to enable safe navigation.
The limits of the barred speed range are to be determined as follows:

(a) The barred speed range is to cover all speeds where the acceptance limits (τ_c) are exceeded. For controllable pitch propellers with the possibility of individual pitch and speed control, both full and zero pitch conditions have to be considered. Additionally the tachometer tolerance has to be added. At each end of the barred speed range the engine is to be stable in operation.
(b) In general and subject to (a) the following formula may be applied, provided that the stress amplitudes at the border of the barred speed range are less than τ_c under normal and stable operating conditions.

$$\frac{16 \times n_c}{18 - \lambda_c} \le n \le \frac{(18 - \lambda_c) \times n_c}{16}$$

Where:

n_c = critical speed in revolutions per minute (resonance speed)

λ_c = speed ratio = n_c/n_o

For the passing of the barred speed range the torsional vibrations for steady state condition are not to exceed the value given by the formula:

$$\pm\tau_T = 1{,}7 \times \frac{\tau_c}{\sqrt{c_K}}$$

Where:

τ_T = permissible stress amplitude in N/mm^2 due to steady state torsional vibration in a barred speed range.

3.1.6 Table of k and c_K factors for different design features (see 3.1.7.2)

Table 3.3.1:

Intermediate shafts with						thrust shafts external to engines		propeller shafts		
integral coupling flange (1) and straight sections	shrink fit coupling (2)	Keyway, tapered connection (3)(4)	Keyway, cylindrical connection (3)(4)	radial hole (5)	longitudinal slot (6)	on both sides of thrust collar (1)	in way of bearing when a roller bearing is used	Flange mounted or keyless taper fitted propellers (8)	Key fitted propellers (8)	Between forward end of aft most bearing and forward stern tube seal
k=1,0	1,0	1,10	1,10	1,10	1,20	1,10	1,10	1,22	1,26	1,15
c_K=1,0	1,0	0,60	0,45	0,50	0,30 (7)	0,85	0,85	0,55	0,55	0,80

Note:

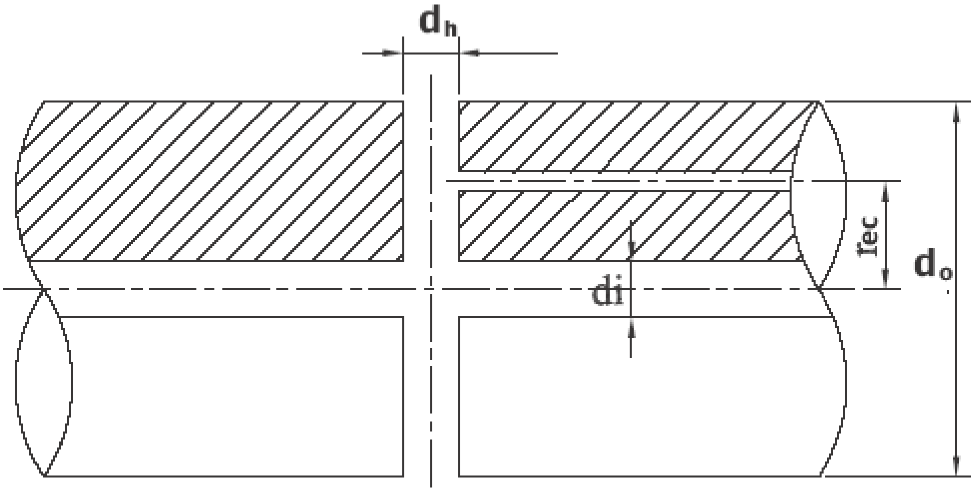
Transitions of diameters are to be designed with either a smooth taper or a blending radius. For guidance, a blending radius equal to the change in diameter is recommended.

Footnotes

(1) Fillet radius is not to be less than 0,08d.
(2) k and c_K refer to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2 % and a blending radius as described in the table note.
(3) At a distance of not less than 0,2do from the end of the keyway the shaft diameter may be reduced to the diameter calculated with k=1,0.
(4) Keyways are in general not to be used in installations with a barred speed range.
(5) Diameter of radial bore (dh) not to exceed 0,3do. The intersection between a radial and an eccentric

(rec) axial bore (see below) is not covered by this UR.

Figure 3.3.1:



(6) Subject to limitations as slot length (l)/outside diameter < 0,8 and inner diameter (di)/outside diameter < 0,7 and slot width (e)/outside diameter > 0,15. The end rounding of the slot is not to be less than e/2. An edge rounding should preferably be avoided as this increases the stress concentration slightly. The k and c_K values are valid for 1, 2 and 3 slots, i.e. with slots at 360 respectively 180 and respectively 120 degrees apart.

(7) c_K = 0,3 is an approximation within the limitations in (6). More accurate estimate of the stress concentration factor (scf) may be determined from M68.7.3 or by direct application of FE calculation. In which case:
$c_K = 1{,}45/scf$
Note that the scf is defined as the ratio between the maximum local principal stress and $\sqrt{3}$ times the nominal torsional stress (determined for the bored shaft without slots).

(8) Applicable to the portion of the propeller shaft between the forward edge of the aftermost shaft bearing and the forward face of the propeller hub (or shaft flange), but not less than 2,5 times the required diameter.

3.1.7 Notes

3.1.7.1 Shafts complying with this UR satisfy the following:

1. Low cycle fatigue criterion (typically < 10^4), i.e. the primary cycles represented by zero to full load and back to zero, including reversing torque if applicable. This is addressed by the formula in 3.1.4.
2. High cycle fatigue criterion (typically >> 10^7), i.e. torsional vibration stresses permitted for continuous operation as well as reverse bending stresses. The limits for torsional vibration stresses are given in 3.1.5. The influence of reverse bending stresses is addressed by the safety margins inherent in the formula in 3.1.4.
3. The accumulated fatigue due to torsional vibration when passing through a barred speed range or any other transient condition with associated stresses beyond those permitted for continuous operation is addressed by the criterion for transient stresses in 3.1.5.

3.1.7.2 Explanation of k and c_K

The factors k (for low cycle fatigue) and c_K (for high cycle fatigue) take into account the influence of:

- The stress concentration factors (scf) relative to the stress concentration for a flange with fillet radius of 0,08do (geometric stress concentration of approximately 1,45).

$$c_K = \frac{1,45}{scf} \quad and \quad k = [\frac{scf}{1,45}]^x$$

where the exponent x considers low cycle notch sensitivity.

- The notch sensitivity. The chosen values are mainly representative for soft steels (σ_B <600), while the influence of steep stress gradients in combination with high strength steels may be underestimated.
- The size factor c_D being a function of diameter only does not purely represent a statistical size influence, but rather a combination of this statistical influence and the notch sensitivity.

The actual values for k and c_K are rounded off.

3.1.7.3 Stress concentration factor of slots

The stress concentration factor (scf) at the end of slots can be determined by means of the following empirical formulae using the symbols in footnote (6):

$$scf = a_{t(hole)} + 0,8 \times \frac{(l-e)/d}{\sqrt{(1-\frac{d_i}{d}) \times \frac{e}{d}}}$$

This formula applies to :

- slots at 120 or 180 or 360 degrees apart.
- slots with semicircular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula.
- slots with no edge rounding (except chamfering), as any edge rounding increases the scf slightly.

$a_{t(hole)}$ represents the stress concentration of radial holes (in this context e = hole diameter) and can be determined as:

$$a_{t(hole)} = 2,3 - 3 \times \frac{e}{d} + 15 \times (\frac{e}{d})^2 + 10 \times (\frac{e}{d})^2 \times (\frac{d_i}{d})^2$$

Or simplified to : $a_{t(hole)}$ =2,3

Appendix I

Special approval of alloy steel used for intermediate shaft material

1. Application

This appendix is applied to the approval of alloy steel which has a minimum specified tensile strength greater than 800 N/mm^2, but less than 950 N/mm^2 intended for use as intermediate shaft material.

2. Torsional fatigue test

A torsional fatigue test is to be performed to verify that the material exhibits similar fatigue life as conventional steels. The torsional fatigue strength of said material is to be equal to or greater than the permissible torsional vibration stress τ_c given by the formulae in 3.1.5. The test is to be carried out with notched and unnotched specimens respectively. For calculation of the stress concentration factor of the notched specimen, fatigue strength reduction factor β should be evaluated in consideration of the severest torsional stress concentration in the design criteria.

2.1 Test conditions

Test conditions are to be in accordance with Table A.1. Mean surface roughness is to be <0,2µm Ra with the absence of localised machining marks verified by visual examination at low magnification (x20) as required by Section 8.4 of ISO 1352:2011. Test procedures are to be in accordance with Section 10 of ISO 1352:2011.

Table A.1: Test condition

Loading type	Torsion
Stress ratio	R=1
Load waveform	Constant-amplitude sinusoidal
Evaluation	S-N curve
Number of cycles for test termination	1 x 10^7 cycles

2.2 Acceptance criteria

Measured high-cycle torsional fatigue strength τ_{C1} and low-cycle torsional fatigue strength τ_{c2} are to be equal to or greater than the values given by the following formulae:

$$\tau_{c1} \geq \tau_{c,\lambda=0} = \frac{\sigma_B + 160}{6} \times c_K \times c_D$$

$$\tau_{c2} \geq 1{,}7 \times \frac{1}{\sqrt{c_K}} \times \tau_{c1}$$

Where:

c_K = factor for the particular shaft design features, see 3.1.7

scf = stress concentration factor, see 3.1.7.3 (For unnotched specimen, 1,0.)

c_D = size factor, see 3.1.5.

σ_B = specified minimum tensile strength in N/mm^2 of the shaft material

3. Cleanliness requirements

The steels are to have a degree of cleanliness as shown in Table 2 when tested according to ISO 4967:2013 method A. Representative samples are to be obtained from each heat of forged or rolled products.

The steels are generally to comply with the minimum requirements of UR W7 Table A.2, with particular attention given to minimising the concentrations of sulphur, phosphorus and oxygen in order to achieve the cleanliness requirements. The specific steel composition is required to be approved by the Society.

Table A.2: Cleanliness requirements

Inclusion group	Series	Limiting chart diagram index *I*
Type A	Fine	1

	Thick	1
Type B	Fine	1,5
	Thick	1
Type C	Fine	1
	Thick	1
Type D	Fine	1
	Thick	1
Type DS	-	1

4. Inspection

The ultrasonic testing required by UR W7 is to be carried out prior to acceptance. The acceptance criteria are to be in accordance with IACS Recommendation No. 68 or a recognized national or international standard.

3.2 Final gear wheel shafts

3.2.1 The diameter of the shaft at the final wheel and the adjacent journals is to be greater than 1,15 times that required for the intermediate shaft, where there is only one pinion geared into the final wheel, or where there are two pinions which are set to subtend an angle at the centre of the shaft of less than 120 degrees.

3.2.2 The diameter of the shaft at the final wheel and the adjacent journals is to be greater than 1,10 times that required for the intermediate shaft, where there are two pinions geared into the final wheel opposite, or nearly opposite, to each other.

3.2.3 In 3.2.1 and 3.2.2, abaft the journals, the shaft may be gradually tapered down to the diameter required for an intermediate shaft determined according to 3.1 where σ_B is to be taken as the specified minimum tensile strength of the final wheel shaft material, in N/mm^2.

3.3 Thrust shafts

3.3.1 The diameter at the collars of the thrust shaft is to be not less than that required for the intermediate shaft as follows from 3.1 with a k-factor value of 1,10.

3.3.2 Outside a length equal to the thrust shaft diameter from the collars, the diameter may be gradually reduced to that required for the intermediate shaft with a k-factor value of 1,0.

3.3.3 In the above calculations σ_B is to be taken as the minimum tensile strength of the thrust shaft material, in N/mm^2.

3.4 Propeller shafts

3.4.1 The minimum diameter of the protected forged steel propeller shaft is not to be less than that calculated from the following formula

$$d_p = 100 \times k \times \sqrt[3]{\frac{P}{n} \times \frac{560}{\sigma_B + 160}} \quad [mm]$$

where:

d_p	=	minimum diameter, mm,
k	=	factor for different shaft design features (propeller shafts), see 3.4.4.
n	=	rated speed of propeller shaft, rpm,
P	=	rated power of the main engine, kW,
σ_B	=	tensile strength of the shaft material taken for calculation, N/mm²

3.4.2 In general, the tensile strength of the steel used shall be between 400 and 800 N/mm². For the calculation of the diameter, σ_B is not to be taken as greater than 600 N/mm².

3.4.3 In general, the part of the propeller shaft located forward of the forward stern tube seal may be gradually reduced to the diameter of the intermediate shaft.

3.4.4 k-factors for different shaft design features (propeller shafts) - see 3.4.1.

(a)

.1 k = 1,22 for propeller shafts

~ where the propeller is keyless fitted onto the propeller shaft taper by an approved shrinkage method

or

~ where the propeller is attached to an integral propeller shaft flange and

~ where the propeller shaft is oil lubricated and provided with approved type of oil sealing glands

or

~ where the shaft is fitted with a continuous liner;

.2 k = 1,26 for propeller shafts

~ where the propeller is keyed onto the propeller shaft taper by an approved method and

~ where the propeller shaft is oil lubricated and provided with approved type of oil sealing glands

or

~ where the shaft is fitted with a continuous liner.

The above values of k apply to the portion of propeller shaft between the forward edge of the aftermost shaft bearing and the forward face of he propeller boss or, if applicable, the forward face of the propeller shaft flange, subject to a minimum of $2{,}5 \cdot d_p$. The determination of k-factors for shaft design features other than these given above is to be especially considered.

(b) k = 1,15 to the portion of propeller and tube shafts between the forward edge of the forward stern tube seal and the forward edge of the aftermost shaft bearing.

3.4.5 The diameter of unprotected propeller shafts and tube shafts of corrosion resistant materials, in general is not to be less than that calculated from the following formula:

$$d_o = 930 \times \sqrt[3]{\frac{P}{\eta} \times \frac{1}{\sigma_B}} \quad [mm]$$

where:

d_{np}	=	minimum diameter, mm
P	=	rated power of the main engine, kW,
η	=	rated speed of propeller shaft, rpm
σ_B	=	tensile strength of the shaft material taken for calculation, N/mm²

Propeller and tube shafts having an actual minimum diameter less than the above will be subject to special consideration.

3.5 Hollow shafts

3.5.1 Where there are central holes in the tube and screw shafts, the outside diameters of the shafts are to be greater than:

$$d_o = d \times \sqrt[3]{\frac{1}{1-\left(\frac{d_i}{d_o}\right)^4}} \quad [mm]$$

Where

d_o	=	minimum diameter, mm
d_i	=	diameter of central hole, mm
d	=	Rule size diameter of solid shaft,

Where the diameter of the central hole does not exceed 0,4 times the outside diameter, no increase over Rule size is required.

3.6 Scantling of coupling flanges (M34 (1980))

3.6.1 For intermediate, thrust and propeller shaft couplings having all fitted coupling bolts, the coupling bolt diameter is to be not less than that given by the following formula.

$$d_b = 0{,}65 \times \sqrt{\frac{d^3(T+160)}{i \times D \times T_b}}$$

where:

d_b	=	diameter of fitted coupling bolt, mm
d	=	Rule diameter, i.e. minimum required diameter of intermediate shaft made of material with tensile strength T, taking into account ice strengthening requirements where applicable

i = number of fitted coupling bolts,

D = pitch circle diameter of coupling bolts, mm,

T = tensile strength of the intermediate shaft material taken for calculation, N/mm²,

T_b = tensile strength of the fitted coupling bolts material taken for calculation, N/mm²

while: $T \leq T_b \leq 1{,}7 \cdot T$, but not higher than 1000 N/mm².

3.6.2 The design of coupling bolts in the shaftline other than that covered by 3.6.1 are to be considered and approved by the Society.

3.6.3 For intermediate shafts, thrust shafts and inboard end of propeller shafts the flange is to have a minimum thickness of 0,20 times the Rule diameter d of the intermediate shaft of the thickness of the coupling bolt diameter calculated for the material having the same tensile strength as the corresponding shaft, whichever is greater. Special consideration will be given by the Society for flanges having non parallel faces, but in no case is the thickness of the flange to be less than the coupling bolt diameter.

3.6.4 Fillet radii at the base of the flange should in each case be not less than 0,08 times the actual shaft diameter. Fillets are to have a smooth finish and should not be recessed in way of nuts and bolt heads.The fillet may be formed of multiradii in such a way that the stress concentration factor will not be greater than that for a circular fillet with radius 0,08 times the actual shaft diameter.

3.7 Bronze or gunmetal liners on shafts

3.7.1 The thickness, of liners fitted on screwshafts or on tube shafts, in way of the bushes, is to be greater than:

$$t = \frac{D + 230}{32} \quad [mm]$$

where:

t = thickness of the liner, mm

D = diameter of the screwshart or tube shaft under the liner, mm,

3.7.2 The thickness of a continuous liner between the bushes is to be not less than 75% of t, where t is given in 3.7.1.

3.7.3 Normally, continuous liners should be cast in one piece. Where this is impracticable they are to be built welded together by using leed-free electrodes or filler rods. The weldings are to be to the Surveyor's satisfaction.

3.7.4 Due care is to be taken in order to ensure the water-tightness of the part of the shaft between the after end of the liner and the propeller boss.

3.7.5 The composition of the gunmetal of each length forming a butt welded liner should be such that the lead content is not to exceed 1%.

3.7.6 The use of pins for securing the liners is not allowed. Liners are to be shrunk on, or forced on, to the shafts by hydraulic pressure.

3.7.7 Every continuous liner or length of liner is to be tested by hydraulic pressure to 2,0 bar after rough machining.

3.8 Keys and keyways

3.8.1 The keyways in the propeller boss and cone of the screwshaft are to be provided with a smooth fillet at their bottom. The keys should be round or sled-runner ended. The edges at the top of the keyways are also to be smooth. The forward end of the keyway is to be so cut in the shaft as to give a gradual rise from the bottom of the keyway to the surface of the shaft.

3.8.2 In general, due care is to be taken for the reduction of the stress concentration as far as practicable.

3.8.3 The key is to fit tightly and safely in the keyway. To this purpose, two screwed pins are to be provided for securing the key in the keyway, and the forward pin is to be placed at least one-third of the length of the key from the end. The depth of the tapped holes for the screwed pins is not to exceed the pin diameter.

3.8.4 The distance between the top of the cone and the forward end of the key way is to be not less than 0,2 of the diameter of the screwshaft at the top of the cone.

3.8.5 The key is to be of sufficient size to transmitt the full torque of the shaft.

3.9 Length of aft stern bush bearing (3.10.1 - 4: IACS M52 (2019))

3.9.1 Oil lubricated bearings of white metal

(a) The length of white metal lined bearings is to be not less than 2,0 times the rule diameter of the shaft in way of the bearing.

(b) The length of the bearing may be less provided the nominal bearing pressure is not more than

8 bar as determined by static bearing reaction calculation taking into account shaft and propeller weight which is deemed to be exerted solely on the aft bearing devided by the projected area of the shaft. However, the minimum length is to be not less than 1,5 times the actual diameter.

3.9.2 Oil lubricated bearings of synthetic rubber, reinforced resin or plastic materials

(a) For bearings of synthetic rubber, reinforced resin or plastics materials which are approved for use as oil lubricated stern bush bearings, the length of the bearing is to be not less than 2,0 times the rule diameter of the shaft in way of the bearing.

(b) The length of bearing may be less provided the nominal bearing pressure is not more than 6 bar as determined by static bearing reaction calculation taking into account shaft and propeller weight which is deemed to be exerted solely on the aft bearing devided by the projected area of the shaft. However, the minimum length is to be not less than 1,5 times the actual diameter. Where the material has proven satisfactory testing and operating experience, consideration may be given to an increased bearing pressure.

(c) Synthetic materials for application as oil lubricated stern tube bearings are to be Type Approved.

3.9.3 Water lubricated bearings of lignum vitae.

(a) The length of the bearing is to be not less than 4,0 times the rule diameter of the shaft in way of the bearing.

(b) For a bearing of synthetic material, consideration may be given to a bearing length not less than 2,0 times the rule diameter of the shaft in way of the bearing, provided the bearing design and material is substantiated by experiments to the satisfaction of the Society.

(c) Synthetic materials for application as water lubricated stern tube bearings are to be Type Approved.

NOTE:

1. Lignum vitae is the generic name for several dense, resinous hardwoods with good lubricating properties. The original high quality Lignum Vitae is almost unobtainable and other types of wood such as Bulnesia Sarmiento (or Palo Santo or Bulnesia Arabia) are commonly used now.

3.9.4 Grease lubricated bearings

(a) The length of a grease lubricated bearing is to be not less than 4,0 times the rule diameter of the shaft in way of the bearing.

3.9.5 For bearings of cast iron and bronze which are oil lubricated and fitted with an approved oil sealing gland, the length of the bearing is to be not less than 4 times the diameter required for the screwshaft.

3.9.6 The length of the grease lubricated bearings is to be not less than 4 times the diameter required for the screwshaft.

3.9.7 Where the shaft diameter is greater than 360 mm and bearings lined with lignum vitae are used forced water lubrication is required. Where bearings lined with rubber or plastics are used forced water lubrication is always required.

3.9.8 Oil sealing glands are to be of an approved type and capable of operating under the various sea water temperatures it may be subject to in service. In particular, in ships classed for unrestricted service oil sealing glands must be capable of accommodating the effects of differential expansion between hull and line of shafting in sea temperatures ranging from arctic to tropical.

3.9.9 Where lubrication is made by means of gravity, the lubricatiing oil tank is to be located above the load waterline and provided with a low level alarm.

3.9.10 Where sternbush bearings are oil lubricated, means are to be provided for cooling the lubricating oil.

3.10 Vibration and alignment

3.10.1 For the requirements for torsional, axial and lateral vibration, and for alignment of the shafting, see Part 5, Chapter 6 of the Society’s “Rules and Regulations for the Classification and Construction of Steel Ships”.

CHAPTER 4 Propellers

Contents

SECTION 1 General

1.1 Application

1.1.1 The requirements of this part apply to propellers which exceed 1,5 m in diameter.

1.1.2 For propellers which do not exceed 1,5 m in diameter and are part of a manufacturer's standard roduct line, neither the Surveyor's attendance for material testing and inspection nor the design review will be required.

1.2 Documents for Approval

1.2.1 The following plans and particulars are to be submitted:

(a) propellers cast in one piece

(b) blades, bolts and hub for built and controllable pitch propellers

(c) blade bolt pretensioning and procedure

(d) pitch control mechanism

(e) data and calculations for fitting of propeller to the shaft.

1.2.2 The plans are to give full details of scandlings and arrangement, as well as, material specification and heat treatment. The manufacturing tolerance class (ISO 484-1 / ISO 484-2) is also to be specified on the propeller drawings.

1.2.3 Where the propeller is fitted to the screwshaft without the use of a key, plans of the following items are to be submitted:

(a) boss

(b) tapered end of screwshaft

(c) propeller nut

(d) sleeve, where applicable

1.2.4 Where a sleeve is fitted, details of the proposed type of material and mechanical properties are also to be submitted.

SECTION 2 Materials

2.1 Castings

2.1.1 Castings for propellers and propeller blades are to comply with the requirements of the Society's Rules for Materials. The specified minimum tensile strength is to be not less than stated in Table 4.3.1.

2.1.2 For materials not included in Table 4.3.1, details of the chemical composition, mechanical properties and density are to be submitted for approval.

SECTION 3 Design

3.1 Calculation of minimum blade thickness

3.1.1 The rules mentioned in the present section apply to propellers of normal design for single and multiscrew propulsion.

3.1.2 The thickness t_b of the propeller blades at 25% radius for propellers cast in one piece, 35% radius for propellers with separate cast blades is not to be less than:

Table 4.3.1:

Material	Special minimum tensile strength (N/mm^2)	Density (g/m^3)	Allowable stress (N/mm^2)
Grey cast iron	250	7,2	17,2
Spheroidal or nodular graphite cast iron	400	7,3	20,6
Carbon and low alloy steels	400	7,9	20,6
13% chromium stainless steels	500	7,7	41
Chromium-nickel austenitic stainless steel	450	7,9	41
Grade Cu 1			
- Manganese bronze (high tensile brass)	440	8,3	39
Grade Cu 2			
- Ni - Manganese bronze (high tensile brass)	440	8,3	39
Grade Cu 3			
- Ni - Aluminium bronze	590	7,6	56
Grade Cu 4			
- Ni - Aluminium bronze	630	7,5	46

(a) fixed-pitch propellers

$$t_{0,25} = k_1 \cdot \sqrt{\frac{A \cdot P}{C \cdot R \cdot N}} \pm 1{,}72 \cdot \frac{B \cdot K}{C}$$

Where

$$A = 1{,}0 + \frac{6}{p_{0,70}} + 4{,}3 \cdot p_{0,25}$$

$$B = \frac{4300 \cdot w \cdot a}{N} \cdot \left(\frac{R}{100}\right)^2 \cdot \left(\frac{D}{20}\right)^3$$

$$C = (1 + 1{,}5 \cdot p_{0,25}) \cdot (W \cdot f - B)$$

(b) controllable-pitch propellers

$$t_{0,35} = k_2 \cdot \sqrt{\frac{A \cdot P}{C \cdot R \cdot N}} \pm 1{,}09 \cdot \frac{B \cdot K}{C}$$

Where

$$A = 1{,}0 + \frac{6}{p_{0,70}} + 3 \cdot p_{0,35}$$

$$B = \frac{4900 \cdot w \cdot a}{N} \cdot \left(\frac{R}{100}\right)^2 \cdot \left(\frac{D}{20}\right)^3$$

$$C = (1 + 0{,}6 \cdot p_{0,35}) \cdot (W \cdot f - B)$$

$t_{0,25}$= required thickness at the 25% radius, mm.

$t_{0,35}$= required thickness at the 35% radius, mm.

k_1 = 1067

k_2 = 857

P = power at rated speed, kW.

R = revolution at rated speed, rpm.

N = number of blades.

$p_{0,25}$= pitch at 25% radius divided by propeller diameter.

$p_{0,35}$= pitch at 35% radius divided by propeller diameter, corresponding to the design ahead conditions.

$p_{0,70}$= pitch at 70% radius divided by propeller diameter, corresponding to the design ahead conditions.

W = expanded width of a cylindrical section at the 0,25 or 0,35 radius, mm.

a = expanded blade area divided by the disc area.

D = propeller diameter, m.

K = rake of the propeller blade in mm/m multiplied by D/2 (with forward rake, use minus sign in equation; with aft rake, use plus sign).

f,w = material constants from the Table 4.3.2.

Table 4.3.2:

Materials	f	w
Austenitic Stainless Steel	2,10	7,75
Cast steel	2,10	8,30
Manganese Bronze	2,10	8,30
Ni - Manganese Bronze	2,25	8,00
Ni - Aluminium Bronze	2,62	7,50

3.1.3 The fillet radius between the root of a blade and the boss of a propeller is to be not less than the Rule thickness of the blade or equivalent at this location. Composite radiused fillets or elliptical fillets which provide a greater effective radius to the blade are acceptable and are to be preferred.

3.1.4 Where the design of a propeller has been based on analysis of reliable wake survey data in conjunction with a detailed fatigue analysis and is deemed to permit scantlings less than required by

3.1.2 and also for propellers of unusual design, or where the propeller is intended for more than one operating regime, such as towing or trawling, a detailed stress computation for the blades is to be submitted for consideration.

SECTION 4 Fitting of Propeller

4.1 Propeller Boss

4.1.1 The propeller boss is to be a good fit on the screwshaft cone. The forward edge of the propeller bosses is to be rounded to about a 6 mm radius. In the case of keyed propellers,the length of the forward fitting surface is to be about one diameter and, where the fitting is by means of a hydraulic nut, the requirements of 4.2, where appropriate, are applicable.

4.2 Final Fitting of Keyless Propellers

4.2.1 After verifying that the propeller and shaft are at the same temperature and the mating surfaces are clean and free from oil or grease, the propeller is to be fitted on the shaft to the satisfaction of the Surveyors. The propeller nut is to be securely locked to the shaft.

4.2.2 Permanent reference marks are to be made on the propeller boss,nut and shaft to indicate angular and axial positioning of the propeller. Care is to be taken in marking the inboard end of the shaft taper to minimize stress raising effects.

SECTION 5 Tests

5.1 Balancing

5.1.1 The finished propeller and the blades of controllable pitch propellers are required to undergo static balancing.

5.2 Testing

5.2.1 Fixed pitch propellers, controllable pitch propellers and controllable pitch propeller systems are to be presented to the Society for final inspection and verification of the dimensions. In addition, controllable pitch propeller systems are required to undergo pressure, tightens and operational tests. The Society reserves the right to require non-destructive tests to be conducted to detect surface cracks or casting defects. With regard to the assessment and the repair of defects on propellers, see the "Rules for the Classification and Construction of Steel Ships", Part 2, Chapter 7, SECTION 1, 1.9.

CHAPTER 5 Piping Systems

Contents

SECTION 1 General

1.1 Application

1.1.1 This Chapter presents the general requirements, which should govern the materials selection, the design and construction of piping systems installed on craft not exceeding 24 m Rule length. Where craft have a Rule length exceeding 24 m the requirements of Part 5 of the *Rules and Regulations for the Classification and Construction of steel ships* are to be complied with, where applicable.

1.1.2 Piping arrangement of fishing vessels will satisfy relevant requirements of Torremolions International Convention for the safety of Fishing Vessels.

1.1.3 Supplementary to paragraph 1.1.1 yachts with the notation "COMMERCIAL YACHT" shall meet the requirements of Section 8 of this Chapter.

1.2 Definitions

1.2.1 Piping is defined to include the following components:

(a) pipes,

(b) expansion elements,

(c) valves and fittings,

(d) flanges and other pipe connections,

(e) hangers and supports,

(f) flexible hoses,

(g) pump housings.

1.2.2 A piping system is defined to include piping, as well as components in direct connection to the piping such as pumps, heat exchangers, starting air vessels, evaporators, tanks, etc. with the exception of main components such as diesel engines, reduction gears etc.

1.2.3 The maximum allowable working pressure of a piping system component is the maximum pressure which the component can sustain in continuous use with regard to the materials used, design, working temperature and undisturbed operation.

1.2.4 The design pressure is the maximum allowable working pressure for which a component or a piping system is designed and is not to be less than the pressure at which the safety equipment will become active (e.g. activation of safety valves, opening of return lines of pumps, operating of over pressure safety arrangements, opening of relief valves) or at which the pumps will operate against closed valves.

1.2.5 The design temperature is the maximum temperature of the internal fluid and is not to be taken less than 50°C.

1.3 Documentation to be submitted

1.3.1 The following plans in triplicate (and/or electronically) are to be submitted for approval:

(a) General arrangement of engine room.

(b) Sanitary system.

(c) Bilge system.

(d) Ballast system.

(e) Vent, sounding and overflow pipes.

(f) Fuel-oil fillings, transfer and service systems.

(g) Lubricating oil-systems.

(h) Fresh water service systems.

(i) Fire-main and fire extinguishing systems.

(j) Steering gear piping systems.

(k) Starting-air piping.

(l) Exhaust systems.

1.3.2 The plans are to include the following particulars:

(a) Outside diameter and wall thickness of pipes.

(b) Materials to be used in pipes, valves and fittings.

(c) Pump type and capacity.

(d) Type of flexible hoses and expansion elements.

(e) Maximum working pressure.

(f) Maximum temperature.

SECTION 2 Materials

2.1 Material requirements

2.1.1 Materials to be used in construction of piping systems are to be manufactured and tested in accordance with the applicable requirements of Part 2 of the "Rules and Regulations for the Classification and Construction of Steel Ships".

2.1.2 The materials to be used are to be suitable for the medium and service for which the system is intended. Unless specifically mentioned, all metallic materials with melting point above 900°C may be used.

2.2 Steel piping

2.2.1 Steel pipes are normally to be of seamless drawn material or fabricated with a welding procedure considered by the Society to be equivalent to the seamless one.

2.3 Copper and copper alloy piping

2.3.1 Copper and copper alloy piping shall be of seamless drawn material or other type approved by the Society.

2.3.2 Copper and copper alloys are in general not be used for media having temperature above the following limiting values:

(a) copper and aluminium brass: 200°C

(b) copper nickel: 300°C

Special bronze suitable for high temperature service may be used for media having temperature up to 260°C.

2.3.3 Pipes for starting air are not to be of copper or copper alloys when the outer diameter exceeds 44,5 mm.

2.3.4 Pipes which have been hardened by cold bending are to be suitably heat treated on completion of fabrication and prior to being tested by hydraulic pressure. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated.

2.4 Non metallic materials

2.4.1 Pipes made from non-metallic materials tested according to an approved specification may be used for the following services:

(a) sea cooling water systems,

(b) ballast water systems,

(c) fresh cooling water system,

(d) bilge systems,

(e) air and sounding pipes for water ballast tanks and fresh water tanks,

(f) pipes for non-essential services not conveying flammable fluids.

2.4.2 Pipes for non-essential services may be of recognised standard for domestic water services.

2.4.3 For ships of special service, e.g. tugs, fire-fighting boats etc. 2.4.1 is applied only after examination of the possible effects of the ship's service on the piping system under consideration.

SECTION 3 Design principles

3.1 General

3.1.1 Piping systems are normally to be made of rigid pipes. The use of flexible hoses of approved type suitable for their intended use may be accepted in lieu of rigid piping upon special consideration. Pipes and fittings are to be supported in such a way that their weight is not taken by connected machinery or that heavy valves and fittings do not cause large additional stresses in adjacent pipes.

3.1.2 Axial forces due to internal pressure, change in direction or cross-sectional area and movement of the ship are to be taken into consideration when mounting the piping system.

3.1.3 The support of the piping system is to be such that detrimental vibrations will not arise in the system.

3.1.4 Metallic pipes are to be connected by welding or brazing or by detachable connections of approved type.

3.1.5 Plastic pipes are to be connected by an approved method, e.g. welding, gluing or cementing, or by approved detachable connections.

3.1.6 Installations of pipes for water or oil, behind or above electric switchboards is to be avoided as far as possible. If this is impracticable, all detachable pipe joints and valves are to be at the safe distance from the switchboard or well shielded from it.

3.1.7 Water pipes and air and sounding pipes through freezing chambers are to be avoided.

3.2 Operation of valves

3.2.1 Sea suction and discharge valves, bilge valves and valves on the fuel oil and lubricating oil tanks which are situated higher than the double bottom tanks are to be arranged for direct mechanical manual operation. The change over to manual operation from possible remote control arrangement is to be simple to execute.

3.2.2 For remotely controlled valves failure in power supply is not to cause:

(a) opening of closed valves

(b) closing of open valves on fuel oil tanks and in cooling water system for propulsion and power generating machinery.

3.2.3 Remotely controlled valves are to be provided with indications for open and closed valve positions at the control station. In cases where possibility of direct manual operation is required in addition to the remote control means of observing the valve position at the valve location is to be provided.

3.3 Direct connections of pipe lengths

3.3.1 Direct connection of pipe lengths may be obtained by: butt-welded joints, socket weld joints, slip-on sleeve welded joints and sleeve threaded joints.

3.3.2 Butt-welded joints shall be of full penetration type with or without provision for a high quality of root side. Joints of this type with special provisions for root side are applicable irrespective of the diameter.

3.3.3 Socket weld fittings are to be of forged steel in accordance with a recognised standard. They may be used with carbon steel pipes not exceeding 60,3 mm outside diameter. They are not to be used in systems involving corrosive service or where fatigue is liable to occur.

3.3.4 Sleeve threaded joints are to be in accordance with a standard recognised by the Society. They are allowed only for subordinate systems (e.g. sanitary and hot water heating systems). Screwed pipe connections and pipe couplings may be used subject to special approval.

3.3.5 Slip-on joints, sleeve threaded joints, socket weld joints and other types of direct connection of pipe lengths may be allowed by the Society in each particular case for small diameter and depending upon the service conditions.

3.4 Flange connections

3.4.1 Flanges may be cut from plates or may be forged or cast. The selection of material is based upon the design temperature. The design pressure helps in determining the appropriate particulars of the flange. Flanges differ in method of attachment to the pipe, that is, whether they are screwed and expanded or welded. Alternative methods of flange attachment may be accepted provided details are submitted for consideration.

3.4.2 The dimensions and materials of flanges and corresponding bolting, and the pressure- temperature rating of bolted flanges in pressure pipelines in accordance with national or other established standards will be accepted.

3.4.3 Acceptable flange connections are described in Part 5, Chapter 8, SECTION 4, 4.2 of the Society's "Rules for the Classification and Construction of Steel Ships".

3.4.4 Welded-on flanges are not to be a tight fit on the pipes. The maximum clearance between the bore of the flange and the outside diameter of the pipe is to be 3 mm, at any point, and the sum of the clearances diametrically opposed is not to exceed 5 mm.

3.5 Required minimum wall thickness

3.5.1 The required minimum wall thickness are not to be less than either those derived by stress analysis or the minimum wall thickness assigned to standard pipe sizes as stated in Table 5.3.1, in the case of steel pipes or in Table 5.3.2, in the case of copper and copper alloy pipes.

3.5.2 The minimum wall thickness, listed in Table 5.3.1 and Table 5.3.2 are the nominal wall thickness and they need no allowance to be made for negative tolerance and reduction in thickness due to bending. The outside diameters and the thickness have been taken from ISO standards. Steel pipes are corresponding to ISO 4200:1992 (E): "Plain end steel tubes, welded and seamless-general tables and dimensions and masses per unit length" For larger diameters, the minimum thickness will be specially considered.

3.5.3 For venting, bilge, ballast, fuel, overflow and sounding pipes as listed Table 5.3.1, provided that they are efficiently protected against corrosion, the thickness may be reduced by not more than 1 mm, at the discretion of the Society.

3.5.4 Protective coatings such as hot-dip galvanising, may be recognised as an effective corrosion protection for steel pipes provided that the preservation of the protective coating during installation is guaranteed.

3.5.5 Pipes made of stainless steel shall have minimum wall thickness determined after special consideration approved by the Society.

3.5.6 The minimum internal diameter for bilge, sounding, venting and overflow pipe shall be:

(a) Bilge pipes: 50 mm

(b) Sounding pipes: 32 mm

(c) Venting and overflow pipes: 50 mm

Table 5.3.1: Minimum wall thickness for steel pipes (mm)

External diameter D (mm)	Pipes in general	Venting overflow and sounding pipes for structural tanks (1)	Bilge ballast and general sea water pipes	Bilge, air, overflow and sounding pipes through fuel tanks and fuel lines through ballast tanks (1, 3)
10,2-12	1,6			
13,5-19,3	1,8			
20	2			
21,3-25	2		3,2	
26,9-33,7	2		3,2	
38-44,5	2	4,5	3,6	6,3
48,3	2,3	4,5	3,6	6,3
51-63,5	2,3	4,5	4	6,3
70	2,6	4,5	4	6,3
76,1-82,5	2,6	4,5	4,5	6,3
88,9-108	2,9	4,5	4,5	7,1
114,3-127	3,2	4,5	4,5	8
113-139,7	3,6	4,5	4,5	8
152,4-168,3	4	4,5	4,5	8,8
177,8	4,5	5	5	8,8
193,7	4,5	5,4	5,4	8,8
219,1	4,5	5,9	5,9	8,8
144,5-273	5	6,3	6,3	8,8
298,5-368	5,6	6,3	6,3	8,8
406,4-457,2	6,3	6,3	6,3	8,8

NOTES:

1. For sounding pipes, except those for cargo tanks with cargo having a flash point less than 60°C, the minimum wall thickness is intended to apply to the part outside the tank.
2. The minimum wall thickness for cargo oil lines and exhaust gas pipes will be subject to special consideration by the Society in each case.
3. The minimum wall thickness for bilge lines and ballast lines through day tanks is to be faced as laying through fuel tanks.

Table 5.3.2: Minimum wall thickness for copper and copper alloy pipes

Outside Diameter	Minimum wall thickness (mm)	
D (mm)	Copper	Copper alloy
8-10	1	0,8
12-20	1,2	1
25-44,5	1,5	1,2
50-76,1	2	1,5
88,9-108	2,5	2
133-159	3	2,5
193,7-267	3,5	3
273-457,2	4	3,5
(470)	4	3,5
508	4,5	4

3.6 Plastic pipes

3.6.1 Minimum wall thickness and acceptable internal pressure of plastic pipes are determined by long term testing of hydraulic pressure strength according to an approved specification.

3.6.2 Evaluation of vacuum and external pressure resistance is necessary for plastic piping. Due to low elasticity modulus the buckling stability may be critical in pipe systems where vacuum or external pressures are to be expected.

3.6.3 Temperature limits and pressure reductions are indicated in Table 5.3.3 and Table 5.3.4. The limits may be extend on basis of acceptable documentation from the pipe manufacturer. The permissible temperatures are stated for long term service. Short periods of marginally higher temperatures may be accepted by case to case considerations.

3.6.4 The Tables are related to water service only. Use for other media shall be considered case by case.

3.6.5 If thermoplastic pipes are to be installed in external areas, the pipes shall either be particularly approved for external use or be protected against ultraviolet radiation.

3.6.6 Plastic pipes are normally made of electrical insulating materials and are as such not acceptable for service in gas hazardous areas. Special qualities can be permitted if they are documented to be electrically conductive (antistatic) according to an approved specification.

3.6.7 The need for expansion elements must be specially considered with respect to the large thermal expansion coefficient of the plastic materials.

3.6.8 Glassfibre reinforced epoxy and polyester pipes are considerably more exposed to damage from impact and local overloading than steel pipes. This must be duly taken into consideration by handling, installation and inspection.

Table 5.3.3: Permissible pressures and temperature limiting values for thermoplastic pipes

Material	Nominal pressure (bar) (1)	Permissible working pressure (bar)						
		-20 - 0 °C	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C
PVC	10 16		7,5 12	6 9	 6			
ABS	10 16	7,5 12	7,5 12	7,5 10,5	6 9	 7,5	 6	
HDPE	10 16	7,5 12	6 9,5	 6				

NOTE:

1. According to recognised standards for water supply on shore.

Table 5.3.4: Permissible pressures and temperature limiting values for glassfibre reinforced epoxy(1) and polyester pipes

Min. heat distortion temp of resin ISO 75 Method A	Nominal pressure PN (2)	Permissible working pressure (bar)							
		-20 - 30 °C	40 °C	50 °C	60 °C	70 °C	80 °C	90 °C	95 °C
80	10 15 25	10 15 16	9 14 16	7,5 12 16	6 9,5 15				
100	10 16 25	10 16 16	10 16 16	9,5 15 16	8,5 13,5 16	7,5 11 16	6 9,5 15		
135	10 16 25	10 16 16	10 16 16	10 16 16	10 16 16	9,5 15 16	8,5 13,5 16	7 11 16	6 9,5 16

NOTE:

1. Minimum heat distortion temperature 135.
2. According to recognised standards for marine use.

SECTION 4 Pumps

4.1 General

4.1.1 The following pumps are to be delivered with the Society’s certificate:

(a) sea-water cooling pumps for main engine,

(b) fresh-water cooling pumps for main engine,

(c) fuel oil service pumps,

(d) fuel injection valve cooling pumps,

(e) lubricating oil pumps for main engine and main reduction gear,

(f) bilge pumps,

(g) ballast pumps,

(h) fire pumps and emergency fire pumps.

4.2 Relief valves

4.2.1 Displacement valves are to be fitted with relief valves. For pumps transporting flammable liquids, the discharge from the relief valve is normally to be led back to suction side of the pump.

4.3 Tests

4.3.1 Hydrostatic tests

Pump housings are to be hydrostatically tested at a pressure of 1,5 times the maximum working pressure. However, the test pressure need not exceed the maximum working pressure by more than 70 bar. For centrifugal pumps the maximum pressure head on the head-capacity curve. For displacement pumps the maximum working pressure is not to be taken less than the relief valve opening pressure.

4.3.2 Capacity tests

(a) Pump capacities are to be checked with the pump running at design conditions.

(b) Capacity test may be dispensed with for pumps produced in series when previous satisfactory tests have been carried out in similar pumps.

(c) For centrifugal pumps having capacities less than 1000 m^3/h, the pump characteristic (head - capacity curve) is to be determined for each type of pump. For centrifugal pumps having capacities equal to or greater than 1000 m^3/h, the pump characteristic is to be determined over a suitable range on each side of the design point, for each pump.

SECTION 5 Valves

5.1 General requirements

5.1.1 Drawings and specifications are to be submitted for approval for valves of new type or unconventional design.

5.1.2 Indicators are to be provided to show the opened and closed position of the valve, unless it can be observed in some other way.

5.1.3 Handles in cocks are to be removable only when the cocks are in the closed position.

5.1.4 Welded necks of valve bodies are to be sufficiently long to ensure that the valves are not distorted as result of welding and subsequent heat treatment of the joints.

SECTION 6 Bilge System

6.1 Application

6.1.1 All craft to which these rules apply, shall be provided with satisfactory bilge pumping arrangement for effective draining of any watertight compartment which is not intended for permanent storage of liquid.

6.1.2 The bilge pumping system for crafts intended for passenger transport is to be capable of operation under all possible values of list and trim after sustaining assumed side and bottom damages as follows:

(a) Assumed side damaged length anywhere on the periphery of the craft:

.1 0,1 L or 3 meters + 0,03 L, or 11 metres, whichever is the least.

.2 Depth of penetration into the craft:

0,2 B or 5 metres, whichever is less. However, where the craft is fitted with inflated shirts or with non-buoyant side structures, the depth of penetration should be at least 0,12 of the width of the main buoyancy hull or tank structure.

.3 The vertical extend of damage should be taken for the full depth of the craft.

(b) Assumed bottom damages anywhere on the bottom of the craft as follows:

.1 Damage length fore and aft. directions:

~ 0,1 L or 3 metres + 0,03 L, or 11 metres, whichever is the least.

.2 Width of damage:

~ 0,2 B or 5 metres, whichever is less, except that in the case of a catamaran or an air-cushion vehicle the damage to the bottom of the bridge deck cross-connecting the hulls or side walls need only be assumed if that structure is submerged with the craft in the undamaged displacement mode. The width of damage in such a case need not be greater than the separation of the hulls or side walls.

.3 the depth of penetration into the craft should be:

~ 0,02 B or 0,5 metres, whichever is less.

6.1.3 For twin hull craft the tunnel breadth on water line may be subtracted from the greatest moulded breadth when calculating the depth of penetration into the craft at assumed side damage.

6.2 Bilge pumping arrangement.

6.2.1 At least one suction suitably arranged shall be provided in every compartment.

6.2.2 Efficient arrangements shall be provided whereby water in any watertight compartment may find its way to the suction pipes.

6.2.3 Where drainage from particular compartments are considered undesirable, the provisions for such drainage may be omitted, provided it can be shown by calculations that the safety of the craft will not be impaired.

6.2.4 Every machinery space shall be provided with at least two bilge suctions suitably arranged. The bilge suctions shall be led from readily accessible mudboxes placed wherever practicable above the level of working floor.

6.2.5 The mudboxes shall have straight tailpipes to the bilges and are to be arranged for easy inspection and cleaning.

6.2.6 Every compartment to be served by portable bilge pump shall be arranged with access for easy connection and operation of such pump. The access for portable bilge pumping operation in compartment not arranged with fixed installed bilge suction shall be from a sheltered place.

6.3 Protection against flooding through bilge pipes

6.3.1 The bilge and ballast pumping systems shall be so arranged as to prevent water passing from sea or from water ballast systems into machinery space or any other dry space or from one watertight compartment to another.

6.3.2 The bilge connection to any pump which effects suction from sea or from water ballast spaces shall be made by means of a screw down non-return valve so arranged that ingress of water into the bilge system is prevented. Branch bilge lines are to be connected to main bilge line by closeable non- return valves.

6.3.3 Any bilge pump and bilge main line serving drainage of more than one watertight compartment is to be installed inboard and above the assumed depth of damage into the craft as specified in 6.1.2. Branch bilge pipes are to be fitted with non return valve in the compartment containing the open end.

6.3.4 Where a fixed installed bilge pumping system is arranged in each watertight compartment serving only the compartment where installed, the requirement for installation of such bilge pumping inside the assumed depth of damage may be omitted.

6.4 Number of capacity of bilge pumps

6.4.1 At least two pumps is to be available for bilge pumping from every compartment of which at least one should be reserved solely for bilge pumping duties. Any other pump of suitable output available on board, except for an oil pump, may be used as the second bilge pump.

6.4.2 The pumps may be fixed or portable and they should be power driven unless the output of each pump is less than 1,5 tons per hour.

6.4.3 The output of each pump should in general meet the following formula:

$$Q = 3{,}75\left(1 + \frac{L}{36}\right)^2 \quad [tons/hour]$$

where:

Q = output [tons/hour]

L = length of the craft [m]. Length (L) means the length of the craft measured on the design waterline in the displacement mode.

6.4.4 The Society may permit a lesser bilge pump output, but the output of each bilge pump shall in no case be less than:

$$Q = 0{,}05 \cdot LW \quad [tons/hour]$$

where:

Q = output [tons/hour] with a minimum of one (1) tone per hour,

LW = line weight of the craf [tons]

6.4.5 Hand pumps shall be installed above the bulkhead deck.

6.4.6 Internal diameters of bilge lines should not be less than 25 mm. Bilge lines are to be fitted with effective strainers.

6.4.7 All cocks and valves shall have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

6.5 Air, sounding and filling pipes.

6.5.1 All compartments and tanks arranged with filling and/or drainage arrangement are to have air pipe and means for ascertaining the level of the liquid.

6.5.2 All tanks containing flammable liquids or which can be pumped up or filled from the sea are to have air pipe extending above the weather deck.

6.5.3 Air pipes from fuel and lubricating oil systems are to be carried up to a position where water cannot enter and so arranged that vapour or overflow cannot be ignited.

6.5.4 All air pipes outlets are to have approved means preventing ingress of water and such arrangement are to be so that the tanks are not exposed to vacuum or pressure exceeding the design pressure or vacuum.

6.5.5 All air pipes carried up to the open air are to extend at least 760 mm above the freeboard deck and 450 mm above the superstructure deck or where carried out through the side of the craft such outlet are wherever practicable to be at least 2300 mm above the waterline. Where these heights may interfere with the operation of the craft, a lower height may be approved by the Society on the condition that satisfactory closing arrangement and other circumstances justify a lower height.

6.5.6 All tanks containing flammable liquids or which can be pumped up or filled from the sea are to have sounding pipe carried up to the open air fitted with screw cap or equivalent. Other approved level indicator or remote sounding arrangement may replace sounding pipe.

6.5.7 Filling pipes to tanks containing flammable liquids shall terminate on the weather deck and shall be so arranged that possible spill cannot escape to the inside of the vessel, but will be collected inside a suitable arranged coaming.

6.5.8 All filling pipes to fuel and lubricating oil tanks are to have screw caps, plugs or similar arrangement preventing water from entering such tanks.

6.5.9 Air pipes for tanks not fitted with overflow pipes are to have a cross sectional area not less than 125% of the filling lines.

6.6 Scuppers and discharges

6.6.1 A sufficient number of scuppers, arranged to provide effective drainage, is to be fitted to all decks.

6.6.2 Scuppers on weather portions of decks and scuppers leading from superstructures or deckhouses not provided with closing appliances are usually to be led overboard.

6.6.3 Scuppers led through the deck or shell are to comply with requirements to material and thickness as given in 6.7.4.

6.6.4 Scupper pipes are to be well stayed to prevent any vibrations. However, sufficient possibility for expansion of the pipes to be provided when necessary.

6.6.5 Scuppers from spaces below the freeboard deck or spaces within closed superstructures may be led to bilges.

6.6.6 Scuppers leading overboard from spaces mentioned in 605 are to comply with the requirements given for discharges. Scuppers from exposed superstructure deck, led through the ship's sides and not having closeable valves, are to have strength as required in 6.7.4.

6.6.7 Discharges led through the shell either from spaces below the freeboard deck or from spaces within superstructures and deckhouses on the freeboard deck, fitted with doors as required in Part 3, Chapter 6, SECTION 1, are to be provided with efficient means for preventing water from passing inboard.

6.7 Fittings on sides and bottom

6.7.1 All sea inlets and discharges are to have easily operable valves of an approved type connected to the side or bottom of the craft by a substantial flange connection or equivalent.

6.7.2 The choice of material combination, dimensioning and corrosion protection of the sea inlet and discharge valves connection to the sides and bottom of the craft is to be so arranged that flooding as a reason of damage of such fitting is avoided.

6.7.3 Exhaust outlets through the side of the craft is to be so arranged that ingress of water into the engine is avoided.

6.7.4 The thickness and diameter of piping between hull plating and closeable or non-return valve are to be chosen so as to achieve equivalent strength as the surrounding hull structure. Due regard to be taken to the corrosion resistance of the piping material.

6.7.5 All sea inlet valves and outlet valves fitted below the waterline are to be arranged for direct mechanical closing with the manoeuvring handle situated easily accessible and visible above the waterline. Valve position indicator is to be visible at the manoeuvring stand.

SECTION 7 Machinery piping system and ventilation

7.1 Tank arrangement for fuel and other flammable fluids.

7.1.1 The requirements in this section apply to craft using diesel oil for internal combustion engine units with a flash point but not lower than 43°C. However, fuel with a lower flash point but not lower than 38°C may be used provided suitable precautions are taken against the risk of fire and explosion.

7.1.2 Fuel oil tanks carrying fuel oil with flash point lower than 43°C used for propulsion shall be located in watertight compartments separate from, but adjacent to the engine room in a non- hazardous fire area.

7.1.3 Fuel tanks for emergency diesel engines shall be located on or above the weather deck outside the engine housing or compartment and as close to the engine as practicable.

7.1.4 The fuel oil tanks shall preferably be part of the craft's structure and shall be located (except for double bottom tanks) outside fire hazard area.

7.1.5 For craft constructed or GRP or aluminium alloy, consideration may be given to fuel oil tanks being constructed of same material, but in no case are they to be installed in fire hazard area, nor are they to form part of the boundary to such spaces.

7.1.6 Daily service tanks of steel or equivalent material may be permitted in fire hazard areas. All pipes connected to such tanks below the highest tank liquid level are to be arranged with remote quick-closing valves.

7.1.7 Tanks containing fuel and other flammable liquid may be rectangular or cylindrical in shape, and shall be designed to withstand the maximum head to which they may be subjected in service taking into account the dynamic forces encountered.

7.1.8 All tanks not forming part of the craft's structure shall be securely fastened and shall be arranged so as to be readily inspected or movable for inspection.

7.1.9 All free-standing fuel oil tanks shall be so installed as to provide a free circulation of air around the tanks.

7.1.10 Cylindrical tanks with longitudinal seams shall be arranged horizontally where practicable so that such seams are located as near to the top as possible.

7.1.11 All tanks containing fuel or other flammable fluids are to be separated from passenger, crew and baggage compartments by cofferdams or equivalent.

7.1.12 Tanks containing fuel or other flammable fluids having connections below the highest tank liquid level are to have spill tray so arranged that any spill can be collected and easily removed in order to prevent leakage or spillage to the bilge from detachable piping connections.

7.1.13 No tubular gage glasses or try-rocks should be fitted to the fuel oil tanks

7.2 Piping conveying fuel or other flammable fluids.

7.2.1 Fuel piping should be accessible protected from mechanical damage, be effectively secured against excessive movements and vibration, and so routed that it does not pass through passenger, cargo crew compartments. Flexible fuel pipes should have suitable connections, be resistant to salt, water, oil and vibration, be visible, easily accessible and should not penetrate watertight bulkheads.

7.2.2 Fuel tank filling, vent and drain lines should be of adequate size and terminate in a manner that will not constitute a hazard.

7.2.3 Provision should be made for the management and control of the fuel system from a position readily accessible to the crew. Where gravity tanks are arranged, remote-controlled shut-off valves should be provided at the tank.

7.2.4 Displacement pumps transporting flammable fluids are to be fitted with relief valves. The discharge from the relief valve is wherever practicable to be lead back to suction side of the pump.

7.2.5 Piping conveying fuel and other flammable liquids are not to be carried through passenger, crew and baggage compartments.

7.2.6 All fuel or other flammable liquid piping leading into fire hazard area are to be arranged with shut-off valves located outside the fire hazard area or equivalent arrangement preventing flow of fuel from damaged piping into such area.

7.3 Fuel oil system

7.3.1 The fuel supply to propulsion and essential service auxiliary machinery is to be arranged with water separating/filtering equipment which can be drained or cleaned without interrupting the fuel supply.

7.3.2 For propulsion or auxiliary machinery arranged with two mutual independent engines with sufficient capacity for the manoeuvrability of the craft the requirement of duplicated filtering equipment may be omitted.

7.4 Lubricating oil system

7.4.1 The lubricating oil systems for propulsion and essential service auxiliary machinery are to be arranged with suitable filtering equipment which can be cleaned without interrupting the oil supply to the engine.

7.4.2 The lubricating oil system shall be designed to function satisfactorily when the craft has a permanent list of at least 15°.

7.4.3 Where the size and design of an engine is such that lubrication before starting is not necessary and an attached pump is normally used, no independent auxiliary pump is required.

7.4.4 If the lubrication oil pump is independently driven (electrically driven the number of such lubrication oil pump shall not be less than 2).

7.5 Cooling water systems

7.5.1 Where water is used as cooling medium for propulsion or auxiliary machinery of essential service, the cooling water circulating system is to be arranged so that in the event of failure of a circulating pump an alternative pump is available for same duty.

7.5.2 For propulsion or auxiliary machinery, arranged with two mutual independent engines with sufficient capacity for the manoeuvrability of the craft, having attached sea water cooling pumps the requirements of space pump for such duty may be omitted.

7.5.3 For propulsion or auxiliary machinery having attached fresh water cooling pumps the requirement of spare pump for such duty may be omitted.

7.5.4 The sea water suction shall be provided with strainers which can be cleaned without interrupting the cooling water supply which are needed for the manoeuvrability of the craft.

7.5.5 Seawater cooling systems for the main and auxiliary machinery are normally to be connected to two separate cooling water inlets, preferably on opposite sides of the craft.

7.6 Starting systems

7.6.1 Propulsion and generator engines are to be equipped with starting arrangement of sufficient capacity which can be easily operated without external aid.

7.6.2 The starting arrangement is to have capacity sufficient for starting each engine 6 times without recharging of the power capacity.

7.6.3 Equipment for recharging of the engine starting power capacities as required in 602 is to be available onboard the craft. In the case of pneumatic starting arrangements such recharging is to be possible within one hour. For other types of starting arrangements required recharging time will be considered case by case.

7.7 Machinery space ventilation

7.7.1 A mechanical ventilation system with suitable weather deck inlets and outlets including dampers shall be provided for the machinery space.

7.7.2 Calculated air quantity required shall be based on the sum of the air demanded for diesel engines and boilers as well as the requirements for exhaustion of heat emitted from diesel engines, electrical equipment, boilers, exhaust pipes and tanks etc. However, in no case shall air supply be less than total sum of needed combustion air plus 50%.

7.7.3 The air ventilation system should be designed so as to keep a slight positive air pressure in the machinery space while operating at normal condition.

7.7.4 The temperature rise (maximum difference between exhaust and supply air) should normally not exceed 10°C assuming maximum ambient air temperature.

7.7.5 The air system should be distributed and balanced in such way as to provide an atmosphere which is agreeable to the personnel, machinery and equipment throughout the space.

7.7.6 Air should not discharge directly on insulated piping or electrical equipment nor should it be necessary that air be directed at any equipment in order for it to function properly.

7.7.7 Fire dampers shall be fitted to all inlets and outlets.

SECTION 8 Additional requirements for commercial yachts

8.1 General

8.1.1 For yachts with the notation “COMMERCIAL YACHT” the requirements of Part 5 (Chapters 8 and 9) of the Rules and Regulations for the Classification and Construction of steel ships, regarding the materials selection, the design and construction of piping systems installed on craft, are to be complied with, where applicable. Additionally, the following requirements shall be met.

8.2 Materials for valves and associated piping

8.2.1 Valves which are fitted below the waterline shall be of steel, bronze or other material having a similar resistance to impact, fire and corrosion. Non-metallic valves shall not normally be considered equivalent.

8.2.2 The associated piping shall, in areas as indicated above, be of steel, bronze, copper or other equivalent material. Non-metallic piping shall not normally be considered equivalent.

8.2.3 Where the use of plastic piping is proposed, it shall be specially considered and full details of the type of piping, its intended location, and use, shall be submitted for approval; with regard to watertight integrity, any plastic piping shall be above the waterline. Due regard shall be paid to the Fire Test Procedures Code, and of Part 7 Chapter 2 paragraph 2.4.4 and Part 7 Chapter 3 paragraph 11.1.6.

8.2.4 The use of flexible piping in any location shall be kept to a minimum compatible with the essential reason for its use. Flexible piping and the means of joining it to its associated hard piping system shall be approved as fit for the purpose.

8.3 Yachts lesser than 500 gross tons

8.3.1 Yachts having plastic pipes fitted should have the piping and the arrangements for its use compliant with the requirements of IMO Fire Test Procedures Code.

8.3.2 Notwithstanding the requirements of 8.3.1, in a fuel supply system to an engine unit, where a flexible section of piping is provided, connections shall be of a screw type or equivalent approved type. Flexible pipes shall be fire resistant/metal reinforced. Materials and fittings shall be of a suitable recognised national or international standard.

8.3.3 Means shall be provided to isolate any source of fuel which may feed a fire in an engine space. A fuel shut-off valve(s) shall be provided which is capable of being closed from a position outside the engine space. The valve(s) shall be fitted as close as possible to the fuel tank(s).

8.3.4 All external high-pressure fuel delivery lines between the high pressure fuel pumps and fuel nozzles shall be protected with a jacketed tubing system capable of containing fuel resulting from a high-pressure line failure. The jacketed tubing system shall include means for collection of leakage and arrangements shall be provided for an alarm to be given in the event of a fuel line failure.

8.3.5 When a glass fuel level gauge is fitted it shall be of the "flat glass" type with self closing valves between the gauge and the tank.

8.3.6 All vessels shall be provided with at least two fixed and independently powered bilge pumps,. For short Range Yachts, the second pump and suction pipes may be portable.

8.3.7 The pumps and their suction pipes should be so arranged that any compartment can be effectively drained when the vessel is heeled to an angle of 10º.

8.3.8 Hand pumps are not permitted.

8.3.9 The location of pumps required by paragraphs 8.3.6-8.3.8, their individual power supplies and controls, including those for bilge valves shall be such that, in the event of any one compartment being flooded at least one of those pumps is capable of removing water from the flooded space and adjacent compartments and discharging this via a dedicated discharge overboard.

8.3.10 Each bilge pump suction line shall be fitted with an efficient strum box.

8.3.11 In the case of a vessel where the propulsion machinery space may be unmanned at any time, a bilge level alarm shall be fitted. The alarm shall provide an audible and visual warning in the Master's cabin and in the wheelhouse. The audible and visual alarm may be accepted elsewhere if it is considered that such a location may be more appropriate.

8.3.12 Pumping and piping arrangements for bilges into which fuel or other oils of similar or higher fire risk could collect, under either normal or fault conditions, shall not contravene MARPOL requirements. Bilge level alarms meeting the requirements of paragraph 8.3.11 shall be fitted to all such bilges.

8.4 Yachts of 500 gross tons and over

8.4.1 The bilge pumping and its installation shall as a minimum meet the cargo vessel standards of SOLAS II-1/Part C -Bilge pumping arrangements Regulation 35-1.

8.4.2 A minimum of two bilge pumps shall be provided. The capacity of the pumps and the size of the bilge main and branches shall meet the capacity requirements for passenger ships contained in SOLAS.

8.4.3 In addition, the minimum requirements for vessels of less than 500GT contained in paragraph 8.3, shall also be met.

8.5 Alternative design and arrangements (all yachts)

8.5.1 Vessels may follow Part 1, Chapter 2, Section 1.9 on Alternative Design and Arrangements for this chapter as allowed by SOLAS II-1/55.

8.5.2 The engineering analysis required by Part 1, Chapter 2, Section 1.9, Paragraph 1.9.3 shall be prepared and submitted to L.H.R., based on the guidelines (SOLAS chapters II-1 and III (MSC.1/Circ.1212)) and shall include, as a minimum, the following engineering analysis elements:

a) determination of the ship type, machinery, electrical installations and space(s) concerned;
b) identification of the prescriptive requirement(s) with which the machinery and electrical installations will not comply;
c) identification of the reason the proposed design will not meet the prescriptive requirements supported by compliance with other recognized engineering or industry standards;
d) determination of the performance criteria for the ship, machinery, electrical installation or the space(s) concerned addressed by the relevant prescriptive requirement(s):
    i. performance criteria shall provide a level of safety not inferior to the relevant prescriptive requirements contained in SOLAS II-1 parts C, D and E; and
    ii. performance criteria shall be quantifiable and measurable;
e) detailed description of the alternative design and arrangements, including a list of the assumptions used in the design and any proposed operational restrictions or conditions;
f) technical justification demonstrating that the alternative design and arrangements meet the safety performance criteria; and
g) risk assessment based on identification of the potential faults and hazards associated with the proposal.

CHAPTER 6 Steering Gear

Contents

SECTION 1 Plans and specifications

1.1 Documents for approval

1.1.1 Before starting construction, all relevant plans and specifications are to be submitted to the Society for approval.

SECTION 2 Definitions

2.1 Main definitions

2.1.1

(a) Steering gear control system means the equipment by which orders are transmitted from the navigating room 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.

(b) Main steering gear means the machinery, rudder actuator(s), the steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudder stock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.

(c) Steering gear power unit means:

.1 in the case of electric steering gear, an electric motor and its associated electrical equipment;

.2 in the case of electrohydraulic steering gear, an electric motor and its associated electrical equipment and connected pumps;

.3 in the case of other hydraulic steering gear, a driving engine and connected pump.

(d) Auxiliary steering gear means the equipment other than any part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

(e) 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 the same purpose.

(f) Maximum ahead service speed means the greatest speed which the ship is designed to maintain in service at sea.

(g) Rudder actuator means the component which converts directly hydraulic pressure into mechanical action to move the rudder.

(h) Maximum working pressure means the expected pressure in the system when the steering gear is operated.

SECTION 3 Power piping arrangement

3.1 General

3.1.1 The power piping for hydraulic steering gears is to be arranged so that transfer between units can be readily effected.

3.1.2 Where the steering gear is arranged so that more than one system (either power or control) can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

3.1.3 For all vessels with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

3.1.4 Arrangements for bleeding air from the hydraulic system are to be provided where necessary.

3.1.5 Piping, joints, valves, flanges and other fittings are to comply with the Society's requirements for Class I components as prescribed in Part 5, Chapter 8, SECTION 13 of the "Rules and Regulations for the Classification and Construction of Steel Ships". The design pressure is to be in accordance with 6.1.8.

SECTION 4 Rudder angle limiters

4.1 General

4.1.1 Power-operated steering gears are to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronized with the gear itself and not with the steering gear control.

SECTION 5 Materials

5.1 Strength requirements

5.1.1 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, or similar components) should be of steel or other approved ductile material, duly tested in accordance with the requirements of the Society. In general, such material should 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 levels, excluding cylinders, upon special consideration.

SECTION 6 Design

6.1 General principles

6.1.1 The construction should be such as to minimize local concentrations of stress.

6.1.2 Welds

(a) The welding details and welding procedures should be approved.

(b) All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads should be full penetration type or of equivalent strength.

6.1.3 Oil Seals

(a) Oil seals between non-moving parts, forming part of the external pressure boundary, should be of the metal upon metal type or of an equivalent type.

(b) Oil seals between moving parts, forming part of the external pressure boundary, should 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 Administration.

6.1.4 All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller. Relevant calculations must be submitted for consideration.

6.1.5 For piping, joints, valves, flanges and other fittings see 3.1.5.

6.1.6 Rudder actuators are normally be designed in accordance with Class I pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

6.1.7 In application of such rules the permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_B}{A} \; or \; \frac{\sigma_y}{B}$$

σ_B = specified minimum tensile strength of material at ambient temperature, N/mm²,

σ_y = specified minimum yield stress or 2% proof stress of the material, at ambient temperature , N/mm²

A, B: given by the Table 6.6.1.

Table 6.6.1:

	Steel	Cast Steel	Nodular Cast iron
A	3,5	4	5
B	1,7	2	3

6.1.8 The design pressure is to be at least equal to the greater of the following:

(a) 1,25 times the maximum working pressure.

(b) the relief valve setting.

6.1.9 Accumulators, if any are to comply with Society requirements for pressure vessels.

6.2 Main steering gear

6.2.1 Main steering gear is to be at least capable of putting the rudder from 35 degrees on one side to 35 degrees on the other side with the vessel running ahead at maximum continuous shaft rpm and at the design waterline. For vessels with a required upper rudder stock diameter of 120 mm and greater, the main steering gear is to be power operated. The main steering gear is to be capable of putting the rudder over from 35 degrees on either side to 30 degrees on the other side in no more than 28 seconds. The arrangement of power operated steering gear fitted on vessels with a required upper rudder stock diameter of less than 120 mm will be specially considered.

6.3 Auxilliary steering gear

6.3.1 Effective auxilliary means for actuating the rudder is to be provided and when power operated is to be capable of putting the rudder from 15 degrees on one side to 15 degrees on the other side in not more than 60 seconds with the vessel running ahead at half speed, or 7 knots whichever is the greater. An auxilliary means of steering will not be required for the following arrangements:

(a) When the steering gear comprises two or more power units, and two independent means of control are provided operable from the navigating room.

(b) When non-power operated mechanical main steering gear is used.

(c) When steering is accomplished by positioning the propulsion unit.

6.4 Protection

6.4.1 The main steering gear is to be protected from the weather and the auxilliary steering gear is to be so protected as to permit satisfactory operation in bad weather.

SECTION 7 Dynamic loads for fatigue and fracture mechanic analysis

7.1 Specification

7.1.1 The assumed dynamic loading in the fatigue and fracture mechanics analysis is to be submitted for consideration. Both the case of high cycle and cumulative fatigue are to be considered.

SECTION 8 Hoses

8.1 Requirements

8.1.1 Hose assemblies of type approved by the Society may be installed between two points where flexibility is required but should not be subjected to torsional deflection (twisting) under normal operating conditions. In general, the hose should be limited to the length necessary to provide for flexibility and for proper operation of machinery.

8.1.2 Hoses should be high pressure hydraulic hoses according to recognized standards and suitable for the fluids, pressures, temperatures and ambient conditions in question.

8.1.3 Rupture pressure of the hoses should not be less than four times the design pressure.

SECTION 9 Relief valves

9.1 Requirements

9.1.1 Relief valves for protecting any part of the hydraulic system which can be isolated, as required by Solas Regulation 29.2.3 should comply with the following:

(a) The setting pressure should not be less than 1,25 times the maximum working pressure.

(b) The minimum discharge capacity of the relief valve(s) should 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 should not exceed 10% of the setting pressure. In this regard, due consideration should be given to extreme foreseen ambient conditions in respect of oil viscosity. The Society may require, for the relief valves, discharge capacity tests and/or shock tests.

SECTION 10 Electrical installations

10.1 Requirements

10.1.1 Electrical installations should comply with the requirements of Part 6 of these Rules.

SECTION 11 Alternative source of power

11.1 General

11.1.1 Where the rudder stock is required to be over 230 mm diameter in way of the tiller an alternative power supply, sufficient at least to supply the steering gear power unit which complies with the requirements of 6.3 and also its associated control system and the rudder angle indicator , shall be provided automatically, within 45 seconds, either from the emrgency source of electrical power or from an independent source of power located in the steering gear compartment. This independent source of power should be used only for this purpose.

11.1.2 Where the required alternative power source is a generator, or an engine driven pump, automatic starting arrangements are to comply with the requirements relating to the automatic starting arrangements of emergency generators.

SECTION 12 Monitoring and alarm systems

12.1 Requirements

12.1.1 Monitoring and alarm systems, including the rudder angle indicators, should be designed, built and tested to the satisfaction of the Society (see also Part 8, Chapter 1).

12.1.2 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.

SECTION 13 Operating instructions

13.1 General

13.1.1 Appropriate operating instructions with a block diagram showing the change-over procedures for the steering gear control systems and steering gear actuating systems should be permanently displayed in the wheel-house and in the steering gear compartment. Where the system failure alarms according to SECTION 12 are provided, appropriate instructions shall be placed on the navigating bridge to shut down the failed system.

SECTION 14 Testing and trials

14.1 Testing

14.1.1 The requirements of the Society relating to the testing of Class I pressure vessels, piping, and relating fittings including hydraulic tenting apply.

14.1.2 A power unit pump is to be subjected to a type test. The type test shall be for a duration of not less than 100 hours, the test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should 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 should be disassembled and inspected. Type tests may be waived for a power unit which has been proven to be reliable in marine service.

14.1.3 All components transmitting mechanical forces to the rudder stock should be tested according to the requirements of the Society.

14.1.4 After installation on board the vessel the steering gear is to be subjected to the required hydrostatic and running tests.

14.2 Trials

14.2.1 The steering gear should 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 should include the operation of the following, as applicable:

(a) the steering gear, including a demonstration of the performances required in 6.2 and 6.3, with craft running ahead at maximum continuous rpm;

(b) auxilliary steering gear performance and transfer between main and auxilliary steering gear;

(c) the power units including transfer between power units;

(d) the steering gear controls, including transfer of control and local control;

(e) the alarms and indicators; these tests may be effected at dockside;

(f) where steering gear is designed to avoid hydraulic locking this feature shall be demonstrated;

(g) the rudder angle indicator;

(h) the motor indicators.

SECTION 15 Additional requirements for commercial yachts

15.1 General

15.1.1 The following requirements shall apply additionally to yachts with the notation "COMMERCIAL YACHT".

15.2 Yachts of less than 500 gross tons

15.2.1 Yachts shall be provided with means for directional control of adequate strength and suitable design to enable the heading and direction of travel to be effectively controlled at all operating speeds. When appropriate to the safe steering of the vessel, the steering gear shall be power operated in accordance with the requirements of L.H.R.

15.2.2 When the steering gear is fitted with remote control, arrangements shall be made for emergency steering in the event of a failure of such control.

15.2.3 The emergency steering position shall be fitted with:

a) The angular position of the rubber; and

b) Heading indication

15.3 Yachts of 500 gross tons and over

15.3.1 For existing and new vessels, the steering gear and its installation shall meet the standards of SOLAS II-1/Part C -Machinery installations for cargo vessels, so far as it is reasonable and practicable to do so.

15.3.2 In any case, the intention shall be to achieve a standard of safety which is at least equivalent to the standard of SOLAS. Equivalence may be achieved by incorporating increased requirements to balance deficiencies and thereby achieve the required overall standard.

15.4 Alternative design and arrangements (all yachts)

15.4.1 Vessels may follow Part 1, Chapter 2, Section 1.9 on Alternative Design and Arrangements for this chapter as allowed by SOLAS II-1/55.

15.4.2 The engineering analysis required by Part 1, Chapter 2, Section 1.9, Paragraph 1.9.3 shall be prepared and submitted to L.H.R, based on the guidelines (SOLAS chapters II-1 and III (MSC.1/Circ.1212)) and shall include, as a minimum, the following engineering analysis elements:

a) determination of the ship type, machinery, electrical installations and space(s) concerned;
b) identification of the prescriptive requirement(s) with which the machinery and electrical installations will not comply;
c) identification of the reason the proposed design will not meet the prescriptive requirements supported by compliance with other recognized engineering or industry standards;
d) determination of the performance criteria for the ship, machinery, electrical installation or the space(s) concerned addressed by the relevant prescriptive requirement(s):
    i. performance criteria shall provide a level of safety not inferior to the relevant prescriptive requirements contained in SOLAS II-1 parts C, D and E; and
    ii. performance criteria shall be quantifiable and measurable;
e) detailed description of the alternative design and arrangements, including a list of the assumptions used in the design and any proposed operational restrictions or conditions;
f) technical justification demonstrating that the alternative design and arrangements meet the safety performance criteria; and
g) risk assessment based on identification of the potential faults and hazards associated with the proposal.