Excerpt from ABS Rules Developed for Internal Combustion Engines (Other than Dual Fuel Diesel and Single Gas Fuel Engines)

ABS

Booklet developed on 1 January, 2026

Excerpt from ABS Rules Developed for Internal Combustion Engines
(Other than Dual Fuel Diesel and Single Gas Fuel Engines)

American Bureau of Shipping

Incorporated by Act of legislature

of the State of New York 1862.

Disclaimer:

While every effort has been made to ensure the accuracy and completeness of the Vendor Rule Book, where there are discrepancies between the Vendor Rule Book content and the pdf versions of the Rules and Guides on American Bureau of Shipping (ABS) Eagle.org, the pdf versions from the web site are to be considered the official version.

ABS Plaza

1701 City Plaza Drive

Spring, Texas 77389 USA

CONTENTS

Foreword

Purpose

This booklet is an excerpt from the ABS Rules. It has been created to support equipment manufacturers in identifying the appropriate ABS Rules for their products.

Application

Equipment manufacturers seeking to have their products approved for marine and offshore applications under ABS classification or certification will find this booklet a practical reference for determining which sections of the ABS Rules are applicable to their specific equipment types.

This excerpt does not replace or supersede the complete ABS Rules. Users are responsible for consulting the full text of the applicable Rules and ensuring compliance with the most current edition, including any published corrigenda and notices.

Additional Information

For questions regarding the applicability of specific Rules to your equipment. Please contact your local ABS office.

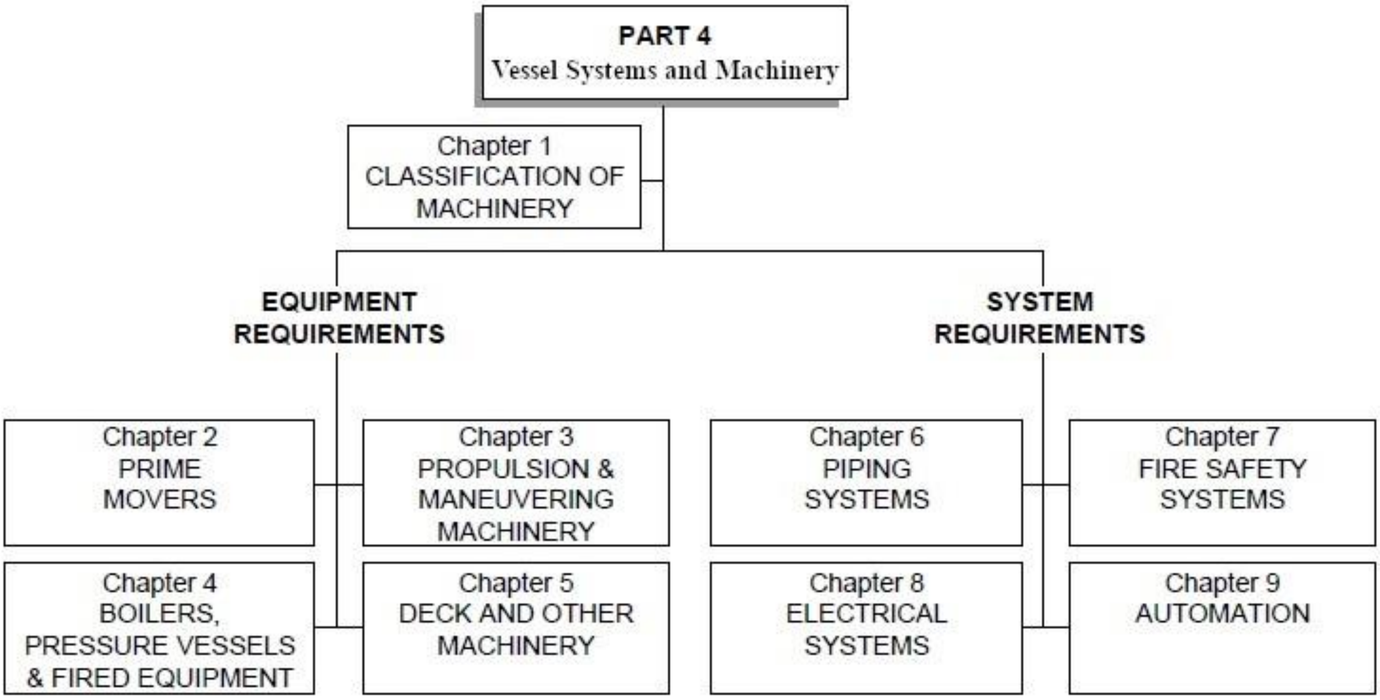
The ABS Rules are available in their complete form at American Bureau of Shipping (ABS) Eagle.org.

1 General

1.1 Organization of Part 4

Part 4 provides classification requirements for machinery. These requirements are organized in two broad segments: that specific to equipment, and that specific to systems. FIGURE 1 shows the overall organization of Part 4.

FIGURE 1
Organization of Part 4



1.2 Objective **(2024)**

1.2.1 Goals

The machinery covered in this section is to be designed, constructed, operated, maintained to:

Goal No.	Goal
POW 1	Provide safe and reliable storage and supply of fuel/energy/power.
POW 5	Enable supply/power for essential services to be restored after malfunction.
PROP 1	Provide sufficient thrust/power to move or maneuver the vessel when required.
PROP 2	Provide redundancy and/or reliability to maintain propulsion.
PROP 3	*Provide sufficient power for going astern...to secure proper control and bring the ship to rest in all normal circumstances.*
SAFE 1	Promote the occupational health and safety of personnel onboard.

Goal No.	Goal
SAFE 1.1	Minimize danger to persons on board, the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.

The goals in the cross-referenced Rules/Regulations are to be met.

1.2.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of machinery are to be in accordance with the following functional requirements:

Functional Requirement No.	Functional Requirements
Propulsion, Maneuvering, Station Keeping (PROP)	
PROP-FR1 (POW)	Operate under anticipated environmental and vessel conditions, such as weather and vibrations.
PROP-FR2	Propulsion machinery is to effectively operate in and efficiently switch over to astern mode without abnormal responses.
PROP-FR3	Propulsion machinery is to provide sufficient astern power to bring the vessel to rest from maximum ahead service speed to avoid a dangerous situation.
PROP-FR4 (POW)	Provide adequate ventilation to allow machinery and personnel to work effectively and machinery for propulsion and emergency services to operate continuously.
Safety of Personnel (SAFE)	
SAFE-FR1	Materials that harm human health are not to be used in machinery.

The functional requirements in the cross-referenced Rules/Regulations are to be met.

1.2.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.3 Requirements for Classification

1.3.1 Scopes of Part 4, Part 5C, Part 5D, and Part 6 **(2024)**

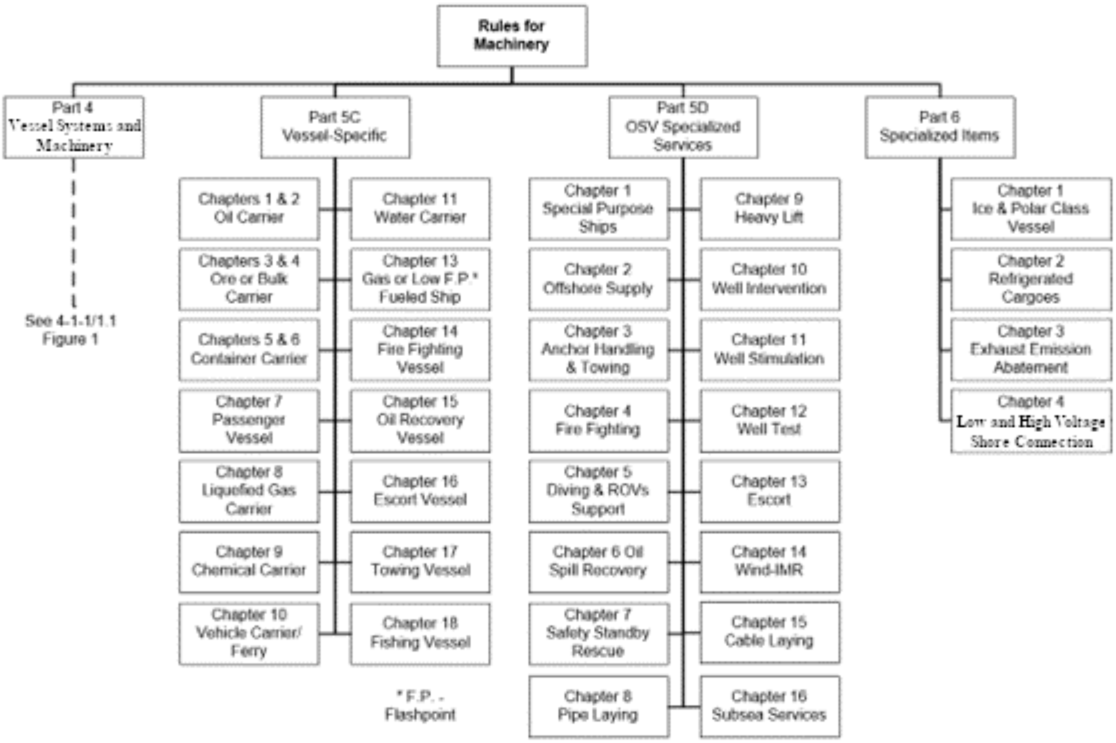
FIGURE 2 shows the overall organization of machinery requirements included in all Parts of the *Marine Vessel Rules*.

Part 4 provides the minimum requirements for machinery of self-propelled vessels. Compliance with Part 4 is a condition for classification of all such vessels, and for assigning the appropriate machinery class notations indicated in 1.5.

Additional requirements for machinery, which are specific for each vessel type, are provided in Part 5C and Part 5D. Compliance with the requirements of Part 5C or Part 5D is a condition for assigning the vessel type class notation specified therein, such as *Oil Carrier*, *Passenger Vessel*, *Liquefied Gas Carrier*, etc.

Additional requirements for specialized items and systems are provided in Part 6. These items and systems used for specific operations include those for navigation in ice, for carrying refrigerated cargoes, for exhaust emission abatement, and for high/low voltage shore connection. Optional class notations in each chapter may be assigned upon compliance with the corresponding requirements in Part 6, such as *Ice Class 1E*, *Ice Class I AA*, *Ice Breaker*, *Ice ClassPC1*, and ✠ *RCC*.

FIGURE 2
Organization of Rules for Machinery in Marine Vessel Rules (2024)



1.3.2 Fundamental Intent of Machinery Rules

1.3.2(a) Propulsion and Maneuvering Capability **(2024)**

Part 4 of the Rules is intended to address the propulsion and maneuvering capability of the vessel through specification of appropriate design, testing, and certification requirements for propulsion, maneuvering and other equipment and their associated systems. See FIGURE 1 for equipment and systems included in the scope.

Loss of propulsion and maneuvering of the vessel may lead to collision or pollution or damage to the vessel and danger to persons on board. Means are to be provided whereby normal operation of propulsion machinery can be sustained or restored even though one of the essential auxiliaries becomes inoperative. ABS, having regard to overall safety considerations, may accept a partial reduction in propulsion capability from normal operation.

1.3.2(b) Machinery Hazards

Part 4 of the Rules is also intended to identify and address hazards associated with machinery aboard a vessel, particularly those hazards which are capable of causing personal injury, flooding, fire or pollution.

1.3.2(c) Cargo Hazards

Hazards associated with cargoes carried (such as oil, dangerous goods, etc.) or to the specialized operations of the vessel (such as navigating in ice) are addressed in Part 5C, Part 5D, or Part 6, as applicable.

1.3.2(d) Hazard Considerations **(2024)**

Design and testing of machinery are to consider the hazards noted in 1.3.2(b) and 1.3.2(c). They are to comply with requirements in the Rules considering the conditions onboard, or in absence of such requirements, with general engineering principles, codes or standards.

The Rules require at least a level of protection for equipment or components such that, when operated incorrectly or failed, will not lead to injury to personnel, damage to asset or pollution. The severity of the consequences upon failure are also to be considered when determining the level of protection to be applied.

In addition, hazardous cargo or related systems are to be designed to mitigate risks considering loss of a single equipment or component. Control and instrumentation systems provided for local, remote control or automation systems are designed to aid machinery operations and their failure are not to lead to injury to personnel, damage or pollution.

Arrangements onboard are to separate sources of ignition from flammable substances and separate hazards from personnel.

Despite risk mitigation, if incidents occur, safety systems are to be provided to help crew address them. Operational aids (such as manuals, training, damage control plans and fire control plans) are also to be provided to assist the crew to respond to emergency and hazardous situations.

1.3.3 Application

Requirements in Part 4 are intended for vessels under construction; but they are to be applied to alterations made to existing vessels, as far as practicable.

1.5 Classification Notations **(2024)**

Classification notations are assigned to a vessel to indicate compliance with particular portions of the Rules. The following classification notations indicate compliance with specific requirements of the Rules for machinery:

AMS indicates that a vessel complies with all machinery requirements in Part 4 other than the requirements associated with the other classification notations below. *AMS* is mandatory for all self-propelled vessels.

ACC indicates that in a self-propelled vessel, in lieu of manning the propulsion machinery space locally, it is intended to monitor the propulsion machinery space and to control and monitor the propulsion and auxiliary machinery from a continuously manned centralized control station. Where such a centralized control station is installed, the requirements of Section 4-9-5 are to be complied with. Upon verification of compliance, *ACC* will be assigned. *ACC* is an optional notation.

ACCU or *ABCU* indicates that a self-propelled vessel is fitted with various degrees of automation and with remote monitoring and control systems to enable the propulsion machinery space to be periodically unattended and the propulsion control to be effected primarily from the navigation bridge. Where periodically unattended propulsion machinery space is intended, the requirements of Section 4-9-6 and Section 4-9-7 are to be complied with. Upon verification of compliance, *ACCU* or *ABCU* will be assigned. *ACCU* and *ABCU* are optional notations.

The optional notation *ABCU-H* indicates that a towing vessel of <500 GT and a length of 20 m (65 ft) ≤ *L* ≤ 46 m (150 ft) is capable of operating with unmanned engine room limited to restricted operations in harbor.

APS indicates that a self-propelled vessel is fitted with athwartship thrusters. *APS* is optional for all self-propelled vessels fitted with such thrusters and indicates compliance with applicable requirements of Section 4-3-5. *APS* is an optional notation.

PAS indicates that a non-self-propelled vessel is fitted with thrusters for the purpose of assisting the movement or maneuvering. *PAS* is only assigned when requested by the Owner and indicates compliance with applicable requirements of Section 4-3-5. *PAS* is an optional notation.

DPS-0, *-0+*, *-1*, *-1+*, *-2*, *-2+*, *-3*, or *-3+* indicates that a vessel, self-propelled or non-self-propelled, is fitted with a dynamic positioning system. The numerals (*-0*, *-1*, *-2* or *-3*) indicates the degree of redundancy in the dynamic positioning system. The symbol + placed after the numeral may be assigned indicating compliance with additional requirements for station keeping capacity and failure modes for static components of the dynamic positioning system. The optional *DPS* notation is assigned only when requested by the owners and indicates compliance with the ABS *Guide for Dynamic Positioning Systems*.

AUTONOMOUS and *REMOTE-CON* notations are mandatory for vessels with permanently installed autonomous or remote controlled functions and signify compliance with ABS *Requirements for Autonomous and Remote Control Functions.*

Commentary:

Autonomous Functions are functions where machines perform each of the four steps in the operational decision loop (i.e., Monitoring, Analysis, Decision and Action) without the need for human intervention to achieve the system mission and perform tasks.

End of Commentary

The above class notations, where preceded by the Maltese cross symbol ✠ (e.g. ✠*AMS*), indicate that compliance with these Rules is to be verified by ABS during construction of the vessel. This includes survey of the machinery at the manufacturer's plant (where required), during installation on board the vessel; and during trials.

Where an existing vessel, not previously classed by ABS, is accepted for class, these class notations are assigned without ✠.

1.7 Alternative Standards (2024)

Equipment, components and systems for which there are specific requirements in Part 4 may comply with requirements of an alternative standard, in lieu of the requirements in the Rules if the alternative standard is determined by ABS to be equivalent to the Rules. Requirements may be imposed by ABS in addition to those contained in the alternative standard so that goals and functional requirements of the Rules are met. In all cases, the equipment, component, or system is subject to design review, survey during construction, tests, and trials, as applicable, by ABS for purposes of verification of its compliance with the alternative standard. The verification process is to be to the extent as intended by the Rules. See also 1A-1-1/1 of the ABS *Rules for Conditions of Classification (Part 1A)*.

1.9 Definitions

Definitions of terms used are defined in the chapter, sections or subsections where they appear. The following are terms that are used throughout Part 4.

1.9.1 Control Station (2024)

A location where controllers or actuators are fitted, along with monitoring devices, as appropriate, for purposes of effecting desired operation of specific machinery.

Control Station is defined solely for purposes of Part 4, Chapter 7 “Fire Safety Systems”, as intended by SOLAS, in 4-7-1/11.21.

Centralized Control Station is defined in 4-9-1/5.1.15 to refer to the space or the location where the following functions are centralized:

- Controlling propulsion and auxiliary machinery,
- Monitoring propulsion and auxiliary machinery, and
- Monitoring the propulsion machinery space.

1.9.2 Machinery Spaces (2024)

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

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

i. Internal combustion machinery used for main propulsion; or
ii. Internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 KW (500 hp); or
iii. Any oil fired boiler or oil fuel unit; or
iv. Any oil-fired equipment other than boilers, such as inert gas generator, incinerator, waste disposal units, etc.

Commentary:

Item iv applies only to fire safety requirements similar to SOLAS Chapter II-2. See IMO MSC/Circ.847 and 4-7-1/11.15.

End of Commentary

1.9.3 Essential Services *(2004)*

For definition of essential services, see 4-8-1/7.3.3.

1.9.4 Hazardous Areas (**2024**)

Areas where flammable or explosive gases or vapors are normally present or likely to be present in quantities that require special precautions for the construction, installation and use of electrical equipment. The flammable or explosive atmosphere may exist continuously or intermittently. Hazardous areas are more specifically defined for certain machinery installations, storage spaces and cargo spaces that present hazards. For example:

- Helicopter refueling facilities, see ;
- Paint stores, see ;
- Cargo oil tanks and other spaces of oil carriers; see
- Cargo tanks and other spaces of an offshore support vessel carrying hazardous and noxious liquid substances with flashpoints not exceeding 60°C (140°F) or carrying hazardous and noxious liquid substances which evolve substances with flashpoints not exceeding 60°C (140°F);
- Recovered oil tanks and other spaces of an offshore support vessel with oil spill response
- Ro-ro cargo spaces; see .

1.9.5 Toxic or Corrosive Substances

Toxic Substances (solid, liquid or gas) are those that possess the common property of being liable to cause death or serious injury or to harm human health if swallowed or inhaled, or by skin contact.

Corrosive Substances (solid or liquid) are those, excluding seawater, that possess in their original state the common property of being able through chemical action to cause damage by coming into contact with living tissues, the vessel or its cargoes, when escaped from their containment.

1.9.6 Dead Ship Condition

Dead ship condition means a condition under which:

i. The main propulsion plant, boilers and auxiliary machinery are not in operation due to the loss of the main source of electrical power, and
ii. In restoring propulsion, no stored energy for starting the propulsion plant, the main source of electrical power and other essential auxiliary machinery is assumed to be available.

1.9.7 Blackout (**1 July 2022**)

Blackout situation means the main and auxiliary machinery installations, including the main power supply, are out of operation but the services for bringing them into operation (e.g., compressed air, starting current from batteries, etc.) are available.

1.9.8 Weathertight (**2024**)

Weathertight means that in any sea conditions, water will not penetrate into the vessel.

1.9.9 Watertight (**2024**)

Watertight means the capability of preventing the passage of water through the structure in any direction under pressure under a head of water for which the surrounding structure is designed.

1.9.10 Normal Operational and Habitable Condition (**2024**)

Normal Operational and Habitable Condition is a condition under which the ship as a whole, the machinery, services, means and aids maintaining propulsion, ability to steer, safe navigation, fire and flooding safety, internal and external communications and signals, means of escape, and emergency boat winches, as well as the designed comfortable conditions of habitability, are in working order and functioning normally.

1.9.11 Main Source of Electrical Power (**2024**)

Main Source of Electrical Power is a source intended to supply electrical power to the main switchboard for distribution to all services necessary for maintaining the ship in normal operational and habitable conditions.

1.9.12 Main Generating Station (**2024**)

Main Generating Station is the space in which the main source of electrical power is situated.

1.9.13 Main Switchboard (**2024**)

Main Switchboard is a switchboard which is directly supplied by the main source of electrical power and is intended to distribute electrical energy to the ship's services.

1.9.14 Emergency Switchboard (**2024**)

Emergency Switchboard is a switchboard which in the event of failure of the main electrical power supply system is directly supplied by the emergency source of power or the transitional source of emergency power and is intended to distribute electrical energy to the emergency services.

3 Certification of Machinery

3.1 Basic Requirements

The Rules define the extent of evaluation, to varying degrees, required for products, machinery, equipment, and their components based on the level of criticality of each item. There are three basic evaluation constituents:

- Design review; type/prototype testing, as applicable;
- Survey during construction and testing at the plant of manufacture; and
- Survey during installation on board the vessel and at trials.

Where design review is required by the Rules, a letter will be issued by ABS upon satisfactory review of the plans to evidence the acceptance of the design. In addition to, or independent of, design review, ABS may require survey and testing of forgings, castings and component parts at the various manufacturers' plants, as well as survey and testing of the finished product. A certificate or report will be issued upon satisfactory completion of each survey to evidence acceptance of the forging, casting, component or finished product. Design review, survey and the issuance of reports or certificates constitute the *certification* of machinery.

Based on the intended service and application, some products do not require certification because they are not directly related to the scope of classification or because normal practices for their construction within the industry are considered adequate. Such products are accepted based on the manufacturers' documentation on design and quality.

Surveys during installation on board the vessel and at trials are required for all items of machinery. This is not considered a part of the product certification process. There may be instances, however, where letters or certificates issued for items of machinery contain conditions which are to be verified during installation, tests or trials.

3.3 Type Approval Program

Products that can be consistently manufactured to the same design and specification may be Type Approved under the ABS Type Approval Program. The ABS Type Approval Program is a voluntary option for the demonstration of the compliance of a product with the Rules or other recognized standards. It may be applied at the request of the designer or manufacturer. The ABS Type Approval Program covers Product Type Approval (1A-1-4/7.7.3 of the ABS *Rules for Conditions of Classification (Part 1A)*), but is also applicable for a more expeditious procedure towards Unit-Certification as specified in 1A-1-4/7.7.2 of the ABS *Rules for Conditions of Classification (Part 1A)*.

See the "ABS Type Approval Program " in Appendix 1A-1-A3 of the ABS *Rules for Conditions of Classification (Part 1A)*.

3.5 Non-mass Produced Machinery

Non-mass produced critical machinery, such as propulsion boilers, slow speed diesel engines, turbines, steering gears, and similar critical items are to be individually unit certified in accordance with the procedure described in 3.1. However, consideration will be given to granting Type Approval to such machinery in the category of Recognized Quality System (RQS). The category of Product Quality Assurance (PQA) will not normally be available for all products and such limitations will be indicated in TABLE 1 to TABLE 6. In each instance where Type Approval is granted, in addition to quality assurance and quality control assessment of the manufacturing facilities, ABS will require some degree of product specific survey during manufacture.

3.7 Details of Certification of Typical Products **(2024)**

TABLE 1 through TABLE 6 summarize certification requirements of typical machinery based on the specific requirements of the Rules for machinery. The tables also provide the applicability of the Type Approval Program for each item.

The tables contain six product categories as follows:

- Prime movers
- Propulsion, maneuvering and mooring machinery
- Electrical and control equipment
- Fire safety equipment
- Boilers, pressure vessels, and fired equipment
- Piping system components

Commentary:

The approval tiers indicated in the tables are the minimum tiers of certification requirements. Refer to Appendix 1A-1-A4 of the ABS *Rules for Conditions of Classification (Part 1A)* for details of each Tier of Approval.

End of Commentary

3.9 ABS Marking on Finished Components and Equipment **(2021)**

All finished component/equipment issued with unit certificates are to be permanently marked at an accessible location for identification and traceability. The identification is to include, but not limited to the model number or part number, serial number and other data that are necessary to comply with other ABS Rule requirements.

At the request of the manufacturer, an ABS Marking may be applied. The marking includes the ABS mark (✠) and a unique identification number generated by ABS.

An example of ABS marking: ✠ 123456.

Markings are to be permanently marked (i.e. steel-die-stamped, laser etched, etc.) at an accessible location by the manufacturer on each finished component or equipment.

ABS Certificates for the components and equipment are to be provided to the responsible party (e.g. owner or shipyard) and Surveyor at installation.

5 Machinery Plans

5.1 Submission of Plans **(2024)**

Machinery and systems plans required by the Rules are to be submitted electronically by the manufacturer, designer, or shipyard to ABS. Where so stated in the shipbuilding contract, the Owner may require the shipyard to provide it with copies of approved plans and related correspondence. A fee will be charged for the review of plans which are not covered by a contract of classification with the shipyard.

All plans are to be submitted and approved before proceeding with the work.

5.3 Plans **(2024)**

Machinery plans required to be submitted for review and approval by ABS are listed in each of the sections in Part 4. Equipment plans are to contain performance data and operational particulars; standard of compliance where standards are used in addition to, or in lieu of, the Rules; construction details such as dimensions, tolerances, welding details, welding procedures, material specifications, etc.; and engineering calculations or analyses in support of the design. System plans are to contain a bill of material with material specifications or particulars, a legend of symbols used, system design parameters, and are to be in a schematic format. Lists of subsystems/components that make up the systems or equipment in the scope of ABS, along with the details of the suppliers responsible for submitting drawings to ABS, are to be provided. Booklets containing standard shipyard practices of piping and electrical installations are required to supplement schematic system plans.

5.3.1 Repair and Modification of Machinery (**2024**)

When repairs or modifications are made to ABS approved systems and equipment, documentation identifying the changes, as well as any documentation that supersedes or replaces previously approved documentation is required to be submitted for ABS review and approval by the equipment designer or responsible party. Repairs and modifications are to be carried out to the satisfaction of the Surveyor.

If the service or product bulletin indicates modification or alterations to the component that would impact the Class approval, these details are to be submitted to ABS Engineering for review and approval.

7 Miscellaneous Requirements for Machinery

7.1 Construction Survey Notification

Before proceeding with the manufacture of machinery requiring test and inspection, ABS is to be notified that survey is desired during construction. Such notice is to contain all the necessary information for the identification of the items to be surveyed.

7.3 Machinery Equations (**2024**)

Equations for rotating parts of the machinery in Part 4 of the Rules are based on strength considerations only and their application does not relieve the manufacturer of the responsibility for mitigating excessive vibrations and other considerations in the machinery at speeds within the operating range.

7.5 Astern Propulsion Power

7.5.1 General (**2026**)

The minimum astern power required by SOLAS II-1/28.1 to secure proper control of the vessel in all normal circumstances is to be determined by the vessel designer and is not to exceed the maximum permissible astern power (MPAP) for which the propulsion plant is designed. Astern trials are to be conducted in accordance with the provisions of ISO 19019:2005, section 5.4: Astern trials. Main propulsion systems with reversing gears, controllable pitch propellers or electric propulsion drive are to be designed for the maximum permissible astern power, which is not to lead to overload of the propulsion machinery.
Note: The designed maximum astern power, as referred to in SOLAS II-1/3.15, defining the maximum astern speed for the design of the main steering gear and rudder stock as per 3-2-14/3.1 and SOLAS II-1 / 29.3.4, are not to be taken less than the MPAP.

The astern tests are to be carried out from control positions. A test plan is to be provided by the shipyard and accepted by the Surveyor. If specific operational characteristics have been defined by the manufacturer these are to be included in the test plan.The ability of the machinery, including the blade pitch control system of controllable pitch propellers, to reverse the direction of thrust of the propeller in sufficient time, and so to bring the vessel to rest within a reasonable distance from maximum ahead service speed, is to be demonstrated and recorded during trials, see 4-3-3/9.11.2.

7.5.2 Steam Turbine Propulsion (**2026**)

Where steam turbines are used for main propulsion, the astern trial is to demonstrate that they are to be capable of operating at their maximum permissible astern power (MPAP) for a period of at least 15 minutes. The astern trial is to be limited to 30 minutes or is to be in accordance with manufacturer’s recommendation to avoid overheating of the turbine due to the effects of “windage” and friction.

7.7 Dead Ship Start

Means are to be provided to bring the machinery into operation from a "dead ship" condition, as defined in 1.9.6. See 4-8-2/3.1.3 and 4-8-4/1.13 for the required starting arrangements.

7.9 Inclinations, Ship Accelerations and Motions (2025)

7.9.1 General (2025)

Machinery installations are to be designed to allow proper operations under the conditions as shown in 4-1-1/9 TABLE 7and in 4-1-1/7.9.2.

7.9.2 Shipboard Accelerations (2025)

Main propulsion and steering machinery and auxiliary machinery that is essential to the propulsion and steering and to the safety of the vessel is to be capable of operation under the effects of acceleration and motions. The requirements in 4-1-1/7.9.3 to 4-1-1/7.9.5 apply where documented evidence of equipment suitability is specifically required by other relevant sections of the Rules for such equipment or requested by ABS.

7.9.3 Documentation (2025)

For vessels subject to the SOLAS Convention, shipbuilders are to identify and document the vessel accelerations and motions periods to which machinery and equipment might be subjected. The expected accelerations and ship motion periods are to be within machinery and equipment manufacturer's requirements. The estimations are to consider vessel type, machinery or equipment location and expected service conditions.

7.9.4 Evaluation of Equipment Suitability (2025)

Machinery and equipment manufacturers are to submit evidence that their machinery or equipment can operate under the required static and dynamic conditions stated in 4-1-1/9 TABLE 7 and at least at the levels of shipboard accelerations as stated in 7.9.2 and/or specified in the relevant sections of the Rules. Documentation of satisfactory performance is to take the form of:

- Test reports showing operation under representative conditions, or
- Calculations or simulation using recognized computational techniques accompanied by detailed and relevant validation data, or
- Evidence of satisfactory service experience

7.9.5 Installation and Operation (2025)

Machinery and equipment manufacturers are to submit details of the requirements/recommendations for installation of the machinery and equipment on board necessary for satisfactory operation in service under the required static and dynamic conditions as described in 4-1-1/9 TABLE 7 and at least at the levels of shipboard accelerations as stated in 7.9.2 and/or specified in the relevant sections of the Rules.
Commentary:

Consideration should be given for positioning machinery in order to minimize the dynamic load on bearings due to ship motions.

End of Commentary

Shipbuilders are to submit details demonstrating that the installation of the machinery and equipment on board is in accordance with manufacturer's requirements/recommendations.

7.11 Ambient Temperature (2024)

For vessels of unrestricted service, ambient temperature as indicated in TABLE 8 is to be considered in the selection and installation of machinery, equipment and components. For ships of restricted or special service, the ambient temperature appropriate for the specific service is to be considered.

7.13 Machinery Space Ventilation (2024)

Ventilation is to be provided for machinery spaces so as to allow simultaneously for crew attendance and for engines, boilers and other machinery to operate at rated power in all weather conditions, including heavy weather. The main propulsion machinery space is to be provided with mechanical means of ventilation.

The supply of air is to be provided through ventilators which can be used in all weather conditions. Ventilators necessary to continuously supply the main propulsion machinery space and the immediate supply to the emergency generator room are to have coamings of sufficient height to eliminate the need to have closing arrangements. See 3-2-17/11.3.

However, where due to the vessel size and arrangement this is not practicable, lesser heights for main propulsion machinery space and emergency generator room ventilator coamings are acceptable with provision of weathertight closing appliances in accordance with 3-2-17/11.3.2 in combination with other suitable arrangements to maintain an uninterrupted and adequate supply of ventilation to these spaces. See also 4-7-2/1.9.5 and 4-7-2/1.9.7.

For emergency generator room ventilation, see also 4-7-2/1.9.8.

7.15 Materials Containing Asbestos

Installation of materials which contain asbestos is prohibited.

7.17 Machinery and Equipment Vibrations (2024)

Mechanical vibrations on board typically originate from rotating machinery (such as propellers, motors, internal combustion engines), pulsating flows in pipes and ducts, and gears. These vibrations transmit throughout the vessel via shafts, foundations, hull, deck structures, pipe supports and equipment mounts. Different modes of vibrations in propulsion shafting systems are to comply with 4-3-2/7. Mechanical joints and electrical equipment for automation are to be tested to vibration limits in 4-6-2/5.9.2(e) and 4-9-9/TABLE 1. Requirements relating to machinery vibrations are also found in vessel specific requirements in Parts 5C, 5D, and 6.

If significant local vibration exists during sea trials, corrective actions or vibration measurements are to be taken at the discretion of the ABS Surveyor.

9 Sea Trials (1 July 2024)

A final under-way trial is to be made of all machinery, steering gear, anchor windlass, stopping and maneuvering capability, including supplementary means for maneuvering, if any. Insofar as practicable, the vessel is to be ballasted or otherwise arranged to simulate fully laden condition so as to allow propulsion machinery to discharge its rated power. The entire machinery installation is to be operated in the presence of the Surveyor to demonstrate its reliability and sufficiency to function satisfactorily under operating conditions. During these operations, no abnormal heating, excessive vibrations or other detrimental operating phenomena are to be observed at speeds within the operating range. All automatic controls, including tripping of all safety protective devices that affect the vessel's propulsion system, are to be tested underway or alongside the pier, to the satisfaction of the Surveyor. References are also to be made to the following for more detailed requirements:

• Steering gear trial:	4-3-4/21.7
• Anchor windlass trial:	4-5-1/9
• Remote propulsion control and automation trial:	4-9-10/5
• Shipboard trials for diesel engines:	4-2-1/13.9

9.1 Sea Trial Records (1 July 2024)

The type/ISO specification of fuel(s) (e.g. ISO 8217) used during the sea trial is to be documented including the viscosity of the fuel(s) as applicable and is to be entered in the classification report.

Based on the sea trials, the following maneuvering characteristics, headings and distances are to be recorded during sea trials to the satisfaction of the Surveyor, and provided on board:

- Speed Trial

- Turning Circle (required only for first vessel of series, subject to flag Administration approval)
- Stopping Ahead/Astern Characteristics
- Astern Propulsion Power under all normal circumstances (see also 4-1-1/7.5)
- For vessels with multiple propellers, or drives, each possible combination of propulsion drive failure is to be tested demonstrating the ability to navigate and maneuver. The evaluation should also include the Lateral Thruster Capability (including single, double, and triple configurations) used to supplement the means of maneuvering or stopping, as applicable. All of the trials are to be conducted under varying test conditions, including 50% MCR (Maximum Continuous Rating), 75% MCR, and 100% MCR.

Commentary:

Reference to be made to IMO Resolution A.209(VII) *Recommendation on Information to be Included in the Maneuvering Booklet* and IMO Resolution A.601(15) *Recommendation on the Provision and the Display of Maneuvering Information on board ships.*

Turning circle results are to be recorded and may be utilized from sister vessels as long as there are no changes to hull lines or rudder characteristics.

End of Commentary

TABLE 1
Certification Details - Prime Movers (1 July 2021)

Prime Movers		ABS Approval Tier (1A-1-A4/1)	Rule Reference
Section 1: Internal Combustion Engines			
1.	Internal Combustion Engines ≥ 100 kW (135 hp), intended for propulsion and aux. services essential for propulsion, maneuvering and safety of the vessel, or required by optional class notation	4/5	4-2-1/1.1, 4-2-1/3, 4-2-1/13.1 - 13.9, 4-2-1/13.11, 4-2-1/15
2.	Internal Combustion Engines < 100 kW (135 hp)	1	4-2-1/1.1
3.	Internal Combustion Engines ≥ 100 kW (135 hp), intended for services not essential for propulsion and aux. services for propulsion, maneuvering and safety of the vessel	1	4-2-1/1.1, 4-2-1/7
4.	Engines operating on natural gas ≥ 100 kW (135 hp), intended for propulsion and aux. services essential for propulsion, maneuvering and safety of the vessel	4/5	4-2-1, 5C-8-1/1.1.3, 5C-8-A7, 5C-13-1/1.7, 5C-13-10, 5C-13-1/1.9
5.	Engines operating on low flashpoint fuels ≥ 100 kW (135 hp), intended for propulsion and aux. services essential for propulsion, maneuvering and safety of the vessel	4/5	4-2-1, 5C-8-1/1.1.3, 5C-13-1/1.7, 5C-13-1/1.2, 5C-13-2/3, 5C-13-10, 5C-8-16/9
Section 2: Turbochargers			
6.	Turbochargers serving cylinder groups > 2500 kW (Category C)	4/5	4-2-2/1.1, 4-2-2/3, 4-2-2/5.7, 4-2-2/11.1 - 11.5, 4-2-2/11.7
7.	Turbochargers serving cylinder groups >1000 kW and ≤ 2500 kW (Category B)	3	4-2-2/5.7, 4-2-2/3,4-2-2/11.1 - 11.5, 4-2-2/11.7
8.	Turbochargers serving cylinder groups ≤ 1000 kW (Category A)	2	4-2-2/1.1, 4-2-2/11.7, 4-2-2/11.5
Section 3: Gas Turbines			
9.	Gas turbines ≥ 100 kW (135 hp), intended for propulsion and aux. services essential for propulsion, maneuvering and safety of the vessel	5	4-2-3/1.1, 4-2-3/5.7, 4-2-3/13.1 - 13.5
10.	Gas turbines that are mass produced per 4-2-3/13.3.2(b)	4	4-2-3/5.7, 4-2-3/13.1 - 13.5
11.	Gas turbines < 100 kW (135 hp)	1	4-2-3/1.1
12.	Gas turbines ≥ 100 kW (135 hp), intended for services not essential for propulsion and aux. services for propulsion, maneuvering and safety of the vessel	1	4-2-3/1.1 , 4-2-3/7

	Prime Movers	ABS Approval Tier (1A-1-A4/1)	Rule Reference
13.	Gas Turbines operating on natural gas or other low flashpoint fuels ≥ 100 kW (135 hp), intended for propulsion and aux. services essential for propulsion, maneuvering and safety of the vessel	4/5	4-2-3, 5C-8-16/8, 5C-8-A8/9.1, 5C-13-10/A1-9, 5C-8-1/1.1.4, 5C-13-10/5
Section 4: Steam Turbines			
14.	Steam turbines ≥ 100 kW (135 hp), intended for propulsion and aux. services essential for propulsion, maneuvering and safety of the vessel	5	4-2-4/1.1, 4-2-4/3, 4-2-4/13.1–13.5
15.	Steam turbines that are mass produced per 4-2-4/13.3.2(b)	4	4-2-4/1.1, 4-2-4/3, 4-2-4/13.1 - 13.5
16.	Steam turbines < 100 kW (135 hp)	1	4-2-4/1.1
17.	Steam turbines ≥ 100 kW (135 hp), intended for services not essential for propulsion and aux. services for propulsion, maneuvering and safety of the vessel	1	4-2-4/1.1 , 4-2-4/7

TABLE 2
Certification Details - Propulsion, Maneuvering and Mooring Machinery (2024)

	Propulsion, Maneuvering and Mooring Machinery	ABS Approval Tier (1A-1-A4/1)	Rule Reference
Section 1: Gears and Clutches			
1.	Gears and clutches ≥ 5590 kW (7500 hp)	5	4-3-1/9.7.1
2.	Gears and clutches ≥ 100 kW (135 hp)	4/5	4-3-1/1.1 , 4-3-1/9.7.2(c)
3.	Gears and clutches < 100 kW (135 hp)	1	4-3-1/9.7.2(d)
Section 2: Propulsion Shafting			
4.	Propulsion shafts, Coupling bolts	5	4-3-2/3.1 - 3.7, 4-3-2/3.7.2(b), 4-3-2/9, 4-3-2/5.19
5.	Cardan Shafts, Couplings	4/5	4-3-2/3.1 - 3.7, 4-3-2/3.7.2(b), 4-3-2/9, 4-3-2/5.21, 4-3-2/5.19
6.	Coupling bolts constructed to a recognized standard	1	N/A
Section 3: Propellers			
7.	Propellers, fixed and controllable pitch (Diameter > 60 imches)	5	4-3-3/7.3
8.	Propellers (Diameter ≤ 60 inches)	2	
9.	Contra Rotating Propellers	5	4-3-9
Section 4: Steering Gears			
10.	Steering Gears	5	4-3-4/19.1 - 19.7
Section 5: Thrusters, Waterjets			
11.	Propulsion Thrusters	4/5	4-3-5
12.	Propulsion Waterjets installed on vessels over 24 m (79 ft)	4/5	4-3-6
13.	Propulsion Waterjets installed on vessels 24 m (79 ft) and below	2	4-3-6
14.	Podded Propulsion Units	5	4-3-8 and 3-2-14/25
15.	Dynamic Positioning Thrusters with optional notation *DPS*	4/5	4-3-5/1.3 and 4-3-5/13, *DPS Guide*
16.	Maneuvering Thrusters with Optional Notations *PAS*, *APS*	4/5	4-3-5/1.3 and 4-3-5/13
Section 6: Anchoring and Mooring			
17.	Anchor Windlass	4/5	4-5-1/7
18.	Mooring Winches	1	4-5-1/1.3

TABLE 3
Certification Details - Electrical and Control Equipment (2025)

Electrical and Control Equipment		ABS Approval Tier (1A-1-A4/1)	Rule Reference
1.	Generators and motors for essential services ≥ 100 kW (135 hp)	4/5	4-8-3/3 , 4-8-5/3.13.1(high voltage)
2.	Motors ≥ 100 kW (135 hp) for liquified gas cargo or vapor handling services.	4/5	5C-8-10/2.12 , 4-8-3/3.17
3.	*(2017)* Generators and motors for essential services < 100 kW (135 hp)	1	4-8-3/3.1
4.	Motors < 100 kW (135 hp) for liquified gas cargo or vapor handling services.	1	4-8-3/3, 5C-8-10
5.	Propulsion generators and motors ≥ 100 kW (135 hp)	5	4-8-3/3 , 4-8-5/5.17.5, 4-8-5/3.11.1 (high voltage)
6.	Switchboards (propulsion, main and emergency)	4/5	4-8-3/5.11.1 , 4-8-5/3.13.2 (high voltage)
7.	Motor controllers for essential services (See 4-8-1/7.3.3) ≥ 100 kW (135 hp) and for services indicated in 4-8-3/Table 7 ≥ 100 kW (135 hp)	4/5	4-8-3/5.11.1
8.	Motor controllers ≥ 100 kW (135 hp) for liquified gas cargo or vapor handling services.	4/5	5C-8-10/2.12
9.	Motor control centers including motor controller for essential services (See 4-8-1/7.3.3)) ≥ 100 kW (135 hp) and for services indicated in 4-8-3/15 TABLE 7 of aggregate load ≥ 100 kW (135 hp)	5	4-8-3/5.11.1
10.	Motor controllers for steering gear	5	4-8-3/5.11.1
11.	Motor control centers $\geq$ 100 kW (135 hp) for liquified gas cargo or vapor handling services.	4/5	4-8-3/5.11.1, 5C-8-10/2.12
12.	Battery charging and discharging units of 25 kW and over for essential services (see 4-8-1/7.3.3), for services indicated in 4-8-3/5.9 or for emergency/transitional source of power.	4/5	4-8-3/5.11.1
13	Computer-based battery charging and discharging units of 25 kW and over for essential services (see 4-8-1/7.3.3), for services indicated in 4-8-3/5.9, or for emergency/transitional source of power, or for services covered under optional notations, including battery chargers under 25 kW.	4/5	4-8-3/5.11.1, 4-9-9/Table 1
14.	Uninterruptible power system (UPS) units of 50 kVA and over for essential services (see 4-8-1/7.3.3), for services indicated in 4-8-3/15 TABLE 7, or for emergency/transitional source of power.	4/5	4-8-3/5.11.1
15	Computer-based UPS controllers of 50 kVA and over for essential services (see 4-8-1/7.3.3), for services indicated in 4-8-3/15 TABLE 7, or for emergency/transitional source of power systems, or for services covered under optional notations, including UPS units under 50 kVA	4/5	4-8-3/5.11.1, 4-9-9/Table 1
16.	Distribution boards associated with the charging or discharging of the battery system of 25 kW and over for emergency source and transitional source of power	4/5	4-8-3/5.11.1
17.	Distribution boards associated with the uninterruptible power system (UPS) units of 50 kVA and over used for essential services (see 4-8-1/7.3.3), for services indicated in 4-8-3/15 TABLE 7 or for emergency/transitional source of power	4/5	4-8-3/5.11.1
18.	Power transformers for essential services and for emergency source of power and converters of low voltage	2	4-8-3/7
19.	Semiconductor converters used to control motor drives having a rated power of 100 kW and over intended for essential services or for services indicated in 4-8-3/15 TABLE 7.	4/5	4-8-3/8

Electrical and Control Equipment		ABS Approval Tier (1A-1-A4/1)	Rule Reference
20.	Non-sparking fans	2	4-8-3/11, 5C-8-12/1.7, 5C-9-12/1.8, 5C-13-13/3.3
21.	Plastic Cable Tray and Protective Casing	2	4-8-4/21.9.4, 4-8-4-A1
22.	Power transformers ≥ 100 kVA and converters for high voltage systems exceeding 1 kV, for essential or emergency source of power	4/5	4-8-5/3.7.5(e) , 4-8-3/8
23.	Cables	2	4-8-5/3.13.3 (high voltage), 4-8-3/9.17, 4-8-3/9.5
24.	Propulsion cables	4/5	4-8-5/5.17.11
25.	Circuit breakers & fuses	1	4-8-3/5.3.3, 4-8-3/5.3.4
26.	Circuit breakers with computer-based tripping units	3	4-8-3/5.3.3, 4-8-3/5.3.4, 4-9-9/ Table 1
27.	Certified safe equipment	2	4-8-3/13.1, 4-8-4/27.13
28.	Electronic Governors/ Governors	2	4-2-1/7.3.3.iii
29.	Cable penetration devices	2	4-8-1/5.3.1
30.	Semiconductor converters for propulsion	4/5	4-8-5/5.17.8
31.	Generator prime mover remote control system	4/5	4-9-9/1, 4-9-3/8, 4-9-9/13 for additional ACC, ACCU and ABCU requirements , 4-9-13, 4-9-14 (as applicable)
32.	Remote auxiliary machinery control system	4/5	4-9-9/1,4-9-3/8, 4-9-9/13 for additional ACC, ACCU and ABCU requirements, 4-9-13, 4-9-14 (as applicable)
33.	Centralized control and monitoring console for *ACC*, *ACCU* and *ABCU* notations	2	4-9-1/7.5, 4-1-1/1.9.1, 4-9-3/8, 4-9-9/1, 4-9-13, 4-9-14 (as applicable)
34.	Control, monitoring and safety system devices, including computers, programmable logic controllers, instrumentation (e.g., electrical/ electronic sensors, transmitters, actuators), etc., for *DPS*, *ACC* and *ACCU* notations and other computer-based systems of Categories II and III. (1)	4/5	4-9-3/8, 4-9-9/13.1, 4-6-2/9.11 (for instrumentation), 4-9-13, 4-9-14 (as applicable)
35.	Complete assembly or subassembly units	4/5	4-9-3/8, 4-9-9/13.1, 4-6-2/9.11 (for instrumentation), 4-9-13, 4-9-14 (as applicable)
36.	Steering control system and computer-based steering system	5	4-3-4/13.9, 4-9-3/8.3.7, 4-9-13, 4-9-14 (as applicable)
37.	Boiler control system (4-9-1/7.3)	5	4-4-1/11.5, 4-9-3/8, 4-9-13, 4-9-14 (as applicable)
38.	CPP control system	5	4-9-3/8 , 4-9-13, 4-9-14 (as applicable)
39.	Control, Safety and Automatic shutdown Systems for generators driven by Gas turbines using gas as fuel	4/5	5C-8-A8/15.1, 5C-13-10/ A1-15.1
40.	Control, Safety and Automatic shutdown Systems for generators driven by Engines using gas as fuel	4/5	4-2-1/13.7.4, 4-9-9, 5C-8-16/7.3, 5C-8-A7/5, 5C-8-A7/7.3.2, 5C-8-A7/3.7, 5C-13-15/7, 5C-13-15/11.5
41.	Cable Management System	4	6-4-3/13

Note:

1. Commercial off-the-shelf (COTS) computer-based system devices such as PLC's, I/O devices, transmitters, transducers, electrical/electronic sensors, etc., can be assigned Tier 2 or Tier 3 as applicable.

TABLE 4
Certification Details - Fire Safety Equipment (2025)

Fire Safety Equipment		ABS Approval Tier (1A-1-A4/1)	Rule Reference
Section 1: Fire Detection and Alarm System Components			
1.	Fire detection and alarm system components	2	4-7-3/11
2.	Computer-based fire detection and alarm panel	4/5	4-7-3/11, 4-9-3, 4-9-13, 4-9-14 (as applicable)
Section 2: Gas Detection and Alarm system Components			
2.	Fixed Hydrocarbon Gas Detection System	2	5C-2-3/20
3.	Liquefied Gas Cargo Gas Detection	2	5C-8-13/6
4.	Gas or Low Flashpoint Fuel Gas Detection	2	5C-13-15
5.	Chemical Cargo Gas Detection	2	5C-9-13/2
Section 3 : Fixed Fire Extinguishing System Components			
6.	Fixed fire extinguishing system components	2	4-7-3/3
7.	Fixed gas systems	2	4-7-3/3
8.	Fixed foam systems	2	4-7-3/5 (IMO MSC/circ. 1165)
9.	Fixed water spray and water-mist systems	2	4-7-3/7
Section 4 : Fireman's Outfit, Hoses, and Portable Extinguishers			
10.	Fireman's outfit(1)	3	4-7-3/15.5
11.	Fire hoses(1)	3	4-7-3/1.13
12.	Portable fire extinguishers(1)	3	4-7-3/15.2

Note:

1. Type approval by flag Administration is acceptable in lieu of ABS Tier requirements.

TABLE 5
Certification Details - Boilers, Pressure Vessels and Fired Equipment (1 July 2024)

Boilers, Pressure Vessels and Fired Equipment		ABS Approval Tier (1A-1-A4/1)	Rule Reference
Section 1: Group I			
1.	Group I boilers and pressure vessels	5	4-4-1/7, 4-4-1/1.9
Section 2: Group II			
2.	Pressure Vessels	4/5	4-4-1/1, 4-4-1/1.11
Section 3: Inert Gas Generators , Incinerators , Boilers, & Fired Heaters			
3.	Incinerators, Boilers, & Fired Heaters	2	4-4-1/1 .vii, 4-4-1/15
4.	Inert Gas Generator	2	4-4-1/1 vii), 4-4-1/15, 5C-2-3/25, 5C-8-9/5, 5C-9-9/1, 5C-13-6/14
5.	Nitrogen Generator	2	4-4-1/1, 5C-2-3/25.41 , 5C-8-9/5.5, 5C-9-9/1, 5C-13-6/14

TABLE 6
Certification Details - Piping System Components (1 July 2024)

Piping System Components		ABS Approval Tier (1A-1-A4/1)	Rule Reference
1.	Pumps related to propulsion diesel engines (bore > 300 mm) (11.8 in.) and gas turbines and gears - fuel, cooling water, lube oil services(1)	4/5	4-6-1/7.3.1, 4-6-1/7.5.3
2.	Pumps related to propulsion steam plant and gears—fuel oil, lube oil, condensate, main circulating, feed water services, vacuum pumps for main condenser(1)	4/5	4-6-1/7.3.1, 4-6-1/7.5.3
3.	Hydraulic pumps of steering gears, controllable pitch propellers, anchor windlass(1)	4/5	4-6-1/7.3.1, 4-6-1/7.5.3
4.	Pumps for fire main, emergency fire pumps, other fire service (fixed water-based, sprinkler, foam), ballast, bilge, liquid cargoes, pumps associated with inert gas(1)	4/5	4-6-1/7.3.1, 4-6-1/7.5.3
5.	Air compressors	1	4-6-5/9.3.3
6.	Gas Cargo/Fuel Compressors	4/5	5C-8-5/13.1.4, 5C-13-9/9
7.	Gas Cargo/Fuel Pumps	4/5	5C-8-5/13.1.3, 5C-13-9/9
8.	Gas Cargo/Fuel Refrigerant Compressor	4/5	5C-8-A5/5.5, 5C-13-6/5.5
9.	Refrigerated Cargo Compressor	5	6-2-6/25.1
10.	Liquefied Gas Cargo Pumps/Fuel Pumps	4/5	4-6-1/7.3.1, 5C-8-5/13.1.3 (IACS), 5C-13-9/9
11.	Steel pipes, classes I and II (except hydraulic piping)(1)	4/5	4-6-1/7.1.1 ,4-6-1/7.5.1, 5C-8-6/2.2, 5C-13-16/1.1
12.	Steel pipes, class III	1	4-6-1/7.1.1,4-6-1/7.5.1, 5C-8-6/2.2, 5C-13-16/1.1
13.	Steel pipes including cargo, gas fuel and vapor pipes at a working temperature at or below minus 18°C (1)	5	2-3-13/27, 4-6-1/7.1.1, 4-6-1/7.5.1, 4-6-2/3.1.7, 5C-8-6/2.2, 5C-13-16/1.1
14.1	Pipe fittings (flanges, elbows, tees etc.), and valves; Classes I & II designed to a recognized standard	1	4-6-1/7.1.1, 4-6-1/7.5.2, 4-6-2/5.17, 5C-8-5/11.6, 5C-8-5/13.1.2, 5C-8-6/2.2, 5C-13-16/1.1, 5C-13-16/7.1
14.2	Pipe fittings (flanges, elbows, tees, etc.), and valves; Classes I & II designed to a non-recognized standard	2	4-6-1/7.1.1, 4-6-1/7.5.2, 4-6-2/5.17, 5C-8-5/11.6, 5C-8-5/13.1.2, 5C-8-6/2.2, 5C-13-16/1.1, 5C-13-16/7.1
15 .	Pipe fittings - flanges, elbows, tees, flexible joints, etc., and valves; class III	1	4-6-1/7.1.1, 4-6-1/7.5.2, 4-6-2/5.17, 5C-8-5/11.6, 5C-8-6/2.2, 5C-8-5/13.1.2, 5C-13-16/1.1, 5C-13-16/7.1
16.	Pipe fittings intended for used at a working temperature at or below minus 18°C and above minus 55°C	1	2-3-13, 4-6-2/3.1.7, 5C-8-5/11.6, 5C-8-6/2.2, 5C-8-5/13.1.2, 5C-13-16/1.1, 5C-13-16/7.1
17 .	Valves , castings and forgings of pipe fittings intended for application at a working temperature at or below minus 55°C	5	5C-8-6/2.2, 5C-8-5/13.1.1, 5C-13-16/1.1, 5C-13-16/7.1
18.	Plastic pipes, fittings, and pipe joints with ISO 9001 certifications	2	4-6-3/9, IACS UR P4
19.	Where Level 1, 2 or 3 is required - Plastic pipes, fittings, and pipe joints w/o ISO 9001 certifications	5	4-6-3/9, IACS UR P4
20.	Where Level 1, 2 or 3 is NOT required - Plastic pipes, fittings, and pipe joints w/o ISO 9001 certifications	2	4-6-3/9, IACS UR P4

Piping System Components		ABS Approval Tier (1A-1-A4/1)	Rule Reference
21.	All flexible hoses and mechanical joints regardless of standard (Does not cover fire hoses. For fire hoses, see 4-1-1/9 TABLE 4)	2	4-6-2/5.7, 4-6-2/5.9, 5C-8-5/11.6, 5C-8-6/2.2, 5C-13-16/1.1
22.	Cargo Hoses for Liquefied Gases and Chemicals	5	5C-8-5/11.7, 5C-9-5/7.3
23.1	Vent heads, flame screens on vent outlets	2	4-6-4/9.3, 5C-8-17/9
23.2	Pressure vacuum valves for cargo tanks	2	5C-2-3/21.11
24 .	Gauges, detectors and transmitters	2	4-6-2/9.11
25 .	Fluid power cylinders and systems, including valve actuators, excluding steering actuators	2	4-6-7/3.5
26.	Shell Valves(1)	4/5	4-6-2/3, 4-6-2/7, 4-6-2/9.13.2

Note:

1. Design review is only required when applying for Type Approval Program.

TABLE 7
Design Angles of Inclination (2026)

Inclinations applied to respective components are as follows:	Angle of inclination, degrees (1)			
	Athwartship		Fore-and-aft	
Installations, components	Static	Dynamic	Static	Dynamic
Propulsion and auxiliary machinery	15	22.5	5	7.5
Safety equipment				
Emergency power installation (3)	22.5	22.5	10	10
Emergency fire pumps and their drives	22.5	22.5	10	10
Switchgear				
Electrical and electronic appliances and control systems	22.5 (2)	22.5 (2)	10	10

Notes:

1. Athwartship and fore-and-aft inclinations occur simultaneously.
2. Switches and controls are to remain in their last set position (no undesired switching operations or operational changes are to occur).
3. In vessels designed for carriage of liquefied gases and of chemicals, the emergency power installation is to remain operable with the vessel flooded to its permissible athwartship inclination up to a maximum of 30 degrees. See and .
4. Where the length of the vessel exceeds 100 m (328 ft), the fore-and-aft static angle of inclination may be taken as 500/*L* degrees, where *L* is the length of the vessel in meters (1640/*L* degrees, where *L* is the length of the vessel in feet), as defined in .

TABLE 8
Ambient Temperatures for Unrestricted Service (1 July 2019)

Air		
Installations, Components	*Location, Arrangement (1, 2)*	*Temperature Range (^{o}C)*
Machinery and electrical installations	Enclosed Spaces - General	0 to +45
	Components mounted on machinery associated with high temperature	According to specific machinery and installation

	In spaces subject to higher temperature (details to be submitted)	According to the actual maximum ambient temperature
	In spaces with temperature lower than +45°C (details to be submitted)	According to the actual ambient temperature subject to minimum +40
	Open Deck(3)	–25 to +45
Water		
Coolant		*Temperature (°C)*
Seawater		+32

Notes:

1. Electronic equipment is to be suitable for operations up to 55°C.
2. For environmentally controlled spaces, see .
3. Control, monitoring and safety devices/systems of equipment for essential services (item (m) of and item (s) of) when located on the open deck are to be rated at -25°C to +45°C. However, the ambient temperature above -25°C is acceptable provided that the selected ambient temperature is specified in the contract specification or the vessel operation manual.

Chapter 2 Prime Movers

Section 1 Internal Combustion Engines

1 General

1.1 Application (2024)

Internal Combustion Engines having a rated power of 100 kW (135 hp) and over intended for propulsion and for auxiliary services essential for propulsion, maneuvering and safety (see 4-1-1/1.3) of the vessel are to be designed, constructed, tested, certified, and installed in accordance with the requirements of this section. For certification requirements, refer to TABLE 1.

Internal Combustion Engines having a rated power of less than 100 kW (135 hp) are not required to comply with the requirements of this section but are to be designed, constructed and equipped in accordance with good commercial and marine practice. Acceptance of such engines will be based on manufacturer's affidavit, verification of engine nameplate data, and subject to a satisfactory performance test after installation conducted in the presence of the Surveyor.

Internal Combustion Engines having a rated power of 100 kW (135 hp) and over intended for services considered not essential for propulsion, maneuvering and safety are not required to be designed, constructed, and certified by ABS in accordance with the requirements of this section. However, the requirements above for internal combustion engines having a rated power of less than 100 kw (135 hp) are to be met. In addition, they are to be provided with safety features as stated in 7, such as crankcase explosion relief valve, overspeed protection. They are also subject to a satisfactory performance test after installation and a verification of the safety features carried out to the satisfaction of the Surveyor.

Piping systems serving internal combustion engines, such as fuel oil, lubricating oil, cooling water, starting air, crankcase ventilation and exhaust gas systems are addressed in Section 4-6-5; hydraulic and pneumatic systems are addressed in Section 4-6-7.

Requirements for turbochargers are provided in Section 4-2-2.

Additional requirements for dual fuel and gas internal combustion engines are provided in Sections 5C-8-16 and 5C-13-10.

Additional requirements for exhaust emission abatement equipment connected to internal combustion engines are provided in Part 6, Chapter 3.

TABLE 1
Certification of Internal Combustion Engines (2024)

Internal Combustion Engines	Certificate Type	Design Assessed	Manufacture Survey	Surveyor Attendance after Installation	Rules Reference
≥ 100 kW (135 hp) for propulsion and aux. services essential for propulsion, maneuvering and safety of the vessel	SC	x	x	x	4-2-1
≥ 100 kW (135 hp) for services NOT essential for propulsion and aux. services for propulsion, maneuvering and safety of the vessel	W	-	-	x	7, 13.9.6, 13.9.8
< 100 kW (135 hp)	W	-	-	x	13.9.6

1.2 Objective **(2024)**

1.2.1 Goals

The internal combustion engines covered in this section are to be designed, constructed, operated, and maintained to:

Goal No.	Goal
PROP 1	provide sufficient thrust/power to move or maneuver the vessel when required.
PROP 3	*provide sufficient power for going astern…to secure proper control and bring the ship to rest in all normal circumstances.*
PROP 7	be provided with means to reduce the risk *of impending or imminent slowdown or shutdown.*
POW 2	provide power to enable the machinery/equipment/electrical installation to perform its required functions necessary for the safe operation of the vessel.
AUTO 1	perform its functions as intended and in a safe manner.
AUTO 2	indicate the system operational status and alert operators of any essential machinery/systems that deviate from its defined design/operating conditions or intended performance.
AUTO 3	have an alternative means to enable safe operation in the event of an emergency or failure of remote control.
SAFE 1	promote the occupational health and safety of personnel onboard.
SAFE 1.1	minimize danger to persons on board, the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.
FIR 1	*prevent the occurrence of fire and explosion.*
FIR 2	*reduce the risk to life caused by fire.*
FIR 3	*reduce the risk of damage caused by fire to the ship, its cargo and the environment.*
MGMT 1	*provide for safe practices in ship operation and a safe working environment.*

Materials are to be suitable for the intended application in accordance with the following goals and support the Tier 1 goals as listed above.

Goal No.	Goal
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.

The goals in the cross-referenced Rules are also to be met.

1.2.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, and maintenance of internal combustion engine and appurtenances are to be in accordance with the following functional requirements.

Functional Requirement No.	Functional Requirements
Materials (MAT)	
MAT-FR1	The material and manufactured components for internal combustion engines are to withstand the maximum working stresses without any deformation or fatigue failure at working temperature.
MAT-FR2	Hardness is to be sufficient for wear/abrasion resistance.
MAT-FR3	Materials other than steel are to be designed and installed to provide an equivalent level of safety as steel application.
MAT-FR4	Materials made of steel designed to work at temperature above 121 °C (250 °F), are to have sufficient tensile properties to resist deformation at the maximum working temperature of the component.
Propulsion, Maneuvering, Station Keeping (PROP)	
PROP-FR1 (POW)	Internal combustion engines and components are designed for producing the rated power in specified ambient conditions.
Power Generation and Distribution (POW)	
POW-FR1 (SAFE)	Internal combustion engines and components are to be designed to withstand the most severe conditions related to pressure, temperature, loads, vessel motions and vibrations.
POW-FR2 (SAFE)	Provide protective means to prevent pressure, temperature, vibration, and loads higher than the designed parameters.
POW-FR3 (SAFE)	Appurtenances are to be designed for optimized and safe operations of the engine and the driven power supply system.
POW-FR4 (SAFE)	Provide mounting arrangements to secure equipment in place and to withstand the equipment weight and transmission of loads/vibrations.
Automation: Control, Monitoring and Safety Systems (AUTO)	
AUTO-FR1	Provide visual and audible notification upon occurrence of a fault in the system, preventing overload.
AUTO-FR2	Monitor, control and maintain the defined environmental conditions inside the crankcases to prevent explosive conditions.
AUTO-FR3	Safeguards are to be provided to monitor the operating parameters and activate alarm, slowdown and shutdown as applicable, preventing overspeed or overheating.
AUTO-FR4	Visual and audible notification at all control and monitoring stations are to be provided upon occurrence of power failure in the system.
AUTO-FR5	*Be able to control the equipment from a local position, even in the case of failure in any part of the automatic or remote control systems. (SOLAS II-1)*
Safety of Personnel (SAFE)	
SAFE-FR1 (MGMT)	Provide arrangements to prevent the engine from being started if the turning gear is engaged.
SAFE-FR2 (MGMT)	Provide means to prevent personnel from contacting hot surfaces.
SAFE-FR3 (MGMT)	Provide means to alert and caution personnel regarding safety and operational issues.
SAFE-FR4	Monitor control and maintain the defined environmental conditions inside the crankcases to prevent explosive conditions.
SAFE-FR5	Provide protective devices if the equipment can be subjected to a pressure more than its design pressure.
Fire Safety (FIR)	
FIR-FR1	Provide safeguards to prevent fire and explosion cause by leakage of flammable liquids.
FIR-FR2	Provide effective containment and extinction of fire within space of origin with due regard to fire growth potential.
FIR-FR3	Safety devices are to be provided to prevent the risk of fire and explosion in crankcase.

The functional requirements covered in the cross-referenced Rules are also to be met.

1.2.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.3 Definitions

For the purpose of this section the following definitions apply:

1.3.1 Internal Combustion Engines (2024)

Internal Combustion Engines mean reciprocating internal combustion engines as listed below:

- Diesel engines, operating with liquid fuel oil
- Dual-Fuel engines, operating with liquid fuel oil and/or with gaseous fuel (and with pilot oil)
- Gas-only engines, operating with gaseous fuel only

Oil fuels may include distillate and residual fuels.

An Internal Combustion Engine is referred to as Engine throughout this Section.

1.3.2 Slow-, Medium-, High-speed Engines (2024)

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

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

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

1.3.3 Rated Power (2025)

The *Rated Power* is the maximum power output at which the engine is designed to run continuously at its rated speed.

1.3.4 Approval of Engines (2020)

Definitions relating to approval of engines are given in Annex 1 of 4-2-1-A1/1.

1.5 Plans and Particulars to be Submitted

1.5.1 Documents for Information (2020)

TABLE 2A lists basic descriptive information to provide ABS 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. See also 13.3.5(a).

1.5.2 Documents for Approval or Recalculation (2020)

TABLE 2B lists the documents and drawings, which are to be approved by ABS. See also 13.3.5(b).

1.5.3 Documents for Inspection and Testing (2020)

TABLE 3 lists the production documents, which are to be submitted by the engine builder/licensee to ABS 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 also 13.3.6(b).

1.5.4 Engine particulars **(2020)**

Type designation of engine is defined by parameters in TABLE 4. Additional engine particulars to be submitted for information are in TABLE 5. See also 13.5.2.

1.5.5 Calculations and Analyses **(1 July 2020)**

Strength analysis for crankshaft and other reciprocating parts.

Strength analysis for engine supports and seating arrangements.

Torsional vibration analysis for propulsion shafting systems for all modes of operation including the condition of one cylinder misfiring.

Calculation demonstrating the adequacy of the bolting arrangement attaching tuning wheels or vibration dampers to the propulsion system to withstand all anticipated torsional vibration and operating loads.

Torsional vibration calculations for AC generating sets when the engine rated power is 110 kW or more, see 4-8-3/3.19.2.

1.5.6 Submittals by Licensee **(2020)**

1.5.6(a) Plans lists

For each diesel engine manufactured under license, the licensee is to submit two listings of plans and data to be used in the construction of the engine:

- One list is to contain drawing numbers and titles (including revision status) of the licenser's plans and data of the engine as approved by ABS (including approval information such as location and date at which they are approved); and
- A second list, which is to contain the drawing numbers and titles (including revision status) of the licensee's plans and data insofar as they are relevant to the construction of the engine. In the event that construction is based solely on licenser's plans, this list is not required.

1.5.6(b) Plans for approval.

Any design change made by the licensee is to be documented and relevant plans and data are to be submitted by the licensee for approval or for information. The licenser's statement of acceptance of the modifications is to be included in the submittal.

1.5.6(c) Plans for surveyor.

A complete set of the licenser's or the licensee's plans and data, as approved by ABS, is to be made available to the Surveyor attending the licensee's plant.

Further details about submittals are in 13.3 and 13.11.

3 Materials

3.1 Material Specifications and Tests **(2020)**

Material specifications are to be in accordance with that in Part 2, Chapter 3 of the ABS *Rules for Materials and Welding (Part 2)* or other specifications approved under 3.3.1. Except as noted in 3.3, materials intended for engines required to be constructed under survey are to be tested and inspected in accordance with TABLE 6. The material tests, where so indicated in the table, are to be witnessed by the Surveyor. Non-destructive tests in TABLE 6are to be carried out by the manufacturer whose test records may be accepted by ABS.

Copies of material specifications or purchase orders are to be submitted to the Surveyor for information.

3.3 Alternative Materials and Tests

3.3.1 Alternative Specifications

Material manufactured to specifications other than those given in Part 2, Chapter 3 of the ABS *Rules for Materials and Welding (Part 2)* may be accepted, provided that such specifications are approved in connection with the design and that they are verified or tested in the presence of a Surveyor, as applicable, as complying with the specifications.

3.3.2 Steel-bar Stock **(2020)**

Hot-rolled steel bars up to 305 mm (12 in.) in diameter may be used when approved for any of the items indicated in TABLE 6, subject to the conditions specified in Section 2-3-8 of the ABS *Rules for Materials and Welding (Part 2)*.

3.3.3 Material for Engines of 375 kW (500 hp) Rated Power or Less

Materials for engines having a rated power of 375 kW (500 hp) or less, including shafting, couplings, and coupling bolts are acceptable on the basis of the material manufacturer's certified test reports and a satisfactory surface inspection and hardness check witnessed by the Surveyor. Coupling bolts manufactured to a recognized bolt standard do not require material testing.

3.3.4 Certification Under Quality Assurance Approval Assessment PQA (Alternative Certification Scheme) **(2020)**

For engines certified under quality assurance assessment PQA (ACS) as provided for in 13.11, material tests required by 3.1 need not be witnessed by the Surveyor; such tests are to be conducted by the engine manufacturer whose certified test reports may be accepted instead.

5 Design

5.1 Bedplate/Crankcase **(2020)**

The bedplate or crankcase is to be of rigid construction, oiltight, and provided with a sufficient number of bolts to secure the same to the vessel's structure. See also 11.1 for seating of engines.

5.3 Crankcase Doors

Crankcase construction and crankcase doors are to be of sufficient strength to withstand anticipated crankcase pressures that may arise during a crankcase explosion taking into account the installation of explosion relief valves required by 7.1. Crankcase doors are to be fastened and secured so that they will not be readily displaced by a crankcase explosion.

5.5 Cylinders and Covers, Liners and Pistons

Cylinders, liners, cylinder covers, and pistons, which are subjected to high temperatures or pressures, are to be of materials suitable for the stresses and temperatures to which they are exposed.

5.7 Securing of Nuts

All nuts of main bearings and of connecting-rod bolts and all other moving parts are to be secured by split pins or other effective locking means.

5.9 Crankshafts

5.9.1 Scope (2020)

These Rules for the design of crankshafts are to be applied to diesel engines for propulsion and auxiliary purposes, where the engines are being so designed as to be capable of continuous operation at their rated power when running at rated speed.

Where a crankshaft design involves the use of surface treated fillets, when fatigue testing is conducted, or when direct stress (strain) measurements are taken, the relevant documents with calculations/analysis and reliability data are to be submitted in order to substantiate the design.

5.9.2 Field of Application (2020)

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

5.9.3 Principles of Calculation (2020)

The design of crankshafts is based on an evaluation of safety against fatigue in the highly stressed areas.

The calculation is also based on the assumption that the areas exposed to highest stresses are:

- Fillet transitions between the crankpin and web as well as between the journal and web,
- Outlets of crankpin oil bores.

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

Calculation of crankshaft strength consists of determining the nominal alternating bending (see 4-2-1-A4/1) and nominal alternating torsional stresses (see 4-2-1-A4/3) which, multiplied by the stress concentration factors (see 4-2-1-A4/5), result in an equivalent alternating stress (uni-axial stress) (see 4-2-1-A4/9). This equivalent alternating stress is then compared with the fatigue strength of the selected crankshaft material (see 4-2-1-A4/11). This comparison shows whether or not the crankshaft concerned is dimensioned adequately (see 4-2-1-A4/13).

5.9.4 Drawings and Particulars to be Submitted (2024)

The following plans and particulars are to be submitted for review, also refer to TABLE 2B.

5.9.4(a) Crankshaft details (2024)

Crankshaft drawing (which contains all data pertaining to the materials, surface treatment and geometrical configurations of the crankshaft)

Connecting rod length L_H, mm (in.)

Oscillating mass of one crank gear, kg (lb.), (in case of V-type engines, where necessary, also for the cylinder unit with master and articulated type connecting rod or forked and inner connecting rod)

Mass of reciprocating parts, kg (lb.)

Digitalized gas pressure curve presented at equidistant intervals, bar (kgf/mm^2, psi) versus crank angle, (intervals equidistant and integrally divisible by the V-angle, but not more than 5 degrees CA)

For engines with articulated-type connecting rod:

- Distance to link point L_A, mm (in.)
- Link angle a_N (degree)
- Connecting rod length (between bearing centers) L_N, mm (in.)
- Tightening torques for pretensioned bolts and studs for reciprocating parts.

- Mass and diameter of flywheel and flywheel effect on engine

5.9.4(b) Crankshaft material **(2020)**

Material designation

Mechanical properties of material (tensile strength, yield strength, elongation (with length of specimen), reduction of area, impact energy)

Type of forging (open die forged (free form), continuous grain flow forged, close die forged (drop-forged), etc., with description of the forging process)

Crankshaft heat treatment

Crankshaft surface treatment

Surface treatment of fillets, journals and pins (induction hardened, flame hardened, nitrided, rolled, shot peened, etc., with full details concerning hardening). For calculation of surface treated fillets and oil bore outlets see Appendix 4-2-1-A9.

Hardness at surface

Hardness as a function of depth, mm (in.)

Extension of surface hardening

5.11 Shaft Couplings and Clutches

The design and construction of fitted bolt and non-fitted bolt couplings, flexible couplings and clutches is to be in accordance with the requirements of 4-3-2/5.19.

7 Engine Appurtenances

7.1 Explosion Relief Valves

7.1.1 Application

Explosion relief valves of an approved type are to be installed on enclosed crankcases of all engines having a cylinder bore of 200 mm (8 in.) or above or having a crankcase gross volume of 0.6 m^3 (21 $ft.^3$) or above.

7.1.2 Valve Construction and Sizing **(2020)**

The following requirements apply:

i. The free area of each explosion relief valve is not to be less than 45 cm^2 (7 in^2), and the total free area of all relief valves is to be not less than 115 cm^2 for each cubic meter (1 in^2 for each 2 ft^3) of crankcase gross volume. The total volume of the stationary parts within the crankcase may be discounted in estimating the crankcase gross volume (rotating and reciprocating components are to be included in the gross volume).
ii. Crankcase explosion relief valves are to be provided with lightweight spring-loaded valve discs or other quick-acting and self-closing devices to relieve a crankcase of pressure in the event of an internal explosion and to prevent the inrush of air thereafter.
iii. The valve discs in crankcase explosion relief valves are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.
iv. Crankcase explosion relief valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0.2 bar (0.2 kgf/cm^2, 2.85 psi).
v. Crankcase explosion relief valves are to be provided with a flame arrester that permits flow for crankcase pressure relief and prevents passage of flame following a crankcase explosion.
vi. Crankcase explosion relief valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine in accordance with Appendix .
vii. Where crankcase relief valves are provided with arrangements for shielding emissions from the valve following an explosion, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

viii. Crankcase explosion relief valves are to be provided with a copy of the manufacturer's installation and maintenance manual that is pertinent to the size and type of valve being supplied for installation on a particular engine. The manual is to contain the following information:
    - Description of valve with details of function and design limits.
    - Copy of type test certification.
    - Installation instructions.
    - Maintenance in service instructions to include testing and renewal of any sealing arrangements.
    - Actions required after a crankcase explosion.

ix. A copy of the installation and maintenance manual is to be provided on board.

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

xi. Valves are to be provided with suitable markings that include the following information:
    - Name and address of manufacturer
    - Designation and size
    - Month/Year of manufacture
    - Approved installation orientation

7.1.3 Location of Valves

Engines having a bore of 200 mm (8 in.) and above, but not exceeding 250 mm (10 in.), are to have at least one valve near each end. However for engines with more than 8 crank throws, an additional valve is to be fitted near the middle of the engine.

Engines having a bore exceeding 250 mm (10 in.), but not exceeding 300 mm (11.8 in.), are to have at least one valve in way of each alternate crank throw, with a minimum of two valves.

Engines having a bore exceeding 300 mm (11.8 in.) are to have at least one valve in way of each main crank throw.

7.1.4 Other Compartments of Crankcase

Additional relief valves are to be fitted on separate spaces of the crankcase such as gear or chain cases for camshaft or similar drives when the gross volume of such spaces is 0.6 m^3 (21 ft^3) and above.

7.1.5 Scavenge Spaces

Explosion relief valves are to be fitted in scavenge spaces which are in open connection to the cylinders.

7.2 Protection Against Crankcase Explosions

7.2.1 General **(2020)**

All engines rated at 2250 kW (3000 hp) and above or having cylinders of more than 300 mm (11.8 in.) bore are to be provided with one of the following arrangements as protection against crankcase explosions.

- oil mist detection arrangements (see), or
- bearing temperature monitoring arrangements (see), or
- alternative arrangements (see).

For low speed engines, the above protection arrangements are to initiate an alarm and an automatic slowdown of the engine.

For medium and high speed engines, they are to initiate an alarm and an automatic shutdown of the engine.

For automatic shutdown or automatic slowdown for vessels with the *ACCUIABCU* notation, see item B7 of 4-9-6/23 TABLE 1A, item B4 of 4-9-6/23 TABLE 1B, item G4 of 4-9-6/23 TABLE 4B and item A3 of 4-9-6/23 TABLE 6.

Automatic shutdown is not permitted for emergency engines, see 4-8-2/5.19.2(c) and item B3 of 4-8-2/TABLE 1.

7.2.2 Oil Mist Detection Arrangements

7.2.2(a) General.

Where crankcase oil mist detection arrangements are fitted to engines, they are to be of an approved type and tested in accordance with Appendix 4-2-1-A3.

7.2.2(b) *Installation.* **(2026)**

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

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

A copy of the oil mist detection equipment maintenance and test manual required is to be provided onboard.

7.2.2(c) *Arrangements.* **(2026)**

The following requirements apply:

i. Oil mist detection and alarm information is to be capable of being read from a safe location away from the engine.
ii. Each engine is to be provided with its own independent oil mist detection arrangement and a dedicated alarm.
iii. Oil mist detection and alarm systems are to be capable of being tested on the test bed and onboard under engine at standstill and engine running at normal operating conditions in accordance with manufacturer's test procedures.
iv. Alarms, automatic slowdowns and automatic shutdowns for the oil mist detection system are to be in accordance with , , , , and as applicable. The system arrangements are to comply with .
v. The oil mist detection arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements.
vi. The oil mist detection system is to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.
vii. Where oil mist detection equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with .
viii. Plans showing details and arrangements of oil mist detection and alarm arrangements are to be submitted for approval in accordance with item 26.

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

   As an alternative to the evidence of studies, an oil mist inlet test may be performed on a running engine. Test conditions such as setup, records or engine loads are to be agreed upon between engine designer, oil mist detector (OMD) manufacturer and respective class society. The test engine is to be chosen to demonstrate OMD arrangement suitability to cover a specified range of engine types and configurations. To allow a repeatable and comparable test, an oil mist generator as described under Appendix 4-2-1-A3 is to be used.

   Commentary:

   The above are based on IACS UR M10 Rev.5.

   End of Commentary

ix. The equipment, together with detectors, is to be tested in the presence of the Surveyor when installed on the test bed and onboard to demonstrate that the detection and alarm system functionally operates.
x. Where sequential oil mist detection arrangements are provided the sampling frequency and time is to be as short as reasonably practicable.

7.2.3 Bearing Temperature Monitoring Arrangements

Where bearing temperature monitoring arrangements are provided, the following requirements apply:

7.2.3(a) Monitoring of bearings. **(2026)**

All bearings (main, crank, crosshead, thrust, etc.) that have open communication with the crankcase are to be monitored for abnormal temperature.

Commentary:

For crosshead engines, "bearing" in the expression "bearing temperature monitoring arrangements" includes at least journal and connecting rod bearings and the crosshead bearings. For trunk piston engines, "bearing temperature monitoring arrangements" may be accepted as an alternative to the oil mist detector only when the temperature of all bearings, including the piston pin bearings, are monitored.

The above are based on IACS UR M10 Rev.5.

End of Commentary

7.2.3(b) Slow Speed Engines. **(2020)**

For slow speed engines, the lubricating oil temperature at the outlet of each main, crank, crosshead and thrust bearing may be monitored in lieu of directly monitoring the temperature of these bearings.

7.2.3(c)

Alarms, automatic slowdowns and automatic shutdowns for bearing temperature monitoring arrangements are to be in accordance with 7.2.1, 4-8-2/TABLE 1, 4-9-6/23 TABLE 1A, 4-9-6/23 TABLE 1B, 4-9-6/23 TABLE 4B and 4-9-6/23 TABLE 6, as applicable. The system arrangements are to comply with 4-9-2/3.1.

7.2.4 Alternative Arrangements (2024)

Where alternative arrangements are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase details are to be submitted for review, in order to determine the effectiveness of the arrangements for each specific engine design. In order to prevent the buildup of a potentially explosive condition, it is necessary to provide combinations of means, such as: oil splash temperature monitoring, crankcase pressure monitoring, recirculation arrangements. The details are to include, but not be limited to the following:

- Engine particulars – type, power, speed, stroke, bore and crankcase volume.
- Details of arrangements to prevent the buildup of potentially explosive conditions within the crankcase.
- Evidence to demonstrate that the arrangements are effective in preventing the buildup of potentially explosive conditions together with details of in-service experience.
- Operating instructions and the maintenance and test instructions.

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

7.3 Speed Governors and Overspeed Protection for Engines (2020)

7.3.1 Governors (2020)

All engines, except those driving electric generators (see 7.5), are to be fitted with governors which will prevent the engines from exceeding the rated speed by more than 15%.

7.3.2 Overspeed Protective Device

In addition to the governor, each main propulsion engine having a rated power of 220 kW (295 hp) and over and which can be declutched or which drives a controllable pitch propeller, is to be fitted with a overspeed device so adjusted that the speed cannot exceed the maximum rated speed by more than 20%. This overspeed device, including its driving mechanism, is to be independent from the normal governor.

7.3.3 Electronic Governors (2020)

Electronic speed governors fitted to main propulsion engines, and which form part of a remote propulsion control system, are to comply with the following:

i. If lack of power to the governor control and actuator systems may cause major and sudden changes in the preset speed and/or direction of thrust of the propeller, an automatically available back up power supply is to be provided so as not to interrupt the power supply to these systems. An alarm for the failure of the main power supply is to be provided at the main and remote (if provided) propulsion control stations.
ii. Local control of the engines is to be possible. For this purpose means are to be provided at the local control position to disconnect the remote control signal. If this disconnects the speed governing functions required by , an additional separate speed governor is to be provided for such local mode of control.
iii. Electronic speed governors and their electrical actuators are to be subjected to prototype environmental tests in accordance with . In addition, the tests required by are to be carried out in the presence of the Surveyor as prototype testing. However, no production unit certification in accordance with is required.

7.5 Speed Governors and Overspeed Protection for Engines Driving Generators (2020)

7.5.1 Governors (2020)

Engines driving propulsion, auxiliary or emergency electric generators are to be fitted with an operating governor which is capable of automatically maintaining the speed within the following limits:

7.5.1(a)

The transient frequency variations in the electrical network when running at the indicated loads below are to be within ±10% of the rated frequency with a recovery time within ±1% of the final steady state condition in not more than 5 seconds when:

i. Running at full load (equal to rated output) of the generator and the maximum electrical step load is suddenly thrown off;

   In the case when a step load equivalent to the rated output of a generator is thrown off, a transient frequency variation in excess of 10% of the rated frequency may be acceptable, provided the overspeed protective device fitted in addition to the governor, as required by , is not activated.
ii. Running at no load and 50% of the full load of the generator is suddenly thrown on, followed by the remaining 50% after an interval sufficient to restore the frequency to steady state.

7.5.1(b) (2020)

Where the electrical power system is fitted with a power management system and sequential starting arrangements, the application of loads in multiple steps of less than 50% of rated load in 7.5.1(a).ii. above may be permitted provided it is in accordance with FIGURE 7. The details of the power management system and sequential starting arrangements are to be submitted and its satisfactory operation is to be demonstrated to the Surveyor.

7.5.1(c) (2020)

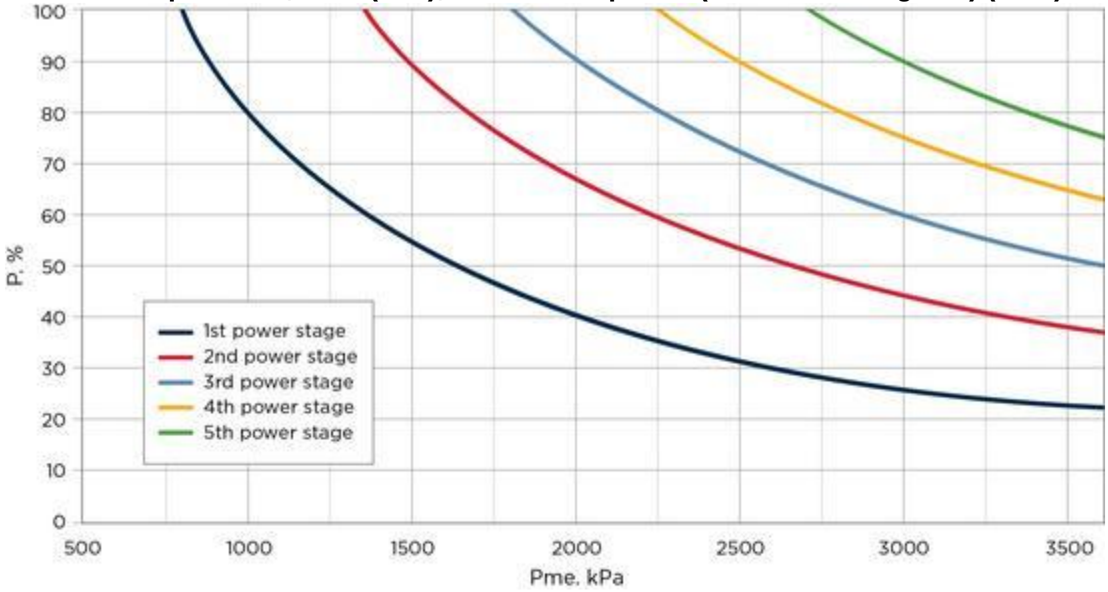
For engines driving emergency generators, the requirements of 7.5.1(a).i. and 7.5.1(d) are to be met even when:

i. Their total consumer load is applied suddenly, or
ii. Their total consumer load is applied in steps, subject to:
   - The total load is supplied within 45 seconds since power failure on the main switchboard
   - The maximum step load is declared and demonstrated
   - The power distribution system is designed such that the declared maximum step loading is not exceeded
   - The compliance of time delays and loading sequence with the above is to be demonstrated at ship's trials.

7.5.1(d)

The permanent frequency variation is to be within ±5% of the rated frequency at any load between no load and the full load.

FIGURE 1
Reference values for maximum possible sudden power P (%) increases as a function of brake mean effective pressure, Pme (kPa), at declared power (four-stroke engines) (2020)



7.5.2 Generators in Parallel **(2020)**

For engines driving AC generators that operate in parallel, the governor's characteristics are to be such that in the range between 20% and 100% of the combined rated load of all generators, the load on any individual generator will not differ from its proportionate share of the total combined load by more than 15% of the rated power of the largest generator or 25% of the individual generator, whichever is less.

Provisions are to be made to adjust the governors sufficiently fine in order to permit a load adjustment within the limits of 5% of the rated load at normal frequency.

7.5.3 Overspeed Protective Device

In addition to the governor each engine driving an electric generator and having a rated power of 220 kW (295 hp) and over is to be fitted with a separate overspeed device so adjusted that the speed cannot exceed the maximum rated speed by more than 15%. Provision is to be made for hand tripping.

7.7 Materials other than Steel on Engine, Turbine and Gearbox Installations (2020)

7.7.1 Materials other than Steel **(2020)**

Materials other than steel will be assessed in relation to the risk of fire associated with the component and its installation. The use of materials other than steel is considered acceptable for the following applications:

i. Internal pipes which cannot cause any release of flammable fluid onto the machinery or into the machinery space in case of failure, or
ii. Components that are only subject to liquid spray on the inside when the machinery is running, such as machinery covers, rocker box covers, camshaft end covers, inspection plates and sump tanks. It is a condition that the pressure inside these components and all the elements contained therein is less than 0.18 N/mm^2 and that wet sumps have a volume not exceeding 100 liters (26.4 gallons), or
iii. Components attached to machinery which satisfy fire test criteria according to standard ISO 19921:2005/19922:2005 or other standards acceptable to the appropriate administration of the vessel's registry, and which retain mechanical properties adequate for the intended installation.

7.7.2 Materials other than Steel for Filters **(2020)**

Aluminum and aluminum alloys may be considered for use in filters attached to engines where; either the engine installation is fitted with an effective fixed local application fire-extinguishing system in compliance with

4-7-2/1.11.2, or where the engine installation has a power rating not greater than 375kW (500 hp). See also 4-6-2/3.5.

7.9 Auxiliary Blowers **(2024)**

Electrically driven auxiliary scavenging blowers that are only used for starting and operation at lower speeds of an engine may be accepted based on the following:

i. For single 2-stroke propulsion engines, at least two (2) independently driven scavenger blowers are provided,
ii. Each blower is capable of supplying the required volume and pressure of scavenging air for the satisfactory operation of the engine over the range required. The required range is determined by the capabilities of the installed turbochargers (Section),
iii. Auxiliary blowers are to shut down at an appropriate engine speed to allow for quick passing through a barred speed range,
iv. Capacity and vibration tests are carried out on each unit by the manufacturer, and
v. Documentation verifying compliance with items ii) and iii) above is to be made available to the surveyor upon request.

Electric motors driving the above auxiliary scavenging blowers are to comply with Section 4-8-3 and are to be considered as a primary essential service in accordance with 4-8-1/TABLE 1, item (c).

Commentary:

As per 13.5.4(b).ii. "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".

End of Commentary

7.11 Fire Extinguishing System for Scavenge Manifold

For crosshead type engines, scavenge spaces in open connection to the cylinder are to be permanently connected to an approved fire extinguishing system entirely separate from the fire extinguishing system of the engine room. A steam smothering system is acceptable for this purpose. Provisions for the design and installation of fixed fire-extinguishing system are in Section 4-7-3.

7.13 Warning Notices

7.13.1 Crankcase

To caution against opening hot crankcase, suitable warning notices are to be fitted preferably on a crankcase door on each side of the engine or on the engine control stand. The notices are to specify a period of time for cooling after shutdown, based upon the size of the engine, but not less than 10 minutes in any case, before opening the door. Such notice is also to warn against restarting an overheated engine until the cause of overheating has been remedied.

7.13.2 Barred Speed Ranges

Where a barred speed range is specified in accordance with torsional vibration analysis, the engine speed indicator is to be so marked. A warning notice is to be fitted to the engine and at all local and remote propulsion control stations to the effect that operation in the barred range is to occur only while passing through the range and that operation within the barred range is to be avoided. See 4-3-2/7.5 for torsional vibration criteria.

7.15 Jacket Drain and Over-pressure Protection

A drain cock is to be fitted at the lowest point of all cooling medium jackets. Means are to be provided to prevent the cooling medium jacket from being over-pressurized. This will not be required if the cooling pump is of the centrifugal type such that the no-flow pressure is no greater than the design pressure of the jacket.

7.19 Engine Turning Gear

Where an engine turning gear arrangement is provided, an interlock is to be furnished so that the starting air system cannot be actuated when the turning gear is engaged.

8 Alarms and Monitoring (2020)

For propulsion machinery spaces intended for centralized or unattended operation, engine and engine system monitoring and safety system functions are provided in Part 4, Chapter 9 (see e.g., 4-9-6/23 TABLE 1A and 4-9-6/23 TABLE 1B).

Required monitoring for engine's fuel oil, lubricating oil, cooling water, starting air and exhaust gas systems are provided in the system requirements, see 9.

9 Piping Systems for Engines (2020)

The requirements of piping systems essential for operation of engines intended for propulsion, maneuvering, electric power generation and vessel safety are provided in Section 4-6-5. These systems include:

Fuel oil:	4-6-5/3
Lubricating oil:	4-6-5/5
Cooling water:	4-6-5/7
Starting air:	4-6-5/9
Electric starting:	4-8-2/11.11
Crankcase ventilation:	4-6-5/13
Exhaust gas:	4-6-5/11
Hydraulic and pneumatic systems:	4-6-7/3 and 4-6-7/5

11 Installation of Engines (2020)

11.1 Seating Arrangements for Engines (2020)

Engines are to be securely supported and mounted to the ships structure by bolted connections under consideration of all static and dynamic forces imposed by the engine.

11.3 Metal Chocks

Where metal chocks are used they are to be made of forged steel, rolled steel or cast steel.

11.5 Cast Resin Chocks

Cast resin chocks of an approved type (see ABS-RL-CLSSHIP 1A-1-A3/5 of the ABS *Rules for Conditions of Classification (Part 1A)* for type approval) may be used provided that the arrangements and installation procedures are in accordance with the manufacturer's recommendations. Arrangements of the proposed installation, along with installation parameters such as engine deadweight, holding-down bolt tightening torque, etc., and calculations showing that the manufacturer's specified pressure is not exceeded, are to be submitted for review in each case.

11.7 Resilient Mountings

Resilient mountings may be used within the limits of the manufacturers instructions and specifications for the resilient elements elasticity and durability under shipboard ambient conditions.

11.9 Hot Surfaces

Hot surfaces likely to come into contact with the crew during operation are to be suitably guarded or insulated. Where the temperature of hot surfaces are likely to exceed 220°C (428°F), and where any leakage, under pressure or otherwise, of fuel oil, lubricating oil or other flammable liquid, is likely to come into contact with such surfaces, they are to be suitably insulated with non-combustible materials that are impervious to such liquid. Insulation material not impervious to oil is to be encased in sheet metal or an equivalent impervious sheath.

13 Testing, Inspection and Certification of Engines

13.1 Testing and Inspection (2020)

13.1.1 Material and Nondestructive Tests (2020)

For testing and non-destructive tests of materials intended for engine construction see 3.1 and 3.3.

13.1.2 Hydrostatic Tests of Engine Components (2020)

Hydrostatic tests of engine parts and components are to be in accordance with TABLE 7. These tests are to be carried out by the manufacturer whose certificate of tests will be acceptable. However, independently driven pumps for fuel oil, lubricating oil, and cooling water services of engines of bores exceeding 300 mm (11.8 in) are required to be certified by the Surveyor; see 4-6-1/7.3.

13.1.2(a) Fuel-injection Systems (**1 July 2022**)

As an alternative to certification specified in TABLE 7, for mass-produced fuel-injection system, the manufacturer may request that ABS design assesses and lists the fuel-injection system under the Type Approval Program. The following is to be carried out under this program:

i. The manufacturer may submit drawings and apply for a Product Design Assessment based on compliance with recognized standards as specified in of the ABS *Rules for Conditions of Classification (Part 1A)*,
ii. A sample of the fuel-injection system type is to be subjected to test as specified in in presence of the Surveyor. Fuel-injection system so assessed may be accepted by ABS for listing on ABS website in the Design Approved Products Index (DA),
iii. The manufacturer is to operate a quality assurance system which is to be certified for compliance with a quality standard in accordance with (AQS)/(RQS) or (PQA) of the ABS *Rules for Conditions of Classification (Part 1A)*. The quality control plan is to have provision to periodically subject mass-produced fuel-injection system to tests specified in to the satisfaction to attending Surveyor. Fuel-injection systems that meet this requirement will be listed in the ABS Type Approval.

13.1.3 Relief and Safety Valves (2020)

13.1.3(a) Crankcase Explosion Relief Valves (**2020**)

All crankcase explosion relief valves are to be type tested in accordance with 4-2-1-A2. The type testing is to be conducted in the presence of an ABS Surveyor. Where the crankcase explosion relief valve is covered by a type approval this type testing can be waived, subject to concurrence by the attending Surveyor and the presentation of a document of conformity by the manufacturer to the Surveyor. The document of conformity is to confirm that the relief valves have been manufactured in accordance with the product design certificate associated with the type approval.

13.1.3(b) Safety Valves (**2020**)

Where provided, safety valves are to be tested and set in the presence of the Surveyor

13.2 Manufacturer's Quality Control

13.2.1 Quality Plan (1 July 2023)

Prior to commencement of construction, the manufacturer(1) is to submit to the Surveyor a quality plan setting out the quality control it plans to perform on but not limited to the following:

- issuance of material specifications for purchasing
- welding defect tracking

- receiving inspection of materials
- receiving inspection of finished components and parts
- dimensional and functional checks on finished components and parts
- edge preparation and fit-up tolerances
- Welding procedure qualification
- Welder qualification
- Weld inspection plan
- subsystem piping and component cleaning and flushing procedures (2)
- NDT written procedures and qualification documentation
- NDT plan
- casting and weld defect resolutions
- assembly and fit specifications
- subassembly inspection: alignment and dimension checks, functional test
- testing of safety devices
- hydrostatic testing plan
- engine test plan

Notes:

1. The manufacturer is the entity responsible for the construction, assembly and testing of the engine and associated systems (e.g., the engine designer/manufacturer or engine licensee). Note that the responsibility for a number of the quality plan actions may also reside with other stakeholders such as equipment vendors, system integrators and/or shipyards. Accordingly, the quality plans of those stakeholders should contain any specified actions required for satisfactory system integration and application. Cleaning of oil, water, fuel (oil and gas systems, as applicable) and hydraulic piping to the specifications and recommendations of the engine designer, many components of which may be located off engine, are examples of this multi responsibility.
2. The cleaning and flushing procedures are to contain any relevant processes and specialized equipment, such as flushing rigs, cleaning pigs, shakers, etc., that may be required to effectively clean the system. Means to verify the cleanliness, such as level of contamination by solid particles indicated by ISO 4406, or other national, industry or designer standards, are to be included in the procedures. The procedures are to cover all engine direct systems and also ancillary systems as may be applicable to the specific engine design (e.g., nitrogen purge and vent lines associated with dual fuel engines).

13.2.2 Welding on Engine Entablatures, Frames, Bedplates and Power Transmitting Component

13.2.2(a) Welding procedure.

Before proceeding with welding, the manufacturer is to prove to the satisfaction of the Surveyor that the intended welding process, welding filler metal, preheat, post weld heat treatment, etc. as applicable, have been qualified for joining the base metal. The intended welding procedure is to be supported by welding procedure qualification record (PQR) acceptable to or conducted in the presence of the Surveyor. The extent to which a PQR may be used to support multiple welding procedures is to be determined based on a recognized welding standard and subject to acceptance by the Surveyor.

13.2.2(b) Welders and welding operators.

Before proceeding with welding, the manufacturer is to prove to the satisfaction of the Surveyor that the welder or the welding operator is qualified for performing the intended welding procedure. Welders and welding operators are to be qualified in accordance with ABS-RL-MATL 2-4-3/11 in the presence of the Surveyor or supported by documented welder performance qualification records (WPQ) acceptable to the Surveyor. The extent to which a WPQ may be used to support multiple welding procedures is to be determined based on a recognized welding standard and subject to acceptance by the Surveyor.

13.2.2(c) Facility-specific PQR and WPQ.

To prove the capability of specific facilities, PQR and WPQ are to be conducted at and certified by the facilities where the fabrication or weld repair is to be conducted. PQR and WPQ conducted at other facilities are normally not acceptable for supporting the intended welding, without specific acceptance by the Surveyor.

13.2.2(d) Welding filler metals.

All welding filler metals are to be certified by their manufacturers as complying with recognized national or international standards. Welding filler metals tested, certified and listed by ABS in its publication, *Approved Welding Consumables*, for meeting such a standard are to used in all cases. See Part 2, Appendix 2 for approval of filler metals. Welding filler metals not so listed may also be accepted provided that:

i. They are of the same type as that proven in qualifying the welding procedure; and
ii. They are of a make acceptable to the Surveyor; and
iii. For welding of Group I engineering structures, representative production test pieces are to be taken to prove the mechanical properties of the weld metal.

13.2.2(e) Tack welds.

Tack welds, where used, are to be made with filler metal suitable for the base metal. Tack welds intended to be left in place and form part of the finished weld are to be made by qualified welders using process and filler metal the same as or equivalent to the welding procedure to be used for the first pass. When preheating is required, the same preheating is to be applied prior to tack welding.

13.2.2(f) Repair of defective welds. **(2020)**

Any weld joint imperfection disclosed by examination in 13.2.3(c) and deemed unacceptable is to be removed by mechanical means or thermal gouging processes, after which the joint is to be welded using the qualified welding procedure by qualified welder. Preheat and post-weld heat treatment is to be performed as applicable. Upon completion of repair the repaired weld is to be re-examined by the technique that disclosed the defect in the original weld.

13.2.2(g) Repair of castings by welding. **(2020)**

Casting surface defects and defects revealed by non-destructive tests specified in TABLE 6 and deemed unacceptable may be repaired by welding. All welding repairs are to be conducted using qualified welding procedure and by qualified welders as per 13.2.2(a), 13.2.2(b) and 13.2.2(c). The welding procedure, preheat and post weld heat treatment, as applicable, are to be in accordance with engine designer's specifications and supported by PQR. The surveyor is to be notified prior to proceeding with the repair. Where welding repair is to be conducted at the foundry, the same procedure is to be adhered to. Defects detected by nondestructive tests required by TABLE 6 are to be re-examined by at least the same technique after completion of repair.

13.2.3 Nondestructive Tests and Inspections

13.2.3(a) Qualification of procedures and operators. **(2020)**

Before proceeding to conduct nondestructive tests required by TABLE 6, the manufacturer is to have a written procedure for conducting each of these tests and for qualifying the operators intended for conducting these tests. Subcontractors, if employed for this purpose, are to be similarly qualified. The processes of qualifying the procedures and the operators and the necessary technical supervision and training are to be in accordance with a recognized standard.

13.2.3(b) Nondestructive test procedures of engine parts. **(2020)**

Parts requiring ultrasonic tests by TABLE 6 are each to be provided with a test plan. Typically for ultrasonic testing the plan is to specify:

- part to be tested	- scanning coverage and rate
- ultrasonic equipment	- calibration procedure
- couplant	- exceptance standards
- reference block(s)	

As a minimum, dye penetrant test plans are to specify the part to be tested, penetrant type and developer, procedure for retest, allowable ambient and test piece temperatures, and acceptance standards; and magnetic particle test plans are to specify parts to be tested, magnetization technique and equipment, surface preparation, type of ferromagnetic particles, and acceptance standards.

13.2.3(c) Nondestructive tests of welds.

The manufacturer's quality plan for weld inspection is to include visual inspection, measurement of weld sizes, as well as nondestructive tests (dye-penetrant, magnetic particle, radiography or ultrasonic) as may be specified by the engine designer for important structural parts

13.2.3(d) Documentation.

The manufacturer is to document and certify the results of the required non-destructive tests. The number and locations of unacceptable indications found are to be reported, together with corrective action taken, preferably on a sketch along with questionable areas and any required areas not examined, where applicable.

13.2.3(e) Witness by Surveyor. **(2020)**

All documents required in 13.2.3 are to be made available to the Surveyor. Where in doubt, or for purposes of verification, the Surveyor may request for a demonstration of any nondestructive tests required by TABLE 6 to be conducted in his presence.

13.2.4 Assembly and Fit

The manufacturer's quality plan is to require checks on important fit, alignment, tolerances, pretensioning, etc. specified by the engine designers. Data measured in the as-assembled condition are to be recorded and made available to the Surveyor, who may request for verification of the recorded data.

13.3 Processes for Approval of Engines **(2024)**

The processes and the documents necessary to approve an engine design for conformance to the Rules and for use during manufacture and installation are listed. The document flow between engine designer, ABS Engineering, engine builder/licensee and ABS Survey is given in Annex 2 of 4-2-1-A1/1.

Definitions relating to approval of engines are given in Annex 1 of 4-2-1-A1/1.

13.3.1 Approval Process

13.3.1(a) 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 13.3.5. This process consists of the engine designer obtaining:

- Drawing and specification approval,
- Conformity of production,
- Approval of type testing program,
- 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.

13.3.1(b) Engine Certificate

Each engine manufactured for a shipboard application is to have an engine certificate. The certification process details for obtaining the engine certificate are in 13.3.6. 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 13.3.1(a), 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.

13.3.2 Document Flow for Engines

13.3.2(a) Document Flow for Obtaining a Type Approval Certificate*

Note:

* Process of Type Approval Certificate for engines is equivalent as a product design assessment (PDA) certificate under ABS Type Approval Program

i. For the initial engine type, the engine designer prepares the documentation in accordance with requirements in and and forwards to the ABS according to the agreed procedure for review.
ii. Upon review and approval of the submitted documentation (evidence of approval), it is returned to the engine designer.

iii. The engine designer arranges for an ABS Surveyor to attend an engine type test and upon satisfactory testing the ABS issues a type approval certificate.
iv. A representative document flow process for obtaining a type approval certificate is shown in .

13.3.2(b) Document Flow for Engine Certificate**

Note:

** Process of engine certificate for each engine is equivalent to “Unit Certification" of the ABS Type Approval program which includes requirements of a valid product design assessment (PDA) and survey at manufacturer’s facility

i. The engine type is to 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.
ii. 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 . See also .
iii. The engine builder/licensee develops a comparison list of the production documentation to the documentation listed in and . An example comparison list is provided in Annex 4 of . If there are differences in the technical content on the licensee’s production drawings/documents compared to the corresponding licensor’s drawings, the licensee is to obtain agreement to such differences from the licensor using the template in Annex 5 of .

    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.
iv. The engine builder/licensee submits the comparison list and the production documentation to the ABS according to the agreed procedure for review/approval.
v. The ABS 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 ABS 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.
vi. The attending ABS Surveyors, at the engine builder/licensee/subcontractors, will issue product certificates as necessary for components manufactured upon satisfactory inspections and tests.
vii. The engine builder/licensee assembles the engine, tests the engine with an ABS Surveyor present. An engine certificate is issued by the Surveyor upon satisfactory completion of assembly and tests.
viii. A representative document flow process for obtaining an engine certificate is shown in 4-2-1-A1/1 FIGURE 2.

13.3.3 Approval of 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.).

13.3.4 Submission Format of Documentation

For plan submission requirements refer to 4-1-1/5.1. ABS determines the documentation format: electronic or paper. If documentation is to be submitted in paper format, the number of copies is determined by ABS.

13.3.5 Type Approval Process

The type approval process consists of the steps in 13.3.5(a) to 13.3.5(d). The document flow for this process is shown in 4-2-1-A1/FIGURE 1.

The documentation, as far as applicable to the type of engine, to be submitted by the engine designer/licensor to ABS is listed in TABLE 2A and TABLE 2B.

13.3.5(a) Documents for Information Table 2A

TABLE 2A lists basic descriptive information to provide ABS 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.

13.3.5(b) Documents for Approval or Recalculation Table 2B

TABLE 2B lists the documents and drawings, which are to be approved by ABS.

13.3.5(c) Design Approval/Appraisal (DA)

DAs are valid as long as no substantial modifications have been implemented. Where substantial modifications have been made, the validity of the DAs is to be renewed based on evidence that the design is in conformance with all current Rules and statutory regulations (e.g., SOLAS, MARPOL). See also 13.3.5(f).

13.3.5(d) Type Approval Test

A type approval test is to be carried out in accordance with 13.3.5 and is to be witnessed by ABS.

The manufacturing facility of the engine presented for the type approval test is to be assessed in accordance with 13.2 and TABLE 6 and TABLE 7 (applicable section).

13.3.5(e) Type Approval Certificate

After the requirements in 13.3.5(a) to 13.3.5(d) have been satisfactorily completed ABS issues a type approval certificate (TAC). See also 13.3.2(a)*
Note:

* Process of Type Approval Certificate for engines is equivalent as a product design assessment (PDA) certificate under ABS Type Approval Program

13.3.5(f) Design Modifications **(2024)**

After ABS has approved the engine type for the first time, only those documents as listed in the tables, which have undergone substantive changes, are to be resubmitted for review.

13.3.5(g) Type Approval Certificate Renewals

A renewal of type approval certificates will be granted upon:

Submission of Information in either 13.3.5(g).i. or 13.3.5(g).ii.

i. The submission of modified documents or new documents with substantial modifications replacing former documents compared to the previous submission(s) for DA.
ii. A declaration that no substantial modifications have been applied since the last DA issued.

13.3.5(h) Validity of Type Approval Certificate

ABS 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 ABS.

13.3.5(i) Document Review and Approval

- The assignment of documents to for information does not preclude possible comments by the individual ABS.
- Where considered necessary, ABS may request further documents to be submitted. This may include details or evidence of existing type approval or proposals for a type testing program in accordance with .

13.3.6 Certification Process

The certification process consists of the steps in 13.3.6(a) to 13.3.6(e). This process is illustrated in 4-2-1-A1/FIGURE 2 showing the document flows between the:

- Engine designer/licensor,
- Engine builder/licensee,

- Component manufacturers,
- ABS approval center, and
- ABS site offices

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

The documents listed in TABLE 3 may be submitted by:

- The engine designer (licensor),
- The manufacturer/licensee

13.3.6(a) Document Development for Production

Prior to the start of the engine certification process, a design approval is to be obtained per 13.3.5(a) to 13.3.5(c) 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 2A and TABLE 2B 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 ABS as per 13.3.5(f).

13.3.6(b) Documents to be Submitted for Inspection and Testing

TABLE 3 lists the production documents, which are to be submitted by the engine builder/licensee to ABS 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 13.3.2(b).i. through 13.3.2(b).iv..

13.3.6(c) 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 is to provide to ABS Engineering 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. See Annex 5 of 4-2-1-A1/1 for a sample format.

13.3.6(d) Manufacturer Approval

ABS assesses conformity of production with ABS’s requirements for production facilities comprising manufacturing facilities and processes, machining tools, quality assurance, testing facilities, etc. See 13.2 and TABLE 6 and TABLE 7 (applicable section). Satisfactory conformance results in the issue of a class approval document.

13.3.6(e) Document Availability

In addition to the documents listed in TABLE 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.

13.3.6(f) Engine Assembly and Testing

Each engine assembly and testing procedure required according to the relevant requirements of this Section are to be witnessed by the ABS attending Surveyor unless an Alternative Certification Scheme meeting the requirements of ABS-RL-CLSSHIP 1A-1-A3/5.5 (applicable sections) is agreed between manufacturer and the ABS.

13.5 Type Tests of Engines (2020)

13.5.1 Application (2024)

Each new type of engine, as defined in 13.5.2, is to be type tested under the conditions specified in 4-2-1/13.5. The testing of the engine for the purpose of determining the rated power and 110% power is to be conducted at the ambient reference conditions given in 13.5.3 or power corrections are to be made.

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

i. 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;
ii. 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;
iii. 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.

Where a previously approved engine of the conventional type (i.e. non-electronically controlled) is modified to be an electronically controlled engine, the requirement to conduct those tests specified in 13.3 which were already conducted as part of the conventional engine approval and for which it can be shown that the results would not be impacted due to the addition of the electronic controls, is subject to ABS technical assessment and approval.

13.5.2 Engine Type Definition **(2020)**

For purposes of type tests, an engine “type”, as specified by the manufacturer’s type designation, is to be defined by the parameters listed in TABLE 4.

Engines may be considered the same type if they do not differ from any of the items listed in TABLE 4

i. A type test carried out for a type of engine at any place of manufacture is acceptable for all engines of the same type built by licensees and licensors. A type test carried out on one engine having a given number of cylinders is acceptable for all engines of the same type having a different number of cylinders. However, a type test of an in-line engine may not always cover the V-version. Subject to the ABS discretion, separate type tests may be required for the V-version (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.
ii. 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 classed rating of 100% is submitted, an increase (if approved based on crankshaft calculation and crankshaft drawings) 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

    Provided 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 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

    If the maximum power of an already type tested engine, even with proven reliability in service, is increased by more than 10%, a new type test is required, including the review of all relevant drawings.

The engine particulars to be submitted are listed in TABLE 5.

13.5.3 Ambient Reference Conditions **(2020)**

The following ambient reference conditions are to be applied by the engine manufacturer for the purpose of determining the rated power of diesel engines used on vessels with unrestricted service. However, the engine manufacturer is not expected to provide simulated ambient reference conditions at any test.

Barometric pressure:	1 bar (1 kgf/cm^2, 15 psi)

Air temperature:	45°C (113°F)
Relative air humidity:	60%
Seawater Temperature (Charging air coolant inlet):	32°C (90°F)

13.5.4 Type Tests **(2020)**

Each type test is subdivided into three stages:

- Stage A: manufacturer's 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 ABS or stipulated by the designer are to be presented to the ABS before starting stage B.
- Stage B: type assessment tests to beconducted in the presence of a Surveyor;
- Stage C: component inspection after the test by a Surveyor.

The complete type testing program is subject to approval by the ABS. The extent the Surveyor’s attendance is to be agreed in each case, but at least during stage B and C. Testing prior to the witnessed type testing (stage B and C), is also considered as a part of the complete type testing program. Upon completion of the type testing (stage A through C), a type test report is to be submitted to ABS for review. The type test report is to contain:

i. Overall description of tests performed during stage A. Records are to be kept by the builders QA management for presentation to ABS;
ii. Detailed description of the load and functional tests conducted during stage B;
iii. Inspection results from stage C.

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.

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 this section.

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

These stages are described in details as follows.

13.5.4(a) Stage A: manufacturer's tests.

The manufacturer is to carry out functional tests in order to collect and record the engine's operating data. During these tests the engine is to be operated at the load points specified by the engine manufacturer and the pertinent operating values are to be recorded. The load points may be selected according to the range of applications.

The tests are to include the normal and the emergency operating modes as specified below:

i. *Normal operating mode*.

   The load points 25%, 50%, 75%, 100% and 110% of the rated power for continuous operation:

   - Along the nominal (theoretical) propeller curve and at constant rated speed for propulsion engines (if applicable mode of operation i.e. driving controllable pitch propellers);
   - At constant rated speed for engines intended to drive electric generators including a test at no load and rated speed;

   The limit points of the permissible operating range, as 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 stipulated by the designer.

ii. *Emergency operating mode*. The manufacturer's test for turbocharged engines is to include the determination of the maximum achievable continuous power output in the following cases of simulated turbocharger damage:

   - Engines with one turbocharger: with the rotor blocked or removed;

◦ Engines with two or more turbochargers: with one turbocharger shut off.

13.5.4(b) Stage B: type tests to be witnessed by Surveyor. **(2024)**

The engine is to be operated at the load points shown in FIGURE8. The data measured and recorded at each load point is to include all necessary parameters for the engine operation.

i. 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. For below, an operating time of two hours is required and two sets of readings are to be taken at a minimum interval of one hour. For through below, the operating time per load point is not to be less than 30 minutes.
   a. Rated power, i.e. 100% output at 100% torque and 100% speed corresponding to load point 1.
   b. 100% power at maximum permissible speed corresponding to load point 2.
   c. Maximum permissible torque (at least and normally 110%) at 100% speed corresponding to load point 3; or maximum permissible power (at least and normally 110%) and 103.2% speed according to 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.
   d. Minimum permissible speed at 100% torque corresponding to load point 4.
   e. Minimum permissible speed at 90% torque corresponding to load point 5.
   f. Part load operation, e.g., 75%, 50%, 25% of maximum continuous rated power and speed according to the nominal propeller curve (i.e. 90.8%, 79.3% and 62.9% speed) corresponding to point 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.
ii. The achievable continuous output is to be determined by the engine designer in the case of the turbocharger damage for single main propulsion engines under the following conditions:
   a. Engines equipped with one turbocharger: with the rotor blocked or removed,
   b. Engines equipped with two or more turbochargers: with one turbocharger shut off.

   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.
iii. Functional tests are to be performed for the following:
   a. The lowest engine speed according to the nominal propeller curve,
   b. The engine starting and reversing appliances, where applicable, for the purpose of determining the minimum air pressure and the consumption for a start.
   c. The speed governor
   d. The safety system, particularly for overspeed and low lubricating oil pressure.
   e. *Integration Test:* For electronically controlled 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 determined based on the FMEA as required in of the Rules.
iv. 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:
   a. 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.
   b. 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 ABS. Readings obtained are to be randomly verified by use of contact thermometers

13.5.4(c) Stage C: component inspection by the Surveyor.

The crankshaft deflections are to be measured in the specified (by designer) condition (except for engines where no specification exists). High speed engines for marine use are normally to be stripped down for a complete inspection after the type test. For all the other engines, after the test run, the following components of one cylinder for in-line and of two cylinders for V-engines are to be presented for the Surveyor's inspection (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, special attention to serrations and fretting on contact surfaces with the bearing backsides) and main bearing, dismantled
- Cylinder liner in the installed condition
- Cylinder head, valves disassembled
- Control gear or chain, camshaft and crankcase with opened covers (the engine is to be turnable by turning gear for this inspection).

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

Further dismantling of the engine may be required by and at the discretion of the Surveyor.

13.5.4(d) De-rated Engine. **(2020)**

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, two 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 2½ hour

13.5.4(e) 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 is to be proposed by the designer/licensor taking into account of impact on engine.

13.5.4(f) Measurements and Recordings. **(2020)**

During all testing the ambient conditions (air temperature, air pressure and humidity) are to be recorded.-As a minimum, the following engine data are to be measured and recorded:

i. Engine speed
ii. Torque
iii. Maximum combustion pressure for each cylinder*
iv. Mean indicated pressure for each cylinder*
v. Charging air pressure and temperature
vi. Exhaust gas temperature in exhaust manifold and, if possible, at each cylinder outlet
vii. Fuel rack position or similar parameter related to engine load
viii. Turbocharger speed
ix. All engine parameters that are required for control and monitoring for the intended use (propulsion, auxiliary, emergency).
    - Characteristics of fuel (eg Lower Calorific Value (LCV), Density, Viscosity and Methane Number, where applicable)
    - Characteristics of lubricating oil (Density and Viscosity)
    - Lubricating oil pressure and temperature
    - Cooling water pressure and temperature
    - Cooling water temperature at charge air cooler inlet
    - Air pressure and temperature at inlet and outlet of turbocharger and cooler
    - Exhaust gas pressure and temperature at inlet and outlet of exhaust gas turbine and charge air cooler

Note:

* 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.

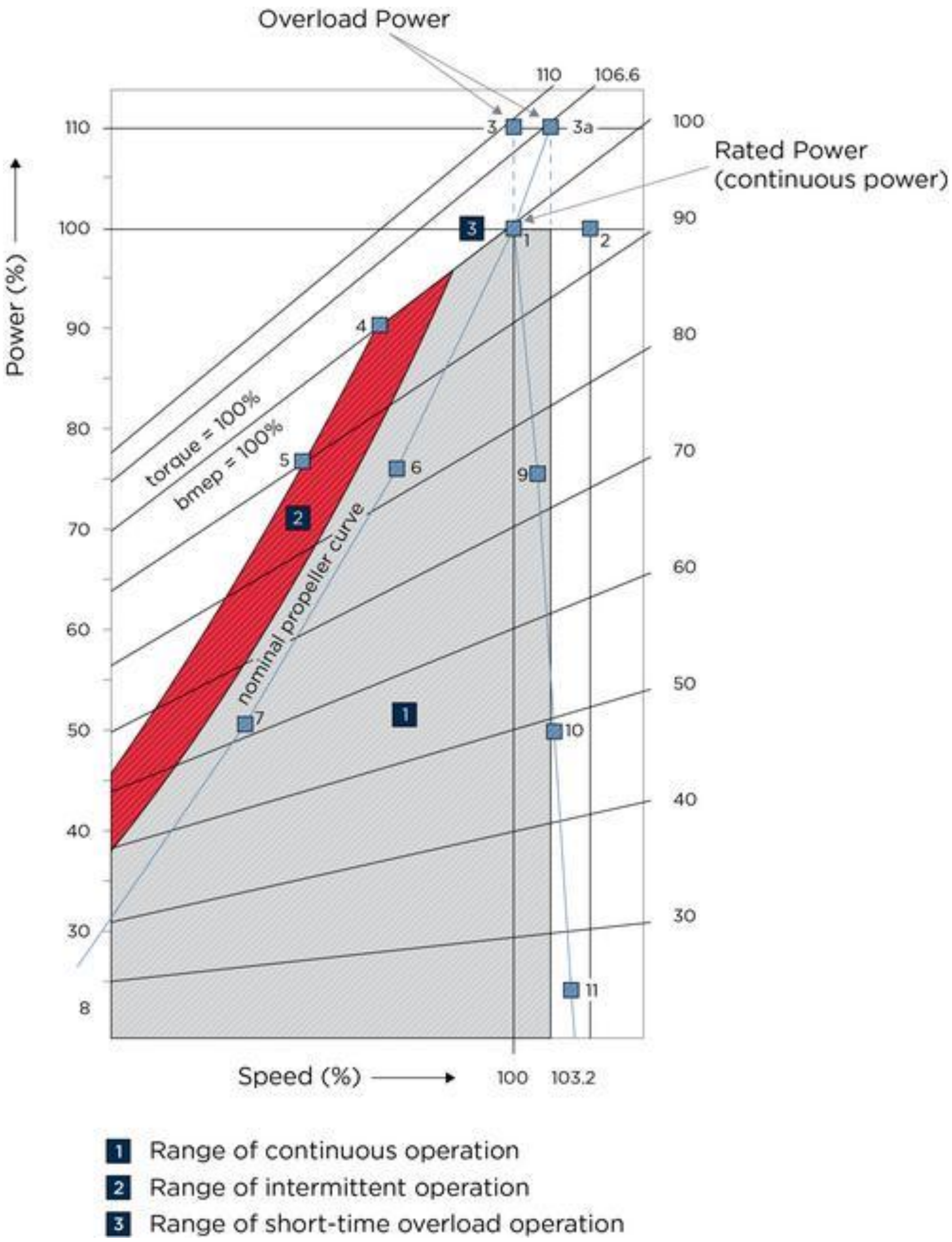
13.5.4(g) Safety Precautions.

Before any test run is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer/shipyard and is to be operational, and its correct functioning is to be verified. This applies especially to crankcase explosive conditions protection, but also over-speed protection and any other shut down function. The inspection for jacketing of high-pressure fuel oil lines and proper screening of pipe connections is also to be carried out before the test runs. Interlock test of turning gear is to be performed when installed.

13.5.5 Additional Tests

For engines intended to be used for emergency services, supplementary tests according to the regulations of the Administration whose flag the vessel flies may be required.

FIGURE 2
Type Test Power/Speed Diagram



13.6 Certification of Engine Components **(2020)**

i. The engine manufacturer is to have a quality control system (and) that is suitable for the actual engine types to be certified by the ABS. The quality control system is also to apply to any sub-suppliers. The ABS reserves the right to review the system or parts thereof. Materials and components are to be produced in compliance with all the applicable production and quality instructions specified by the engine manufacturer. The ABS requires that certain parts are verified and documented by means of Society Certificate (SC), Work's Certificate (W) or Test Report (TR).

ii. *Society Certificate (SC).*

   This is a document issued by the ABS stating:

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

iii. *Work's Certificate (W).*

   This is a document signed by the manufacturer stating:

   - Conformity with requirements.

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

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

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

iv. *Test Report (TR).*

This is a document signed by the manufacturer stating:

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

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

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

vii. The manufacturer is not exempted from responsibility for any relevant tests and inspections of those parts for which documentation is not explicitly requested by the ABS.

The manufacturing process and equipment is to be set up and maintained in such a way that all materials and components can be consistently produced to the required standard. This includes production and assembly lines, machining units, special tools and devices, assembly and testing rigs as well as all lifting and transportation devices.

viii. *Parts to be documented*

The extent of parts to be documented depends on the type of engine, engine size and criticality of the part. A summary of the required documentation for the engine components is listed in and .

13.7 Factory Acceptance Test **(2020)**

Before any test run is carried out, all required safety devices are to be installed by the manufacturer / shipyard and are to be operational. This applies especially to crankcase explosive conditions protection, but also to over-speed protection and any other shut down function. 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 is to be verified by the Surveyor.

13.7.1 General **(2020)**

Before any official testing, the engines are to be run-in as prescribed by the engine manufacturer. Adequate test bed facilities for loads as required in this section are to 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.

The operational data corresponding to each of the specified test load conditions are to be determined and recorded and 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. Calibration records for the instrumentation are to be presented to the attending Surveyor. In each case, all measurements conducted at the various load points are to be carried out at steady operating conditions. The readings for 100% power (rated power at rated speed) are to be taken twice at an interval of at least 30 minutes.

13.7.1(a) Environmental Test Conditions.

The following environmental test conditions are to be recorded

i. Ambient air temperature.
ii. Ambient air pressure.

iii. Atmospheric humidity.

13.7.1(b) Load Points.

For each required load point, the following parameters are to be recorded:

i. Power and speed.
ii. Fuel index (or equivalent reading).
iii. Maximum combustion pressures (only when the cylinder heads installed are designed for such measurement).
iv. Exhaust gas temperature before turbine and from each cylinder (to the extent that monitoring is required in this Section and in Section).
v. Charge air temperature.
vi. Charge air pressure.
vii. Turbocharger speed (to the extent that monitoring is required in Section).

13.7.1(c) Inspections.

Engines are to be inspected for:

i. Jacketing of high-pressure fuel oil lines including the system used for the detection of leakage.
ii. Screening of pipe connections in piping containing flammable liquids.
iii. Insulation of hot surfaces by taking random temperature readings that are to be compared with corresponding readings obtained during the type test. This is to 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 ABS may request temperature measurements.

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

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

13.7.2 Engines Driving Propellers or Impellers only **(2021)**

Main propulsion engines driving propellers are to be tested under the following conditions:

i. 100% of rated power (MCR) at rated engine speed (n_o) , for at least 60 minutes.
ii. 110% of rated power at an engine speed of $n = 1.032n_o$ in accordance with nominal propeller curve or constant rated speed (whichever is applicable).Records to be taken after 15 minutes or after having reached steady conditions, whichever is shorter.
   Note:
   Only required once for each different engine/turbocharger configuration.
iii. Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
iv. 90% (or normal continuous cruise power), 75%, 50% and 25% of rated power, in accordance with the nominal propeller curve, or at constant rated speed (the sequence to be selected by the engine manufacturer).
v. Starting and reversing maneuvers.
vi. After running on the test bed, the fuel delivery system of the engine is to be adjusted so that the engine output is limited to the rated power and so that the engine cannot be overloaded under service condition, unless intermittent overload power is approved by the ABS. In that case, the fuel delivery system is to be blocked to that power.
vii. Testing of governor and independent overspeed protective device.
viii. Testing of shutdown device.

13.7.3 Engines Driving Generators dedicated for Propulsion Motors

For engines intended for driving electric propulsion generators the tests are to be performed at rated speed with a constant governor setting under the following conditions:

i. 100% rated power for at least 60 min..
ii. 110% of rated power for 15 min., after having reached steady conditions.
iii. After running on the test bed, the fuel delivery system of the engine is to be adjusted so that an overload power of 110% of the rated power can be supplied. Due regard being given to service conditions after installation on board and to the governor characteristics including the activation of generator protective devices. See also for governor characteristics associated with power management systems.
iv. 75%, 50% and 25% of rated power and idle run (the sequence to be selected by the engine manufacturer).
v. Start-up tests.
vi. Testing of governor and independent overspeed protective device.
vii. Testing of shutdown device.

13.7.4 Engines Driving Generators for Auxiliary Purposes **(2020)**

Engines intended for driving vessel service generators and emergency generators are to be tested as specified in 13.7.3. After running on the test bed, the fuel delivery system of the engine is to be adjusted so that an overload power of 110% of the rated power can be supplied. Due regard is to be given to service conditions after installation on board and to the governor characteristics including the activation of generator protective devices. See also 7.5.1(b) for governor characteristics associated with power management systems.

13.7.5 Propulsion Engines also Driving Power Take Off (PTO) Generator

For propulsion engines driving a generator through a power take off the following tests are to be performed:

i. 100% rated power at corresponding speed n_o for at least 60 min.
ii. 110% power at engine speed n_o for 15 min., after having reached steady conditions.
iii. Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
iv. 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.

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.

13.7.6 Engines Driving Auxiliaries

For engines driving auxiliaries the following tests are to be performed:

i. 100% rated power at corresponding speed n_o for at least 30 min.
ii. 110% power at engine speed n_o for 15 min., after having reached steady conditions.
iii. Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
iv. 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

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.

13.7.7 Turbocharger **(2020)**

After installation on the engine, each turbocharger is to be operated in the presence of the Surveyor to demonstrate its ability to function satisfactorily under operating conditions and be free from excesive vibrations at speeds within the operating range. The tests related to engine shop tests are to be as indicated in 4-2-2/11.

13.7.8 Integration Tests **(2020)**

Integration tests are to be conducted for electronically controlled engines and other engine subsystems (Turbocharger, Engine Control System, Dual Fuel, Exhaust Gas treatment…). They 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 determined based on those tests that have been established for the type testing. If such tests are technically unfeasible at the works, these tests may be conducted during sea trial. The scope of these tests is to be agreed with the ABS for selected cases based on the FMEA required in this Section.

13.7.9 Inspection After Tests

After shop tests, engine components, randomly selected at the discretion of the Surveyor, are to be presented for inspection. Where engine manufacturers require crankshaft deflection to be periodically checked during service, the crankshaft deflection is to be measured at this time after the shop test and results recorded for future reference

13.9 Shipboard Trials **(2020)**

After the conclusion of the Factory Acceptance Test program, engines are to undergo shipboard trials in the presence of a Surveyor, in accordance with the following procedure. 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). Tests other than those listed below may be required by statutory instruments (e.g., EEDI verification).

13.9.1 Engines Driving Fixed Pitch Propellers or Impellers **(2020)**

For main propulsion engines directly driving fixed pitch propellers or impellers, the following running tests are to be carried out:

i. At rated engine speed (n_o) , for at least 4 hours.
ii. At engine speed $n = 1.032n_o$ for 30 minutes (where engine adjustment permits).
iii. At minimum on-load speed (Minimum engine speed to be determined).
iv. Starting and reversing maneuvers.
v. Testing of the monitoring and safety systems.
vi. At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer

During stopping tests according to Resolution MSC.137 (76), see 13.9.7 for additional requirements in the case of a barred speed range.

13.9.2 Engines Driving Controllable Pitch Propellers **(2020)**

For main propulsion engines driving controllable pitch propellers or reversing gears the tests as per 13.9.1 apply. In addition, controllable pitch propellers are to be tested with various propeller pitches. With reverse pitch suitable for maneuvering, see 13.9.7 for additional requirements in the case of a barred speed range.

13.9.3 Engines Driving Propulsion Generators, Main Power Supply Generators and/or Emergency Generators (**2020**)

The running tests are to be carried out at rated speed, under the following conditions:

i. At 100% power (rated electrical power of generator) for at least 60 min.
ii. At 110% power (rated electrical power of generator) for at least 10 min.
Each engine is to be tested at 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.
iii. Demonstration of the generator prime movers' and governors' ability to handle load steps as described in .

13.9.4 Propulsion Engines also Driving Power Take Off (PTO) Generator (**2026**)

The running tests are to be carried out at the rated speed, under the following conditions:

i. 100% engine power (MCR) at corresponding speed n_o for at least 4 hours.
ii. 100% propeller branch power at engine speed n_o (unless already covered in the above test) for 2 hours.
iii. 100% PTO branch power at engine speed n_o for at least 1 hour
iv. Tests specified in 4-2-1/13.9.1 ii), iii), iv), v) and vi) are also to be carried out

13.9.5 Engines Driving Auxiliaries (**2020**)

Engines driving auxiliaries are to be subjected to an operational test for 100% power (MCR) at corresponding speed n_o at least 30 min, and at approved intermittent overload (testing for duration as approved).

13.9.6 Engines Burning Residual Fuel Oil or Other Special Fuel Oils (**2020**)

The suitability of propulsion and auxiliary engines to burn residual fuel oils or other special fuel oils is to be demonstrated, where they are intended to burn such fuel oils in service.

13.9.7 Torsional Vibration Barred Speed Range (**2024**)

Where torsional vibration analyses indicate that torsional vibratory stresses are close to or exceed the allowable vibratory stresses within the engine operating speed range, the conduct of torsiograph tests and marking of the barred speed range, as appropriate, are to be carried out in accordance with 4-3-2/11.3.1. See also 7.13.2.

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.
Notes:

1. Applies both for manual and automatic passing-through systems;
2. 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.
3. 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).

13.9.8 Shipboard Trials for Internal Combustion Engines having Power ≥ 100 kW Intended for Non-essential Services (2024)

After installation on board, each internal combustion engine having power ≥ 100 kW intended for non-essential services, including all starting, control and safety system, are to be operated in the presence of the Surveyor to demonstrate satisfactory function and freedom from excessive vibrations at speeds within the operating range. Overspeed shutdown is to be verified to the satisfaction of the attending Surveyor.

13.11 Processes for Certification of Engines (2020)

13.11.1 General (2020)

Each engine required to be approved and certified by 1.1 is:

i. To have its design approved by ABS; for which purpose, plans and data as required by are to be submitted to ABS for approval, showing compliance with the requirements of this Section.
ii. To have a type approval certificate to be obtained by the engine designer. The process details for obtaining a type approval certificate are in and *,
Note:
* Process of Type Approval Certificate for engines is equivalent as a product design assessment (PDA) certificate under ABS Type Approval Program.
and,
iii. To have an engine certificate for a shipboard application. The process details for obtaining the engine certificate are in and **
Note:
** Process of engine certificate for each engine is equivalent to “Unit Certification" of the ABS Type Approval program which includes requirements of a valid product design assessment (PDA) and survey at manufacturer’s facility

13.11.2 ABS Type Approval Program (2020)

13.11.2(a) Product Design Assessment (PDA). **(2020)**

Upon application by the manufacturer, each model of a type of engine is to be design assessed as described in ABS-RL-CLSSHIP 1A-1-A3/5.1. For this purpose, each design of an engine type is to be approved in accordance with 13.11.1.i.). Engines so approved may be applied to ABS for listing on the ABS website in the Product Design Assessment (PDA) index (see ABS-RL-CLSSHIP 1A-1-A3/5.1). Once listed, and subject to renewal and updating of certificate as required by ABS-RL-CLSSHIP 1A-1-A3/5.7, engine particulars are not required to be submitted to ABS each time the engine is proposed for use on board a vessel.

13.11.2(b) Manufacturing Assessment (MA). **(2020)**

An engine manufacturer, who operates a quality assurance system in the manufacturing facilities, may apply to ABS for quality assurance assessment described in ABS-RL-CLSSHIP 1A-1-A3/5.3.1(a) (Manufacturers Procedure), ABS-RL-CLSSHIP 1A-1-A3/5.3.1(b) (RQS) or ABS-RL-CLSSHIP 1A-1-A3/5.5 (PQA, Alternative Certification Scheme).

13.11.2(c) Product Quality Assurance (PQA). **(2020)**

Upon satisfactory assessment under ABS-RL-CLSSHIP 1A-1-A3/5.5 (PQA), engines produced in those facilities do not require a Surveyor’s attendance at the tests and inspections indicated in 13.11.1.ii. and 13.11.1.iii.. Such tests and inspections are to be carried out by the manufacturer whose quality control documents are acceptable. Certification of each engine is to be based on verification of approval of the design and on continued effectiveness of the quality assurance system. See also 13.11.2(e).

13.11.2(d) Type Approval Program. **(2020)**

Engine types which have their designs approved in accordance with 13.11.2(a)and the quality assurance system of their manufacturing facilities approved in accordance with 13.11.2(b) are deemed to be Type Approved and are eligible for listing on the ABS website as Type Approved Products.

13.11.2(e) *Unit-Certification.* **(2020)**

When a Type Approved Product is proposed for use on board a vessel, it is to comply with all applicable requirements in the Rules, and where required Unit Certification (ABS-RL-CLSSHIP 1A-1-A3/5.7.1) is also to be completed as follows:

i. *Products Covered by Product Quality Assurance - PQA ().* Products requiring unit-certification for use on a vessel, are to be unit-certified by the ABS office having jurisdiction over the manufacturer (see), and
ii. *Products with Manufacturing Assessment () Requiring Unit Certification*. Where the Rules require attendance of the ABS Surveyor during any stage of manufacturing, including but not limited to any testing, the unit certification is to be issued by the attending Surveyor upon completion of all required surveys and tests.

15 Spare Parts (2024)

While spare parts are not required for purposes of classification, the spare parts listed in Appendix 4-2-1-A11 are provided as a guidance for vessels intended for unrestricted service. The maintenance of spare parts aboard each vessel is the responsibility of the owner.

Commentary:

ABS offers spare parts certification through the optional Preventative Maintenance Program's Reliability Based Maintenance (RBM) and Reliability Centered Maintenance (RCM) risk-based maintenance development processes. Refer to Appendix 7-A1-14 of the ABS *Rules for Survey After Construction (Part 7)* and the ABS *Guide for Surveys Based on Machinery Reliability and Maintenance Techniques*.

End of Commentary

.

TABLE 2A
Type Approval Process - Documentation to be Submitted for Information, as Applicable (1 July 2023)

No.	Item
1	Engine particulars (e.g., Data sheet with general engine information (see Annex 3 of 4-2-1-A1/1), 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

No.	Item	
	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)	

Notes:

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 4-9-9/TABLE 1.

TABLE 2B
Type Approval Process - Documentation to be Submitted for Approval, as Applicable (2020)

No.	Item	
1	Bedplate and crankcase of welded design, with welding details and welding instructions(1,2)	
2	Thrust bearing bedplate of welded design, with welding details and welding instructions(1)	
3	Bedplate/oil sump welding drawings(1)	
4	Frame/framebox/gearbox of welded design, with welding details and instructions(1,2)	
5	Engine frames, welding drawings(1,2)	
6	Crankshaft, details, each cylinder No. (see 5.9.4)	
7	Crankshaft, assembly, each cylinder No.	
8	Crankshaft calculations, for each cylinder configuration (see 5.9.3)	
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)	

No.	Item
20	Construction of accumulators (common rail) (for electronically controlled engine)
21	Construction of common accumulators (common rail) (for electronically controlled engine)
22	Arrangement and details of the crankcase explosion relief valve (see 7.1) [5]
23	Calculation results for crankcase explosion relief valves (see 4-2-1-A2)
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 7.2)
27	Details of mechanical joints of piping systems (see 4-6-2/5.9)
28	Documentation verifying compliance with inclination limits (see 4-1-1/TABLE 7)
29	Documents as required in Section 4-9-3, as applicable
30	Structural supporting and seating arrangements
31	Arrangement of foundation bolts (for main engines only)
32	Vibration damper assembly
33	Governor arrangements
34	Turbochargers and superchargers, see 4-2-2/1.5
35	Couplings and clutches

Notes:

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 ABS requirements for material, NDT and pressure testing as applicable.
4. All engines.
5. Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m^3 or more.
6. The documentation to contain specifications for pressures, pipe dimensions and materials.
7. The type test report may be submitted shortly after the conclusion of the type test.

TABLE 3
Type Approval Process - Documentation for the Inspection of Components and Systems (2024)

- Upon satisfactory ABS technical assessment, approval will be given to engines of identical design and application
- For engine applications refer to and and

No.	Item	
1	Engine particulars as per data sheet in Annex 3 of 4-2-1-A1/1	
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

No.	Item	
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 7.1)(6)	
24	Oil mist detection and/or alternative alarm arrangements (see 7.2)	
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	
49	Structural supporting and seating arrangements	
50	Governor arrangements	
51	Turbochargers and superchargers, see 4-2-2	
52	Couplings and clutches	

Notes:

1 For comparison with ABS 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 ABS for information or approval, as applicable. See 13.3.2(b).ii., Annexes 4 and 5 of 4-2-1-A1/1

TABLE 4
Type Defining Parameters (2020)

No.	Item
1	Engine Type / Working cycle (4-stroke, 2-stroke)
2	Application (Propulsion - Single engine /Multi-engine installation, Auxiliary, Emergency)
3	Cylinder arrangement (In-line, Vee, other) (1)
4	Cylinder Bore, mm (in.)
5	Stroke, mm (in.)
6	Rated Power, kW/cyl. (PS, hp /cyl.) (2)
7	Rated engine speed (rpm) (2)
8	Max Firing Pressure, bar (kgf/mm^2, psi) (2)
9	Fuel injection (Direct, Indirect, Cam controlled injection, Electronically controlled injection)
10	Injection System – operation (Pump+Pipe+Injector, Common Rail, other)
11	Valve operation (Cam control, Electronic control)
12	Kind of fuel (Liquid, Dual-fuel, Gaseous)
13	Turbocharging system (Pulsating, Constant pressure, Single-stage, Two stage, None)
14	Charge air cooling system (with intercooler, without intercooler)

Notes:

1 See 13.5.2.i.

2 See 13.5.2.ii.

TABLE 5
Engine Data (to be submitted for information) (2020)

No.	Item
1	Number of Cylinders
2	Sense of rotation (Clockwise, Counter-clockwise)
3	Firing order (with the respective ignition intervals and, where necessary, V-angle, α_V)
4	Mean Indicated Pressure, bar (kgf/mm^2, psi)
5	Mean Effective Pressure, bar (kgf/mm^2, psi)
6	Mean piston speed (m/s)
7	Charge air pressure, bar (kgf/mm^2, psi), (before inlet valves or scavenge ports, whichever applies)
8	Nominal compression ratio
9	Exhaust Gas Treatment (EGR, SCR) (1)

Notes:

1 Sub-systems separately approved by Integration tests according to 13.5.4(e)

TABLE 6

Required Material and Nondestructive Tests of Engine Parts [1] (1 July 2024)

	Engine Part [4, 5, 6, 7, 8]	Material Properties [2]	Nondestructive Tests & Inspections [3]		Visual Inspection and Component Certificate	
			Magnetic Particle, Liquid Penetrant, or Similar Tests, Ultrasonic Tests	Dimensional Inspection, Including Surface Condition	Visual Inspection (Surveyor)	Component Certificate
1	Welded bedplate	W(C+M)	W(UT+CD)		fit-up + post welding	SC
2	Bearing transverse girders GS	W(C+M)	W(UT+CD)		X	SC
3	Welded frame box	W(C+M)	W(UT+CD)		fit-up + post welding	SC
4	Welded cylinder frames (crosshead engines)	W(C+M)	W(UT+CD)		fit-up + post welding	SC
5	Engine block GJS > 400 kW/cyl.	W(M)				
6	Cylinder liner D > 300 mm	W(C+M)				
7	Cylinder head GS D > 300 mm	W(C+M)	W(UT+CD)		X	SC
8	Forged cylinder head D > 300 mm	W(C+M)	W(UT+CD)		X	SC
9	Piston crown GS D > 400 mm	W(C+M)	W(UT+CD)		X	SC
10	Forged piston crown D > 400 mm	W(C+M)	W(UT+CD)		X	SC
11	Crankshaft: made in one piece	SC(C+M)	W(UT+CD)	W	Random, of fillets and oil bores	SC
12	Semi-built crankshaft (Crankthrow, forged main journal and journals with flange)	SC(C+M)	W(UT+CD)	W	Random, of fillets and shrink fittings	SC
13	Piston rod D > 400 mm, crosshead engines	SC(C+M)	W(UT+CD)		Random	SC
14	Cross head (crosshead engines)	SC(C+M)	W(UT+CD)		Random	SC
15	Connecting rod with cap	SC(C+M)	W(UT+CD)	W	Random, of all surfaces, in particular those shot peened	SC
16	Coupling bolts for crankshaft	SC(C+M)	W(UT+CD)	W	Random, of interference fit	SC
17	Bolts and studs for main bearings D>300mm	W(C+M)	W(UT+CD)			
18	Bolts and studs for cylinder heads D > 300 mm	W(C+M)	W(UT+CD)			
19	Bolts and studs for connecting rods D > 300 mm	W(C+M)	W(UT+CD)	TR of thread making		

	Engine Part (4, 5, 6, 7, 8)	Material Properties (2)	Nondestructive Tests & Inspections (3)		Visual Inspection and Component Certificate	
			Magnetic Particle, Liquid Penetrant, or Similar Tests, Ultrasonic Tests	Dimensional Inspection, Including Surface Condition	Visual Inspection (Surveyor)	Component Certificate
20	Tie rod (crosshead engines)	W(C+M)	W(UT+CD)	TR of thread making	Random	SC
21	High pressure fuel injection pump body	W(C+M)				
22	High pressure fuel injection pipes including common fuel rail	W(C+M)				
23	High pressure common servo oil system	W(C+M)				
24	Cooler, both sides D > 300 mm	W(C+M)				
25	Accumulator (all engines with accumulators with a capacity of >0.5 l)	W(C+M)				
26	Piping, pumps, actuators, etc. for hydraulic drive of valves, if applicable > 800 kW/cyl.	W(C+M)				
27	Bearings for main, crosshead, and crankpin>800 kW/cyl.	TR(C)	TR (UT for full contact between base material and bearing metal)	W		

Symbol Description:

C: chemical composition; CD: crack detection by MPI or DP; D: cylinder bore diameter (mm); GJL: gray cast iron; GJS: spheroidal graphite cast iron; GS: cast steel; M: mechanical properties; SC: class certificate; TR: test report; UT: ultrasonic testing; W: work's certificate; X: visual examination of accessible surfaces by the Surveyor.

Notes:

1. For engines < 375 kW, see 3.3.3.
2. Material properties include chemical composition and mechanical properties, and also surface treatment such as surface hardening (hardness, depth and extent), peening and rolling (extent and applied force).
3. Nondestructive examination means e.g. ultrasonic testing, crack detection by MPI or DP (see 13.2.3). When certain NDE method on the finished component is impractical (for example UT for items 7 and 8), the NDE method can be performed at earlier appropriate stages in the production of the component, see 4-2-1/13.6.ii.
4. For Category C turbochargers, see 4-2-2/3.5 and 4-2-2/11.1.1.
5. Crankcase explosion relief valves are to be type tested in accordance with 4-2-1-A2 and documented according to 7.1.
6. Oil mist detection systems are to be type tested in accordance with 4-2-1-A3 and documented according to 7.2.2.
7. For speed governor and overspeed protective devices, see 7.3 and 7.5.
8. Material certification requirements for pumps and piping components are dependent on the operating pressure and temperature. Requirements given in Table 6 apply except where alternative requirements are explicitly given elsewhere in the Rules.

TABLE 7
Test Pressures for Parts of Internal-combustion Engines (1 July 2022)

Engine part	Test pressure (P = max. working pressure of engine part)(2)
Engine block GJL & GJS, Cylinder block GJL & GJS(1) >400 kW/cyl	1.5P
Cylinder cover, cooling space(1)	7 bar (7 kgf/cm^2, 100 psi)
Cylinder liner, over the whole length of cooling space (1)	7 bar (7 kgf/cm^2, 100 psi)
Cylinder jacket, cooling space (1)	4 bar (4 kgf/cm^2, 58 psi) but not less than 1.5P
Exhaust valve, cooling space (crosshead engines)	4 bar (4 kgf/cm^2, 58 psi) but not less than 1.5P
Piston crown, cooling space, where the cooling space is sealed by piston rod or by piston rod and skirt (test after assembly). For forged piston crowns test methods other than pressure testing may be used, e.g. nondestructive examination and dimensional checks.	7 bar (7 kgf/cm^2, 100 psi)
Fuel-injection system (pump body pressure side, injection valves - only for those not autofretted - and pipes including common fuel rail, for those that are not autofretted), D > 300 mm, Test Report for D $\leq$ 300 mm.(3)	1.5P or P + 300 bar (P + 306 kgf/cm^2, P + 4350 psi) whichever is less
High pressure common servo oil system (D > 300 mm, Test Report for D ≤ 300 mm), high pressure piping, pumps, actuators etc. for hydraulic drive of valves (> 800 kW/cyl.)	1.5P
Accumulator > 0.5l	1.5P
Scavenge-pump cylinder	4 bar (4 kgf/cm^2, 58 psi)
Turbocharger, cooling space (see 4-2-2/11.1.3)	4 bar (4 kgf/cm^2, 58 psi) but not less than 1.5P
Exhaust pipe, cooling space	4 bar (4 kgf/cm^2, 58 psi) but not less than 1.5P
Engine-driven air compressor, (cylinders, covers, intercoolers and aftercoolers) air side	1.5P
Engine-driven air compressor, (cylinders, covers, intercoolers and aftercoolers) water side	4 bar (4 kgf/cm^2, 58 psi) but not less than 1.5P
Coolers, each side; (charge air coolers need only be tested on the water side) for D > 300mm	4 bar (4 kgf/cm^2, 58 psi) but not less than 1.5P
Engine driven pumps (oil, water, fuel, bilge), > 800 kW/cyl, other than pumps covered in other parts of the Table.	4 bar (4 kgf/cm^2, 58 psi) but not less than 1.5P
Independently driven pumps (oil, water, fuel) for engines with bores > 300 mm (11.8 in.)	1.5P, for certification of pumps; see 4-6-1/7.3.

Notes:

1. Hydraulic testing is also required for those parts filled with cooling water and having the function of containing the water which is in contact with the cylinder or cylinder liner (D > 300 mm).
2. Where design or testing features may require modification of these testing requirements, special consideration may be given.
3. For mass-produced fuel-injection systems, refer to .

Appendix 1 Documentation for the Approval of Internal Combustion Engines

1 Documentation/Processes/Glossary Related to Approval of Engines (2025)

This Appendix contains information about the definitions, the documentation and the processes related to the Approval of engines, as described in 4-2-1/13.3.

ANNEX 1 - Glossary

Term	*Definition*

Acceptance criteria	A set of values or criteria which a design, product, service or process is required to conform with, in order to be considered in compliance
Accepted	Status of a design, product, service or process, which has been found to conform to specific acceptance criteria
Alternative Certification Scheme (ACS	A system, by which a society evaluates a manufacturer's quality assurance and quality control arrangements for compliance with Rule requirements, then authorizes a manufacturer to undertake and witness testing normally required to be done in the presence of a Surveyor. The Alternative Certification Scheme as presently administrated by the IACS Member Societies.
Appraisal	Evaluation by a competent body
Approval	The granting of permission for a design, product, service or process to be used for a stated purpose under specific conditions based upon a satisfactory appraisal
Assembly	Equipment or a system made up of components or parts
Assess	Determine the degree of conformity of a design, product, service, process, system or organization with identified specifications, Rules, standards or other normative documents
Audit	A systematic and independent examination to verify whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve the stated objectives
Auditor	Individual who has the qualifications and experience to perform audits
Certificate	A formal document attesting to the compliance of a design, product, service or process with acceptance criteria
Certification	A procedure whereby a design, product, service or process is approved in accordance with acceptance criteria
Class	Short for ABS
Class approval	Approved by ABS
Classification	Specific type of certification, which relates to the ABS Rules
Competent body	Organization recognized as having knowledge and expertise in a specific area
Component	Part, member of equipment or system
Conformity	Where a design, product, process or service demonstrates compliance with its specific requirements
Contract	Agreement between two or more parties relating to the scope of service
Contractor	see “Supplier”
Customer	Party who purchases or receives goods or services from another
Design	All relevant plans, documents, calculations described in the performance, installation and manufacturing of a product
Design analysis	Investigative methodology selectively used to assess the design
Design appraisal	Evaluation of all relevant plans, calculations and documents related to the design
Design review	Part of the appraisal process to evaluate specific aspects of the design
Drawings approval/ plan approval	Part of the design approval process which relates to the evaluation of drawings and plans
Equipment	Part of a system assembled from components
Equivalent	An acceptable, no less effective alternative to specified criteria
Evaluation	Systematic examination of the extent to which a design, product, service or process satisfies specific criteria
Examination	Assessment by a competent person to determine compliance with requirements
Inspection	Examination of a design, product service or process by an Inspector
Inspection plan	List of tasks of inspection to be performed by the Inspector
Installation	The assembling and final placement of components, equipment and subsystems to permit operation of the system
Manufacturer	Party responsible for the manufacturing and quality of the product
Manufacturing process	Systematic series of actions directed towards manufacturing a product
Manufacturing process approval	Approval of the manufacturing process adopted by the manufacturer during production of a specific product
Material	Goods supplied by one manufacturer to another manufacturer that will require further forming or manufacturing before becoming a new product
Modification	A limited change that does not affect the current approval

Modification notice	Information about a design modification with new modification index or new drawing number replacing the earlier drawing
Performance test	Technical operation where a specific performance characteristic is determined
Producer	See “Manufacturer”
Product	Result of the manufacturing process
Prototype test	Investigations on the first or one of the first new engines with regard to optimization, fine tuning of engine parameters and verification of the expected running behavior
Quality assurance	All the planned and systematic activities implemented within the quality system, and demonstrated as needed to provide adequate confidence that an entity will fulfil requirements for quality. Refer to ISO 9001.
Regulation	Rule or order issued by an executive authority or regulatory agency of a government and having the force of law
Repair	Restore to original or near original condition from the results of wear and tear or damages for a product or system in service
Requirement	Specified characteristics used for evaluation purposes
Information	Additional technical data or details supplementing the drawings requiring approval
Revision	Means to record changes in one or more particulars of design drawings or specifications
Specification	Technical data or particulars which are used to establish the suitability of materials, products, components or systems for their intended use
Substantive modifications or major modifications or major changes	Design modifications, which lead to alterations in the stress levels, operational behavior, fatigue life or an effect on other components or characteristics of importance such as emissions
Subsupplier/ subcontractor	One who contracts to supply material to another supplier
Supplier	One who contracts to furnish materials or design, products, service or components to a customer or user
Test	A technical operation that consists of the determination of one or more characteristics or performance of a given product, material, equipment, organism, physical phenomenon, process or service according to a specified procedure. A technical operation to determine if one or more characteristic(s) or performance of a product, process or service satisfies specific requirements
Traceability	Ability to follow back through the design and manufacturing process to the origin
Type approval	The establishment of the acceptability of a product through the systematic: i. Evaluation of a design to determine conformance with specifications ii. Witnessing manufacture and testing of a type of product to determine compliance with the specification iii. Evaluation of the manufacturing arrangements to confirm that the product can be consistently produced in accordance with the specification
Type approval test	Last step of the type approval procedure. Test program in accordance with 4-2-1/13.5
Witness	Individual physically present at a test and being able to record and give evidence about its outcome

ANNEX 2 – Representative Document Flow Diagrams

The document flow diagrams in this Annex are provided as an aid to all parties involved in the engine certification process as to their roles and responsibilities. Variations in the document flow may vary in response to unique issues with regard to various factors related to location, availability of components and surveys. In any case, the text in 4-2-1/13.3 takes precedence over the flow diagrams below.

FIGURE 1
Type Approval Document Flow

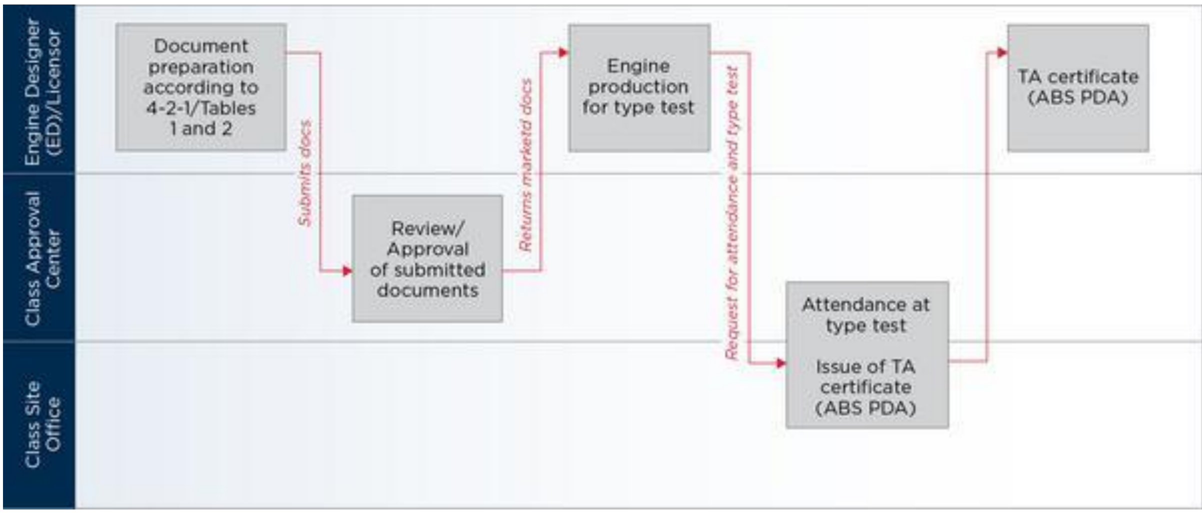
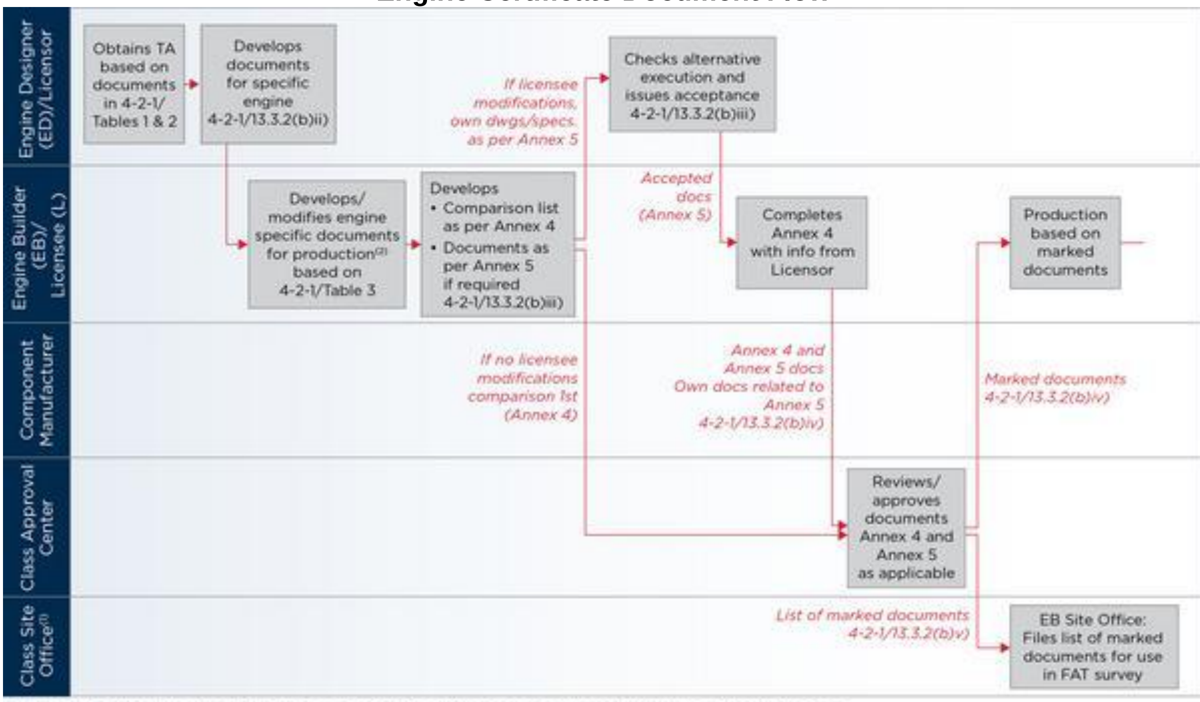
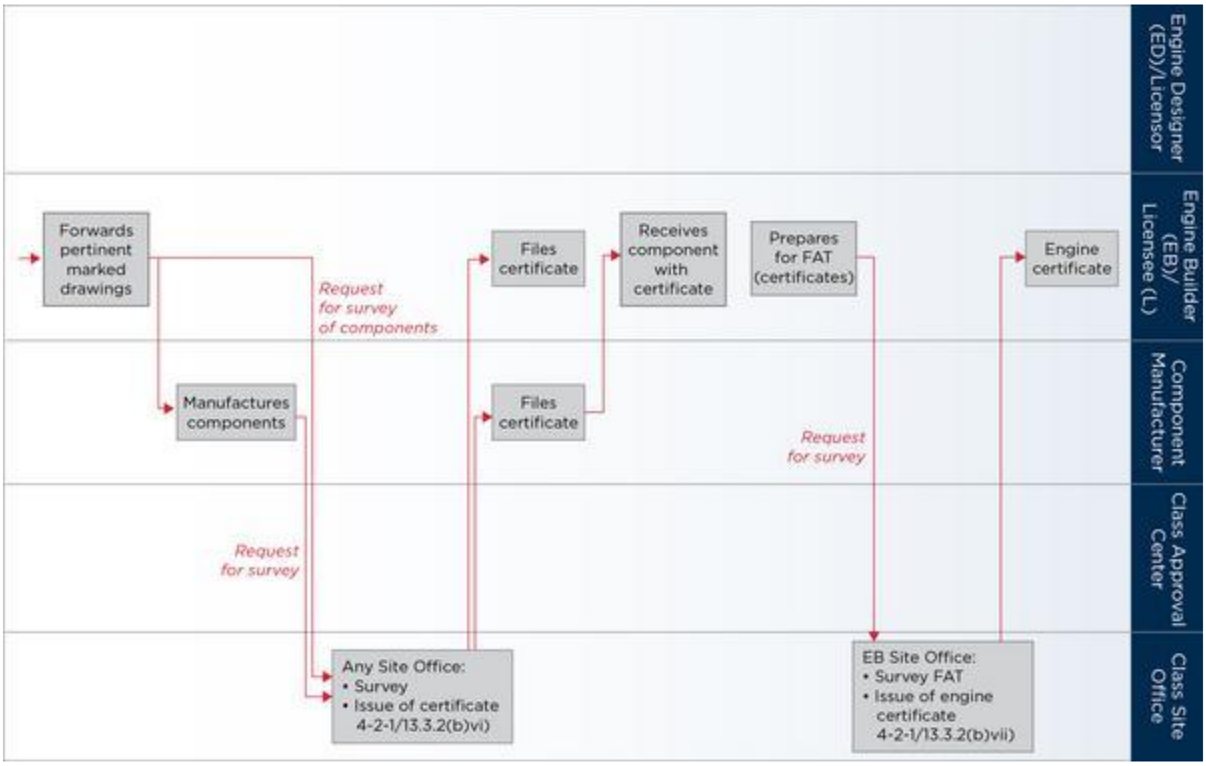


FIGURE 2
Engine Certificate Document Flow



1 Class Site office with responsibility for engine builder and/or component manufacturers in different locations
2 For alternative execution, see 4-2-1/13.3.6(c)



ANNEX 3 – Internal Combustion Engine Approval Application Form and Data Sheet

Class Application number (if applicable): Engine Manufacturer's Application Identification Number:

General Data	
Engine Designer: Contact Person: Address:	Engine Manufacturer(s), Licensee(s) and/or Manufacturing Sites Name Country

1. Document purpose *(select options from either 1a or 1b)*	
1a. Type Approval Application	
Service Requested	*Required activities*†
☐ New Type Approval	• *DA, TT, CoP*
☐ Renew Type Approval	• *CoP, if design change then amended or new certificate process to be followed*
☐ Amend Type Approval	• *DA & CoP, Further TT if previously approved engine has been substantively modified (as required by UR M71)*
☐ Design Evaluation	• *DA, TT, applicable where designer does not have production facilities, Type Approval to be granted to specific production facility once associated CoP has been completed*
☐ Update TA Supplement	• *Update to Supplement, only for minor changes not affecting the Type Approval Certificate*
☐ Other	• *e.g. National/Statutory Administration requirements i.e. MSC.81(70) for emergency engines*
For TA Cert amendments or Supplement updates, details of what is to be changed:	
For 'Other', Details of the requirements to be considered:	
1b. Addendum for Individual Engine FAT and Certification	
☐ Individual engine requiring FAT and Certification, only where the performance data for the engine being certified differs from the details provided on the original Type Approval Application. Only section 3b requires completion. Where changes to other sections are necessary, a new Type Approval Application may be required.	
Reference number of *Internal Combustion Engine Approval Application Form* previously submitted and reference number of the Type Approval Certificate.	*(Copy of original application form to be attached to this document)*

2. Existing documentation			
Previous Class Type Approval Certificate No. or related Design Approval No. *(if applicable)*			
Formerly issued documentation for engine *(E.g. previous type test reports, in-service experience justification reports, etc.)*	Issuing Body:	Document Type:	Document No.:
Existing Certification *(E.g. Manufacturer's quality certification ISO 9001 etc.)*	Issuing Body:	Document Type:	Document No.:

3. Design *(mark all that apply)*					
3a. Engine Particulars:					
Engine Type Manufactured Since‡:			Number of delivered marine engines‡:		
Application	☐ Direct drive Propulsion (☐ Single engine / ☐ Multi-engine installation)		☐ Auxiliary (☐ Aux. Services / ☐ Electric Propulsion)		☐ Emergency
Mechanical Design	☐ 2-stroke ☐ Cross-head Cylinder bore(mm)	☐ 4-stroke ☐ Trunk-piston	☐ In-line ☐ Reversible Length of piston stroke (mm)	☐ Vee (V-angle °) ☐ Non-reversible	☐ Other ( )
Supercharging	☐ Without supercharging	☐ With supercharging ☐ Without charge air cooling ☐ Constant-pressure charging system		☐ With charge air cooling ☐ Pulsating pressure charging system	
Valve operation	☐ Cam control	☐ Electronic control			
Fuel Injection	☐ Direct injection	☐ Indirect injection	☐ Cam controlled injection	☐ Electronically controlled injection	

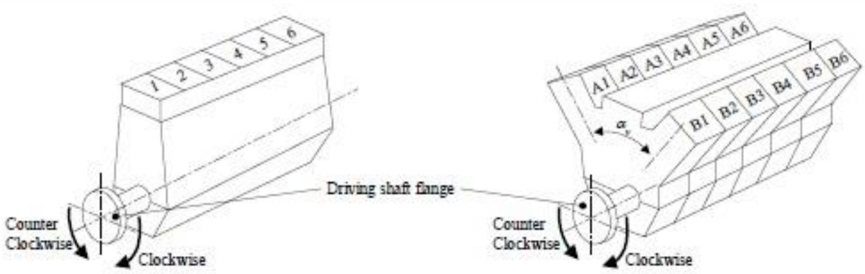
Fuel Types§ (Classification according to ISO 8216)	☐ Marine residual fuel cSt (Max. kinematic viscosity at 50°C) ☐ Marine distillate fuel DMA, DMB, DMC ☐ Marine distillate fuel DMX ☐ Low flashpoint liquid fuel (specify fuel type) ☐ Gas (specify gas type) ☐ Other (specify) ☐ Dual Fuel (specify combinations of fuels to be used simultaneously)

3b. Performance Data *(Related to: Barometric pressure 1,000 mbar; Air temperature 45°C; Relative humidity 60%; Seawater temperature 32°C)*		
Model reference No. (if applicable)		
Max. continuous rating	kW/cyl	
Rated speed	1/min	
Mean indicated pressure	MPa	
Mean effective pressure	MPa	
Max. firing pressure	MPa	
Charge air pressure	MPa	
Compression ratio	-	
Mean piston speed	m/s	

3c. Crankshaft				
Design	☐ Solid	☐ Semi-built	☐ Built	
Method of Manufacture	☐ Cast	☐ Forged ☐ Slab forged	☐ Approved die forged	☐ Continuous grain flow process
State approved forge/works name:				
Is the crankshaft hardened by an approved process which includes the fillet radii of crankpins and journals? ☐ Yes ☐ No If yes, state process:				
Crankshaft material specification: U.T.S. (N/mm^2) Yield strength (N/mm^2) Hardness value (Brinell/Vickers) Elongation (%)				

Dimensional Data	
If shrunk on webs, state shrinkage allowance (mm)	Yield strength of crankweb material (N/mm^2)
Centre of gravity of connecting rod from large end centre (mm)	Radius of gyration of connecting rod (mm)
Mass of each crankweb (kg)	Centre of gravity of web from journal axis (mm)
Mass of each counterweight (kg)	Centre of gravity of each counterweight from journal axis (mm)
Axial length of main bearing (mm)	Main bearing working clearance (mm)
Mass of flywheel at driving end (kg)	Mass of flywheel at opposite end (kg)
Nominal alternating torsional stress in crankpin (N/mm^2)	Nominal alternating torsional stress in crank journal (N/mm^2)
Length between centres (Total length)(mm)	

3d. Firing order



State numbering system of cylinders from left to right as per above diagrams (as applicable)

Number of cylinders	Clockwise firing order	Counter-clockwise firing order

4. Engine Ancillary Systems					
4a. Turbochargers		☐Fitted		☐Not Fitted	
Turbocharger oil supply by:		☐Engine lub. oil system		☐TC internal lub. oil system	
No. of cylinders	No. of aux blowers	No. of charge air coolers	No. of TC	TC manufacturer & type	TC type approval certificate No.
				/ / / / / /	

4b. Speed governor			
Engine application (Main/Aux/Emergency)	Manufacturer / type	Mode of operation	Type approval cert. No. (if electric / electronic gov.)
	/ / /		

4c. Overspeed protection

Independent overspeed protection available ☐ Yes ☐ No Mode of operation:

Manufacturer / type, if electronic: / Type approval certificate No.

4d. Electronic systems

Engine control and management system

Note: use Remarks section to identify when a different engine control system will be used for Type Test

Hardware: Manufacturer & Model: / Type approval certificate No.

Software: Name & Version: / Software conformity certificate No.

Additional electronic system 1: System function:

Manufacturer & type: / Type approval certificate No.

Additional electronic system 2: System function:

Manufacturer & type: / Type approval certificate No.

Additional electronic system 3: System function:

Manufacturer & type: / Type approval certificate No.

4e. Starting System

Type:

4f. Safety devices/functions

A flame arrestor or a bursting disk is installed in the starting air system: before each starting valve ☐ Yes ☐ No; in the starting air manifold ☐ Yes ☐ No

Crankcase relief valves available ☐ Yes ☐ No Manufacturer / type: /

Type approval certificate No.

No. of cyl.	Total crankcase gross volume incl. attachments (m^3)	Type & size (mm) of relief valve	Relief area per relief valve (mm^2)	No. of relief valves
		/ / / /		

Method used for detection of potentially explosive crankcase condition:

☐ Oil mist detector: Manufacturer / type: / Type approval certificate No.

☐ Alternative method: *(mark all that apply)* ☐ crankcase pressure monitoring ☐ bearing temperature monitoring ☐ other: ☐ oil splash temperature monitoring ☐ recirculation arrangements

Cylinder overpressure warning device available ☐ Yes ☐ No

Type: Opening pressure (bar):

4g. Attached ancillary equipment *(Mark all that apply)*

Engine driven pumps:

☐ Main lubricating oil pump ☐ Sea cooling water pump ☐ LT-fresh cooling water pump

☐ HT-fresh cooling water pump ☐ Fuel oil booster pump ☐ Hydraulic oil pump ☐ Other ( )

Engine attached motor driven pumps:

☐ Lubricating oil pump ☐ Cooling fresh water pump ☐ Fuel oil booster pump

☐ Hydraulic oil pump ☐ Other ( )

Engine attached cooler or heater:					
☐ Lubricating oil cooler		☐ Lubricating oil heater		☐ Fuel oil valve cooler	
☐ Hydraulic oil cooler		☐ Cooling fresh water cooler			
Engine attached filter:					
Lubricating oil filter	☐ Single	☐ Duplex	☐ Automatic		
Fuel oil filter	☐ Single	☐ Duplex	☐ Automatic		

5. Inclination limits *(engine operation is safeguarded under the following limits)*	Athwartships Static	Athwartships Dynamic	Fore-and-aft Static	Fore-and-aft Dynamic
Main & Auxiliary machinery	☐ 15.0°	☐ 22.5°	☐ 5.0°	☐ 7.5°
Emergency machinery	☐ 22.5°	☐ 22.5°	☐ 10.0°	☐ 10.0°
Emergency machinery on ships for the carriage of liquefied gas and liquid chemicals	☐ 30.0°	☐ 30.0°		

6. Main engine emergency operation		
At failure of one auxiliary blower, engine can be started and operated at partial load	☐ Yes	☐ No
At failure of one turbocharger, engine operation can be continued	☐ Yes	☐ No

7. References: *Additional Information Attached to Application*

Document Name/Number	Summary of information contained in document

8. Further Remarks:

* All parties that affect the final complete engine (e.g. manufacture, modify, adjust) are to be listed. All sites where such work is carried out may be required to complete CoP assessment.

† DA = Design Appraisal, TT = Type Test, CoP = Assessment of Conformity of Production. See 1-1-A3, 4-2-1/13.3, 4-2-1/13.5, and 4-2-1/A1.

‡ Only in case of TA Extension.

§ See 'Definitions' at the end of this application form for more information.

Completed By: Signature: ____________________

Company:

Job Title: Stamp:

Date:

Definitions:
Complete Engine includes the control system and all ancillary systems and equipment referred to in the Rules that are used for safe operation of the engine and for which there are rule requirements, this includes systems allowing the use of different fuel types. The exact list of components/items that will need to be tested in together with the bare engine will depend on the specific design of the engine, its control system and the fuel(s) used but may include, but are not limited to, the following: (a) Turbocharger(s) (b) Crankcase explosion relief devices (c) Oil mist detection and alarm devices (d) Piping (e) Electronic monitoring and control system(s) – software and hardware (f) Fuel management system (where dual fuel arrangements are fitted) (g) Engine driven pumps (h) Engine mounted filters **Fuel Types**: All fuels that the engine is designed to operate with are to be identified on the application form as this may have impact on the requirements that are applicable for Design Appraisal and the scope of the tests required for Type Testing. Where the engine is to operate in a Dual Fuel mode, the combinations of fuel types are to be detailed. E.g. Natural Gas + DMA, Natural Gas + Marine Residual Fuel, the specific details of each fuel are to be provided as indicated in the relevant rows of the Fuel Types part of section 3a of this form.

ANNEX 4 – Tabular Listing of Licensor's and Licensee's Drawing and Data

Licensee:__________________________ Licensor:__________________________

Licensee Engine No. :__________________________ Engine type:__________________________

No.	Components or System	Licensor			Licensee		Has Design been modified by Licensee?		If Yes, indicate following information	
		Dwg. No. & Title	Rev. No.	Date of Class Approval or Review	Dwg. No.	Rev. No.	Yes	No	Identification of Alternative approved by Licensor	Date of Class Approval or Review of Licensee Dwg.
1										
2										
3										
4										
5										
6										
7										
8										
9										
...										

I attest the above information to be correct and accurate.

Person in Charge (Licensee):

______________________ ______________________

Printed Name Signature

Date:__________________________

ANNEX 5 – Sample Template for Confirmation of the Licensor's Acceptance of Licensee's Modifications

Engine Licensee Proposed Alternative to Licensor's Design			
Licensee information			
Licensee:		Ref No.:	
Description:		Info No.:	
Engine type:		Main Section:	
Engine No.:		Plant Id.:	
Design Spec: ☐ General ☐ Specific Nos:			
Licensor design:	*State relevant part or drawing. numbers. Insert drawing clips or pictures. Add any relevant information*		*Licensee Proposed Alternative*
	For example: • Differences in geometry • Differences in the functionality • Material • Hardness • Surface condition • Alternative standard • Licensee production information introduced on the drawing • Weldings or castings • etc.		
Reason: ☐ Licensee's production ☐ Sub-supplier's production ☐ Cost down ☐ Tools	Interchangeability w. licensor design ☐ Yes ☐ No	Non-conformity Report Research, Assessment, Evaluation ☐ NCR ☐ RAE	Certified by licensee: Initials: Date:
Licensor comments			
LoAE: ☐ Accepted as alternative execution *(Licensor undertakes responsibility)* ☐ No objection *(Licensee undertakes responsibility)* ☐ Not acceptable		NCR: ☐ Approved ☐ Conditionally approved ☐ Rejected	Certified by licensor: Initials: Date:
Licensor ref.:			Date:
Licensee ref.:			Date:

Appendix 2 Type Testing Procedure for Crankcase Explosion Relief Valves

1 Scope (2024)

This Appendix specifies type tests and identifies standard test conditions using methane gas and air mixture to demonstrate that crankcase explosion relief valves intended to befitted to engines and gear casesare satisfactory.

This test procedure is only applicable to explosion relief valves fitted with flame arrestors.

Note:

Where internal oil wetting of a flame arrester is a design feature of an explosion relief valve, alternative testing arrangements that demonstrate compliance with this Appendix may be proposed by the manufacturer. The alternative testing arrangements are to be agreed by ABS.

The requirements in this Appendix are based on IACS UR M66, Type Testing Procedure for Crankcase Explosion Relief Valves.

3 Recognized Standards (1 July 2022)

i. ISO 16852: Flame arresters – Performance requirements, test methods and limits for use.
ii. ISO/IEC 17025: General requirements for the competence of testing and calibration laboratories.
iii. ISO 12100: Safety of Machinery – General principles for design – Risk assessment and risk reduction.
iv. VDI 3673: Part 1: Pressure Venting of Dust Explosions.
v. IMO MSC/Circular 677 –Revised Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame into Cargo Tanks in Tankers, as amended by MSC/Circ.1009 and MSC.1/Circ.1324.

5 Purpose

The purpose of type testing crankcase explosion relief valves is:

i. To verify the effectiveness of the flame arrester.
ii. To verify that the valve closes after an explosion.
iii. To verify that the valve is gas/air tight after an explosion.
iv. To establish the level of overpressure protection provided by the valve.

7 Test Facilities (2024)

Test facilities carrying out type testing of crankcase explosion relief valves are to meet the following requirements in order to be acceptable to ABS:

i. The test facilities are to be accredited to a National or International Standard, e.g., ISO/IEC 17025 and are to be acceptable to ABS.
ii. The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.
iii. The test facilities are to have equipment for controlling and measuring a methane gas in air concentration within a test vessel to an accuracy of ±0.1%.
iv. The test facilities are to be capable of effective point located ignition of methane gas in air mixture.
v. The pressure measuring equipment is to be capable of measuring the pressure in the test vessel in at least two positions: one at the valve and the other at the test vessel center. The measuring arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequencyrecognizingthe speed of events during an explosion. The result of each test is to be documented by video recording and, if necessary, by recording with a heat sensitive camera.
vi. The test vessel for explosion testing is to have documented dimensions. The dimensions are to be such that the vessel is not "pipe like" with the distance between dished ends being not more than 2.5 times its diameter. The internal volume of the test vessel is to include any standpipe arrangements.
vii. The test vessel for explosion testing is to be provided with a flange, located centrally at one end perpendicular to the vessel longitudinal axis, for mounting the explosion relief valve. The test vessel is to be arranged in an orientation consistent with how the valve will be installed in service, i.e., in the vertical plane or the horizontal plane.
viii. A circular plate is to be provided for fitting between the pressure vessel flange and valve tested with the following dimensions:
    - Outside diameter of 2 times the outer diameter of the valve top cover
    - Internal bore having the same internal diameter as the valve to be tested.
ix. The test vessel is to have connections for measuring the methane in an air mixture at the top and bottom.
x. The test vessel is to be provided with a means of fitting an ignition source at a position specified in .
xi. The test vessel volume is to be, as far as practicable, related to the size and capability of the relief valve to be tested. The volume is to correspond to the requirement in for the free area of explosion relief valve to be not less than 115 cm^2/m^3 (0.505 in^2/ft^3) of crankcase gross volume.
    Notes:
    1. This means that the testing of a valve having 1150 cm^2 (178.25 in^2) of free area, would require a test vessel with a volume of 10 m^3 (353.15 ft^3).
    2. Where the free area of relief valves is greater than 115 cm^2/m^3 (0.505 in^2/ft^3) of the crankcase gross volume, the volume of the test vessel is to be consistent with the design ratio.

3. In no case is the volume of the test vessel to vary by more than +15% to -15% from the design cm^2/m^3 volume ratio.

9 Explosion Test Process

All explosion tests to verify the functionality of crankcase explosion relief valves are to be carried out using an air and methane mixture with a volumetric methane concentration of 9.5% ±0.5%. The pressure in the test vessel is to be not less than atmospheric and not exceed the opening pressure of the relief valve.

The concentration of methane in the test vessel is to be measured at the top and bottom of the vessel and these concentrations are not to differ by more than 0.5%.

The ignition of the methane and air mixture is to be made at the centerline of the test vessel at a position approximately one third of the height or length of the test vessel opposite to where the valve is mounted.

The ignition is to be made using a maximum 100 Joule (0.0947 BTU) explosive charge.

11 Valves to be Tested

i. The valves used for type testing [including testing specified in] are to be selected from the manufacturer's normal production line for such valves.
ii. For approval of a specific valve size, three valves are to be tested in accordance with and . For a series of valves, refers.
iii. The valves selected for type testing are to have been previously tested at the manufacturer's works to demonstrate that the opening pressure is in accordance with the specification within a tolerance of ±20% and that the valve is airtight at a pressure below the opening pressure for at least 30 seconds.

    Note:

    This test is to verify that the valve is airtight following assembly at the manufacturer's works and that the valve begins to open at the required pressure demonstrating that the correct spring has been fitted.
iv. The type testing of valves is to recognizethe orientation in which they are intendedto be installed on the engine or gear case. Three valves of each size are to be tested for each intended installation orientation, i.e., in the verticaland/or horizontal positions.

13 Method

13.1 General Requirements

The following requirements are to be satisfied during explosion testing:

i. The explosion testing is to be witnessed by the Surveyor.
ii. Where valves are to be installed on an engine or gear case with shielding arrangements to deflect the emission of explosion combustion products, the valves are to be tested with the shielding arrangements fitted.
iii. Successive explosion testing to establish a valve's functionality is to be carried out as quickly as possible during stable weather conditions.
iv. The pressure rise and decay during all explosion testing is to be recorded.
v. The external condition of the valves is to be monitored during each test for indication of any flame release by video and heat sensitive camera.

13.3 Stages of Testing

The explosion testing is to be in three stages for each valve that is required to be approved as being type tested.

13.3.1 Stage 1

Two explosion tests are to be carried out in the test vessel with the circular plate described in 4-2-1-A2/7.viii fitted and the opening in the plate covered by a 0.05 mm (0.002 inch) thick polythene film.

Note:

These tests establish a reference pressure level for determination of the capability of a relief valve in terms of pressure rise in the test vessel [see 4-2-1-A2/15.vi].

13.3.2 Stage 2

13.3.2(a)

Two explosion tests are to be carried out on three different valves of the same size. Each valve is to be mounted in the orientation for which approval is sought, i.e., in the vertical or horizontal position with the circular plate described in 4-2-1-A2/7.viii located between the valve and pressure vessel mounting flange.

13.3.2(b)

The first of the two tests on each valve is to be carried out with a 0.05 mm (0.002 inch) thick polythene bag having a minimum diameter of three times the diameter of the circular plate and volume not less than 30% of the test vessel enclosing the valve and circular plate. Before carrying out the explosion test the polythene bag is to be empty of air. The polythene bag is required to provide a readily visible means of assessing whether there is flame transmission through the relief valve following an explosion consistent with the requirements of the standards identified in 4-2-1-A2/3.

Note:

During the test, the explosion pressure will open the valve and some unburned methane/air mixture will be collected in the polythene bag. When the flame reaches the flamearrester and if there is flame transmission through the flame arrester, the methane/air mixture in the bag will be ignited and this will be visible.

13.3.2(c) Provided that the first explosion test successfully demonstrated that there was no indication of combustion outside the flame arrester and there are no visible signs of damage to the flame arrester or valve, a second explosion test without the polythene bag arrangement is to be carried out as quickly as possible after the first test. During the second explosion test, the valve is to be visually monitored for any indication of combustion outside the flame arrester and video records are to be kept for subsequent analysis. The second test is required to demonstrate that the valve can still function in the event of a secondary crankcase explosion.

13.3.2(d) After each explosion, the test vessel is to be maintained in the closed condition for at least 10 seconds to enable the tightness of the valve to be ascertained. The tightness of the valve can be verified during the test from the pressure/time records or by a separate test after completing the second explosion test.

13.3.3 Stage 3

Carry out two further explosion tests as described in Stage 1, (see 4-2-1-A2/13.3.1). These further tests are required to provide an average base line value for assessment of pressure rise recognizing that the test vessel ambient conditions may have changed during the testing of the explosion relief valves in Stage 2, (see 4-2-1-A2/13.3.2).

15 Assessment and Records (2024)

For the purposes of verifying compliance with the requirements of this Appendix, the assessment and records of the valves used for explosion testing is to address the following items:

i. The valves to be tested are to have been design approved.
ii. The designation, dimensions and characteristics of the valves to be tested are to be recorded. This is to include the valve free area of the valve and of the flame arrester and the amount of valve lift at 0.2 bar (0.2 kgf/cm^2, 2.85 lbf/in^2).
iii. The test vessel volume is to be determined and recorded.
iv. For acceptance of the functioning of the flame arrester there is not to be any indication of flame or combustion outside the valve during an explosion test. This is to be confirmed by the test laboratory taking into account measurements from the heat sensitive camera.
v. The pressure rise and decay during an explosion is to be recorded with indication of the pressure variation showing the maximum overpressure and steady under pressure in the test vessel during testing. The pressure variation is to be recorded at two points in the pressure vessel.
vi. The effect of an explosion relief valve in terms of pressure rise following an explosion is ascertained from maximum pressures recorded at the center of the test vessel during the three stages. The pressure rise within the test vessel due to the installation of a relief valve is the difference between average pressure of the four explosions from Stages 1 and 3 (see and) and the average of the first tests on the three valves in Stage 2, (see). The pressure rise is not to exceed the limit specified by the manufacturer.

vii. The valve tightness is to be ascertained by verifying from records at the time of testing that an underpressure of at least 0.3 bar (3.06 kgf/cm^2, 43.5 psi) is held by the test vessel for at least 10 seconds following an explosion. The test is to verify that the valve has effectively closed and is reasonably airtight/gas-tight following dynamic operation during an explosion.
viii. After each explosion test in Stage 2, (see), the external condition of the flame arrester is to be examined for signs of serious damage and/or deformation that may affect the operation of the valve.
ix. After completing the explosion tests, the valves are to be dismantled and the condition of all components is to be ascertained and documented. In particular, any indication of valve sticking or uneven opening that may affect operation of the valve is to be noted. Photographic records of the valve condition are to be taken and included in the report.

17 Design Series Qualification

17.1 General

The qualification of quenching devices to prevent the passage of flame can be evaluated for other similar devices of identical type, where one device has been tested and found satisfactory.

17.3 Flame Arrester

The quenching ability of a flame arrester depends on the total mass of quenching lamellas/mesh. Provided the materials, thickness of materials, depth of lamellas/thickness of mesh layer and the quenching gaps are the same, then the same quenching ability can be qualified for different size flame arresters. This is subject to i) and ii) being satisfied.

i. $$\frac{n_1}{n_2} = \sqrt{\frac{S_1}{S_2}}$$

ii. $$\frac{A_1}{A_2} = \frac{S_1}{S_2}$$

where

n_1	=	total depth of flame arrestor corresponding to the number of lamellas of size 1 quenching device for a valve with a relief area equal to S_1
n_2	=	total depth of flame arrestor corresponding to the number of lamella of size 2 quenching device for a valve with a relief area equal to S_2
A_1	=	free area of quenching device for a valve with a relief area equal to S_1
A_2	=	free area of quenching device for a valve with a relief area equal to S_2

17.5 Valves of Larger Sizes than Have Been Satisfactorily Tested

The qualification of explosion relief valves of larger sizes than that which has been previously satisfactorily tested in accordance with 4-2-1-A2/13 and 4-2-1-A2/15 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

17.5.1

The free area of a larger valve does not exceed three times +5% that of the valve that has been satisfactorily tested.

17.5.2

One valve of the largest size, subject to 4-2-1-A2/17.5.1, requiring qualification is subject to satisfactory testing required by 4-2-1-A2/11.iii and 4-2-1-A2/13.3.2 except that a single valve will be accepted in 4-2-1-A2/13.3.2(a) and the volume of the test vessel is not to be less than one third of the volume required by 4-2-1-A2/7.xi.

17.5.3

The assessment and records are to be in accordance with 4-2-1-A2/15 noting that 4-2-1-A2/15.vi) will only be applicable to Stage 2 for a single valve.

17.7 Valves of Smaller Sizes than Have Been Satisfactorily Tested

The qualification of explosion relief valves of smaller sizes than that which has been previously satisfactorily tested in accordance with 4-2-1-A2/13 and 4-2-1-A2/15 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

17.7.1

The free area of a smaller valve is not less than one-third of the valve that has been satisfactorily tested.

17.7.2

One valve of the smallest size, subject to 4-2-1-A2/17.7.1, requiring qualification is subject to satisfactory testing required by 4-2-1-A2/11.iii and 4-2-1-A2/13.3.2 except that a single valve will be accepted in 4-2-1-A2/13.3.2(a) and the volume of the test vessel is not to be more than the volume required by 4-2-1-A2/7.xi

17.7.3

The assessment and records are to be in accordance with 4-2-1-A2/15 noting that 4-2-1-A2/15.vi) will only be applicable to Stage 2 for a single valve.

19 Reporting

The test facility is to provide a full report that includes the following information and documents:

i. Test specification.
ii. Details of test pressure vessel and valves tested.
iii. The orientation in which the valve was tested, (vertical or horizontal position).
iv. Methane in air concentration for each test.
v. Ignition source
vi. Pressure curves for each test.
vii. Video recordings of each valve test.
viii. The assessment and records stated in .

21 Acceptance

Acceptance of an explosion relief valve will be based on design approved plans and particulars and on the test facility’s report of the results of the type testing.

1 Scope (2020)

This Appendix specifies the tests required to demonstrate that crankcase oil mist detection and alarm equipment intended to be fitted to engines demonstrate compliance with a defined standard for type testing.

Note:

This test procedure is also applicable to oil mist detection and alarm equipment intended for gear cases.

3 Recognized Environmental Test Standards

Equipment tests as required in 4-2-1/7.2.2 are to be in accordance with 4-9-9/15.7 TABLE 1.

5 Purpose

The purpose of type testing crankcase oil mist detection and alarm equipment is:

i. To verify the functionality of the system.
ii. To verify the effectiveness of the oil mist detectors.
iii. To verify the accuracy of oil mist detectors.
iv. To verify the alarm set points.
v. To verify time delays between oil mist leaving the source and alarm activation.
vi. To verify functional failure detection.
vii. To verify the influence of optical obscuration on detection.

7 Test Facilities

Test facilities for carrying out type testing of crankcase oil mist detection and alarm equipment are to satisfy the following criteria:

i. A full range of provisions for carrying out the environmental and functionality tests required by this procedure are to be available and acceptable to ABS.
ii. The test facility that verifies the functionality of the equipment is to be equipped so that it can control, measure and record oil mist concentration levels in terms of mg/l to an accuracy of ±10% accordance with this procedure.
iii. When verifying the functionality, test facilities are to consider the possible hazards associated with the generation of the oil mist required and take adequate precautions. The use of low toxicity, low hazard oils as used in other applications will be accepted, provided it is demonstrated to have similar properties to SAE 40 monograde mineral oil specified.

9 Equipment Testing

The range of tests is to include the following (see also 4-9-9/13.1–Prototype Environmental Testing):

9.1 For the Alarm/Monitoring Panel

i. Functional tests described in .
ii. Electrical power supply failure test.
iii. Power supply variation test.
iv. Dry heat test.
v. Damp heat test.
vi. Vibration test.
vii. EMC test.
viii. Insulation resistance test.
ix. High voltage test.
x. Static and dynamic inclinations, if moving parts are contained.

9.3 For the Detectors

i. Functional tests described in .

ii. Electrical power supply failure test.
iii. Power supply variation test.
iv. Dry heat test.
v. Damp heat test.
vi. Vibration test.
vii. EMC test where susceptible.
viii. Insulation resistance test.
ix. High voltage test.
x. Static and dynamic inclinations.

11 Functional Test Process

i. All tests to verify the functionality of crankcase oil mist detection and alarm equipment are to be carried out in accordance with through with an oil mist concentration in air, known in terms of mg/l to an accuracy of ±10%.
ii. The concentration of oil mist in the test chamber is to be measured in the top and bottom of the chamber and these concentrations are not to differ by more than 10%. See also
iii. The oil mist detector monitoring arrangements are to be capable of detecting oil mist in air concentrations of between 0 and 10% of the lower explosive limit (LEL) or between 0 and a percentage of weight of oil in air determined by the Manufacturer based on the sensor measurement method (e.g., obscuration or light scattering) that is acceptable to ABS taking into account the alarm level specified in iv) below.

   Note:

   The LEL corresponds to an oil mist concentration of approximately 50 mg/l (~4.1% weight of oil-in air mixture).
iv. The alarm set point for oil mist concentration in air is to provide an alarm at a maximum level corresponding to not more than 5% of the LEL or approximately 2.5 mg/l.
v. Where alarm set points can be altered, the means of adjustment and indication of set points are to be verified against the equipment manufacturer’s instructions.
vi. The performance of the oil mist detector in mg/l is to be demonstrated. This is to include: range (oil mist detector); resolution (oil mist detector); sensitivity (oil mist detector).

   Sensitivity of a measuring system: quotient of the change in an indication of a measuring system and the corresponding change in a value of a quantity being measured.

   Resolution: smallest change in a quantity being measured that causes a perceptible change in the corresponding indication.
vii. Where oil mist is drawn into a detector/monitor via piping arrangements, the time delay between the sample leaving the crankcase and operation of the alarm is to be determined for the longest and shortest lengths of pipes recommended by the manufacturer. The pipe arrangements are to be in accordance with the manufacturer’s instructions/recommendations. Piping is to be arranged to prevent pooling of oil condensate which may cause a blockage of the sampling pipe over time.
viii. It is to be demonstrated that openings in detector equipment that is in contact with the crankcase atmosphere and may be exposed to oil splash and spray from engine lubricating oil do not occlude or become blocked under continuous oil splash and spray conditions. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by ABS. The temperature, quantity and angle of impact of the oil to be used is to be declared and their selection justified by the manufacturer.
ix. It is to be demonstrated that exposed to water vapor from the crankcase atmosphere, which may affect the sensitivity of the detector equipment, will not affect the functional operation of the detector equipment. Where exposure to water vapor and/or water condensation has been identified as a possible source of equipment malfunctioning, testing is to demonstrate that any mitigating arrangements, such as heating, are effective. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by ABS.

   Note:

   This testing is in addition to that required by and is concerned with the effects of condensation caused by the detection equipment being at a lower temperature than the crankcase atmosphere.
x. It is to be demonstrated that an indication is given where lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

13 Detectors and Alarm Equipment to be Tested

The detectors and alarm equipment selected for the type testing are to be selected by the Surveyor from the manufacturer's usual production line.

Two detectors are to be tested. One is to be tested in the clean condition and the other in a condition representing the maximum level of lens obscuration specified by the manufacturer.

15 Method (2024)

The following requirements are to be satisfied during type testing:

i. Oil mist generation is to satisfy to

   a. The ambient temperature in and around the test chamber is to be at the standard atmospheric conditions defined in for Type Test before any test run is started.

   b. Oil mist is to be generated with suitable equipment using an SAE 40 monograde mineral oil or equivalent and supplied to a test chamber. The selection of the oil to be used is to take into consideration risks to health and safety, and the appropriate controls implemented. A low toxicity, low flammability oil of similar viscosity may be used as an alternative. The oil mist produced is to have an average (or arithmetic mean) droplet size not exceeding 5 μm. The oil droplet size is to be checked using the sedimentation method or an equivalent method to a relevant international or national standard. If the sedimentation method is chosen, the test chamber is to have a minimum height of 1 m and a volume of not less than 1 m^3.

      Note: The calculated oil droplet size using the sedimentation method represents the average droplet size.

   c. The oil mist concentrations used are to be ascertained by the gravimetric deterministic method or equivalent.Where an alternative technique is used its equivalence is to be demonstrated.

      Note:

      For this test, the gravimetric deterministic method is a process where the difference in weight of a 0.8 μm pore size membrane filter is ascertained from weighing the filter before and after drawing 1 liter of oil mist through the filter from the oil mist test chamber. The oil mist chamber is to be fitted with a recirculating fan.

   d. Samples of oil mist are to be taken at regular intervals and the results plotted against the oil mist detector output. The oil mist detector is to be located adjacent to where the oil mist samples are drawn off.

   e. The results of a gravimetric analysis are considered invalid and are to berejected if the resultant calibration curve has an increasing gradient with respect tothe oil mist detection reading. This situation occurs when insufficient time hasbeen allowed for the oil mist to become homogeneous. Single results that aremore than 10% below the calibration curve are to be rejected. This situation occurs when the integrity of the filter unit has been compromised and not all ofthe oil is collected on the filter paper.

   f. The filters require to be weighed to a precision of 0.1 mg and the volume of air/oil mist sampled to 10 ml.

ii. The testing is to be witnessed by the Surveyor.

iii. Oil mist detection equipment is to be tested in the orientation (vertical, horizontal or inclined) in which it is intended to be installed on an engine or gear case as specified by the equipment manufacturer.

iv. Type testing is to be carried out for each type of oil mist detection and alarm equipment for which a manufacturer seeks approval. Where sensitivity levels can be adjusted, testing is to be carried out at the extreme and mid-point level settings.

17 Assessment

Assessment of oil mist detection equipment after testing is to address the following:

i. The equipment to be tested is to have been design approved.

ii. Details of the detection equipment to be tested are to be recorded, such as name of manufacturer, type designation, oil mist concentration assessment capability and alarm settings, and the maximum percentage level of lens obscuration used in .

iii. After completing the tests, the detection equipment is to be examined and the condition of all components is to be ascertained and documented. Photographic records of the monitoring devices condition are to be taken and included in the report.

19 Design Series Qualification

The approval of one type of detection equipment may be used to qualify other devices having identical construction details. Proposals are to be submitted for consideration.

21 Reporting

The test facility is to provide a full report which includes the following information and documents:

i. Test specification.
ii. Details of equipment tested.
iii. Results of tests, to include a declaration by the manufacturer of the oil mist detector of the following:

    - Performance, in mg/L
    - Accuracy, of oil mist concentration in air
    - Precision, of oil mist concentration in air
    - Range, of oil mist detector
    - Resolution, of oil mist detector
    - Response time, of oil mist detector
    - Sensitivity, of oil mist detector
    - Obscuration of sensor detection, declared as percentage of obscuration. 0% totally clean, 100% totally obscure
    - Detector failure alarm

23 Acceptance

Acceptance of crankcase oil mist detection equipment will be based on design approved plans and particulars and on the test facility's report of the results of the type testing.

The following information is to be submitted for acceptance of oil mist detection equipment and alarm arrangements:

i. Description of oil mist detection equipment and system including alarms.
ii. Copy of the test facility's report identified in .
iii. Schematic layout of engine oil mist detection arrangements showing location of detectors/ sensors and piping arrangements and dimensions.
iv. Maintenance and test manual which is to include the following information:

    - Intended use of equipment and its operation.
    - Functionality tests to demonstrate that the equipment is operational and that any faults can be identified and corrective actions notified.
    - Maintenance routines and spare parts recommendations.
    - Limit setting and instructions for safe limit levels.
    - Where necessary, details of configurations in which the equipment is intended to be used and in which it is not to be used.

Appendix 4 Crankshaft strength calculations

1 Calculation of Alternating Stresses Due to Bending Moments and Radial Forces

1.1 Assumptions

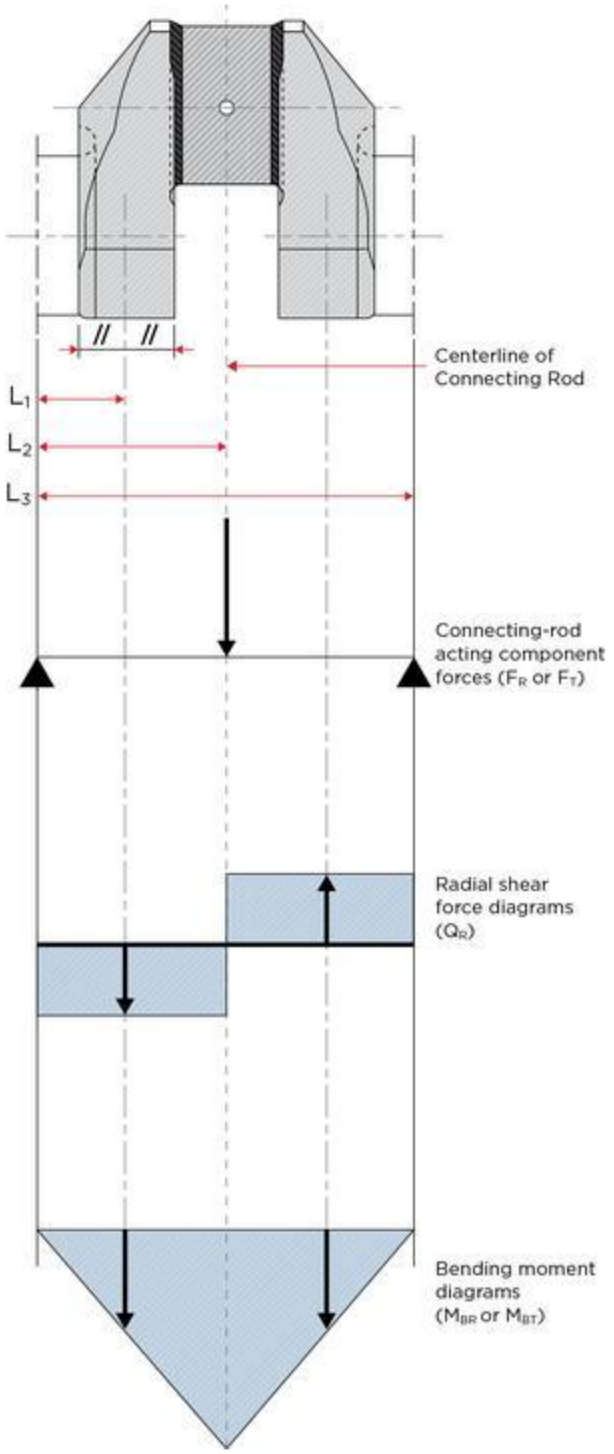
The calculations are based on a quasi-static model where the steady alternating loads are combined in a statically determined system. The statically determined system is composed of a single crank throw supported in the center of adjacent main journals and subject to gas and inertia forces. The bending length is taken as the length between the two main bearing midpoints (distance L_3, as per 4-2-1-A4/1.1.i FIGURE 1 and 4-2-1-A4/1.1.i FIGURE 2).

The bending moments M_{BR} and M_{BT} are calculated in the relevant section based on triangular bending moment diagrams due to the radial component F_R and tangential component F_T of the connecting-rod force, respectively (see 4-2-1-A4/1.1.i FIGURE 1).

For crank throws with two connecting-rods acting upon one crankpin the relevant bending moments are obtained by superposition of the two triangular bending moment diagrams according to phase (see 4-2-1-A4/1.1.i FIGURE 2).

i. *Bending moments and radial forces acting in web*. The bending moment M_{BRF} and the radial force Q_{RF} are taken as acting in the center of the solid web (distance L_1) and are derived from the radial component of the connecting-rod force.
The alternating bending and compressive stresses due to bending moments and radial forces are to be related to the cross-section of the crank web. This reference section results from the web thickness W and the web width B (see). Mean stresses are neglected.

FIGURE 1
Crank Throw for In Line Engine

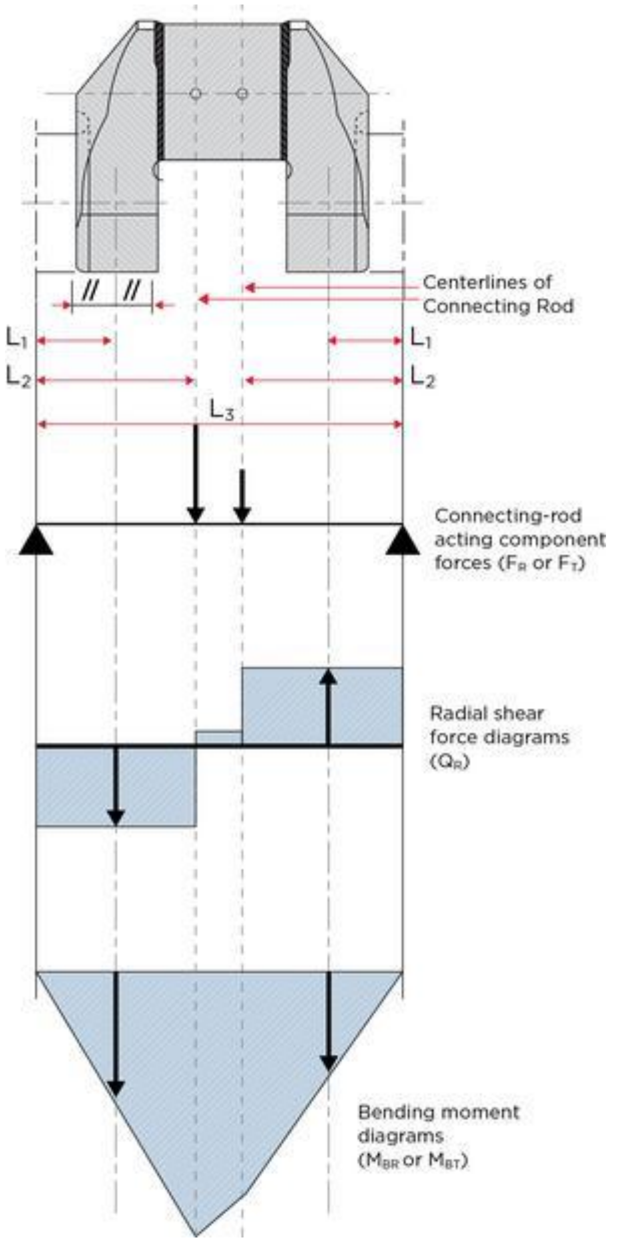


L_1 = Distance between main journal centerline and crank web center (see also for crankshaft without overlap)

L_2 = Distance between main journal centerline and connecting-rod center

L_3 = Distance between two adjacent main journal centerlines

FIGURE 2
Crank Throw for Vee Engine with 2 Adjacent Connection-Rods

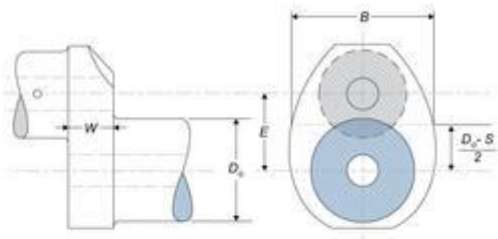


L_1 = Distance between main journal centerline and crank web center (see also for crankshaft without overlap)

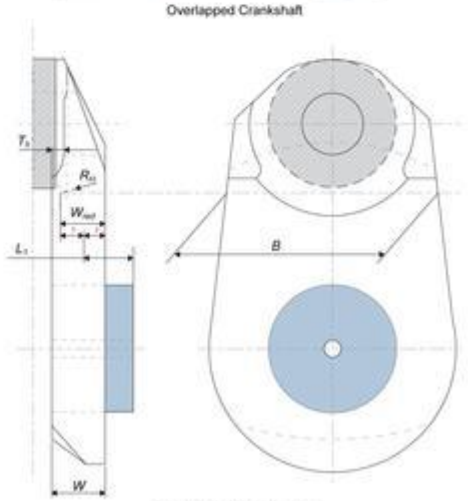
L_2 = Distance between main journal centerline and connecting-rod center

L_3 = Distance between two adjacent main journal centerlines

FIGURE 3
Reference Area of Crank Web Cross Section



Overlapped Crankshaft



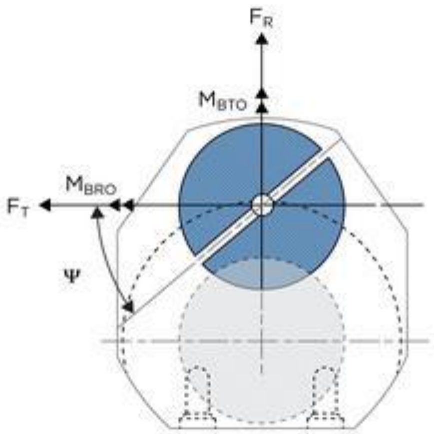
Crankshaft without Overlap

ii. *Bending acting in outlet of crankpin oil bore*. The two relevant bending moments are taken in the crankpin cross-section through the oil bore.

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

Mean bending stresses are neglected.

FIGURE 4
Crankpin Section Through the Oil Bore



M_{BTO}	is the bending moment of the radial component of the connecting-rod force
M_{BRO}	is the bending moment of the tangential component of the connecting-rod force

1.3 Calculation of nominal alternating bending and compressive stresses in web **(2024)**

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

Using the forces calculated over one working cycle and taking into account the distance from the main bearing midpoint, the time curve of the bending moments M_{BRF}, M_{BRO}, and M_{BTO} radial forces Q_{RF}, as defined in 4-2-1-A4/1.1.i and 4-2-1-A4/1.1.iiand 4-2-1-A4/1.1 FIGURE 4 will then be calculated.

In case of V-type engines, the bending moments – progressively calculated from the gas and inertia forces – of the two cylinders acting on one crank throw are superposed according to phase. Different designs (forked connecting-rod, articulated-type connecting-rod or adjacent connecting-rods) are to be taken into account.

Where there are cranks of different geometrical configurations in one crankshaft, the calculation is to cover all crank variants.

The decisive alternating values will then be calculated according to:

$$X_N = \frac{1}{2}\left[X_{\max} - X_{\min}\right]$$

where

X_N	=	considered as alternating force, moment or stress
$X_{\max}$	=	maximum value within one working cycle
$X_{\min}$	=	minimum value within one working cycle

i. *Nominal alternating bending and compressive stresses in web cross section*. The calculation of the nominal alternating bending and compressive stresses is as follows:

$$\sigma_{BFN} = \frac{M_{BRFN}}{W_{eqw}} 10^3 K_e$$

$$\sigma_{QFN} = \frac{Q_{RFN}}{F} K_e$$

where

σ_{BFN}	=	nominal alternating bending stress related to the web, in N/mm^2
M_{BRFN}	=	alternating bending moment related to the center of the web, in N-m (see and)
	=	$\frac{1}{2}\left[M_{BFN\max} - M_{BFN\min}\right]$
W_{eqw}	=	section modulus related to cross-section of web, in mm^3
	=	$\frac{B \cdot W^2}{6}$
K_e	=	empirical factor considering to some extent the influence of adjacent crank and bearing restraint
	=	0.8 for 2-stroke engines
	=	1.0 for 4-stroke engines
σ_{QFN}	=	nominal alternating compressive stress due to radial force related to the web, in N/mm^2
Q_{RFN}	=	alternating radial force related to the web, in N (see and)

$= \quad \frac{1}{2}\left[Q_{RF\max} - Q_{RF\min}\right]$

F = area related to cross-section of web, in mm^2

$= \quad B \cdot W$

ii. *Nominal alternating bending stress in outlet of crankpin oil bore.* The calculation of nominal alternating bending stress is as follows:

$$\sigma_{BON} = \frac{M_{BON}}{W_e} 10^3$$

where

σ_{BON} = nominal alternating bending stress related to the crank pin diameter, in N/mm^2

M_{BON} = alternating bending moment calculated at the outlet of crankpin oil bore, in N-m

$= \quad \frac{1}{2}\left[M_{BO\max} - M_{BO\min}\right]$

M_{BO} = $(M_{BTO} \cdot \cos\psi + M_{BRO} \cdot \sin\psi)$

ψ = angular position, in degrees (see)

W_e = section modulus related to cross-section of axially bored crankpin, in mm^3

$= \quad \frac{\pi}{32}\left[\frac{D^4 - D_{BH}^4}{D}\right]$

1.5 Calculation of alternating bending stresses in fillets

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

- For the crankpin fillet :

$$\sigma_{BH} = (\alpha_B \sigma_{BFN})$$

where

σ_{BH} = alternating bending stress in crankpin fillet, in N/mm^2

α_B = stress concentration factor for bending in crankpin fillet (see)

- For the journal fillet (not applicable to semi-built crankshaft):

$$\sigma_{BG} = (\beta_B \sigma_{BFN} + \beta_Q \sigma_{QFN})$$

where

σ_{BG} = alternating bending stress in journal fillet, in N/mm^2

β_B = stress concentration factor for bending in journal fillet (see)

β_Q = stress concentration factor for compression due to radial force in journal fillet (determination as per)

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

$$\sigma_{BO} = (\gamma_B \sigma_{BON})$$

where

σ_{BO} = alternating bending stress in outlet of crankpin oil bore, in N/mm^2

γ_B = stress concentration factor for bending in crankpin oil bore (determination as per 4-2-1-A4/5)

3 Calculation of Alternating Torsional Stresses

3.1 General

The alternating torsional stresses that are to be used in determining the equivalent alternating stress in the crankshaft are to be provided by the engine manufacturer, and substantiated either by calculations, or by crankshaft fatigue testing.

Where applicable, the calculation for nominal alternating torsional stresses is to be undertaken by the engine manufacturer according to the information contained in 4-2-1-A4/3.3. In either case supporting documentation is to be submitted for review.

3.3 Calculation of nominal alternating torsional stresses

The maximum and minimum torques are to be ascertained for every mass point of the complete dynamic system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1st order up to and including the 15th order for 2-stroke cycle engines and from the 0.5th order up to and including the 12th order for 4-stroke cycle engines. Allowance is to be made for the damping that exists in the system and for unfavorable conditions (misfiring [*] in one of the cylinders). The speed step calculation is to be selected in such a way that any resonance found in the operational speed range of the engine is to be detected.

Note:

* Misfiring is defined as cylinder condition when no combustion occurs but only a compression cycle.

Where barred speed ranges are necessary, they are to be arranged so that satisfactory operation is possible despite their existence. There are to be no barred speed ranges above a speed ratio of λ ≥ 0.8 for normal firing conditions.

The values received from such calculation are to be submitted for review.

The nominal alternating torsional stress in every mass point, which is essential to the assessment, results from the following equation:

$$\tau_N = \frac{M_{TN}}{W_P} 10^3$$

$$M_{TN} = \frac{1}{2}\left[M_{T\max} - M_{T\min}\right]$$

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

where

τ_N = nominal alternating torsional stress referred to crankpin or journal, in N/mm^2

M_{TN} = maximum alternating torque, in N-m

W_P = polar section modulus related to cross-section of axially bored crankpin or bored journal, in mm^3

$M_{T\max}$ = maximum value of the torque, in N-m

$M_{T\min}$ = minimum value of the torque, in N-m

For the purpose of the crankshaft assessment, the nominal alternating torsional stress considered in further calculations is the highest calculated value, according to the above method, occurring at the most torsionally loaded mass point of the crankshaft system.

Where barred speed ranges exist, the torsional stresses within these ranges are not to be considered for assessment calculations.

Approval of the crankshaft will be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum figure specified by the engine manufacturer).

Thus, for each installation, it is to be ensured by suitable calculation that this approved nominal alternating torsional stress is not exceeded. This calculation is to be submitted for review.

3.5 Calculation of alternating torsional stresses in fillets and outlet of crankpin oil bore

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

- For the crankpin fillet:

$$\tau_H = (\alpha_T \tau_N)$$

where

τ_H = alternating torsional stress in crankpin fillet, in N/mm^2

α_T = stress concentration factor for torsion in crankpin fillet (determination as per)

τ_N = nominal alternating torsional stress related to crankpin diameter, in N/mm^2

- For the journal fillet (not applicable to semi-built crankshafts)

$$\tau_G = (\beta_T \tau_N)$$

where

τ_G = alternating torsional stress in journal fillet, in N/mm^2

β_T = stress concentration factor for torsion in journal fillet (determination as per)

τ_N = nominal alternating torsional stress related to journal diameter, in N/mm^2

- For the outlet of crankpin oil bore

$$\tau_{TO} = (\gamma_T \tau_N)$$

where

τ_{TO} = alternating stress in outlet of crankpin oil bore due to torsion, in N/mm^2

γ_T = stress concentration factor for torsion in outlet of crankpin oil bore (determination as per)

τ_N = nominal alternating torsional stress related to crankpin diameter, in N/mm^2

5 Evaluation of Stress Concentration Factors

5.1 General (1 July 2018)

The stress concentration factors are evaluated by means of the equations in 4-2-1-A4/5.3, 4-2-1-A4/5.5 and 4-2-1-A4/5.7 applicable to the fillets and crankpin oil bore of solid forged web-type crankshafts and to the crankpin fillets of semi-built crankshafts only. The stress concentration factor equations concerning the oil bore are only applicable to a radially drilled oil hole. Where the geometry of the crankshaft is outside the boundaries of the analytical stress concentration factors (SCF) the calculation method detailed in 4-2-1-A7 may be undertaken. All crank dimensions necessary for the calculation of stress concentration factors are shown in 4-2-1-A4/5.1 FIGURE 5.

The stress concentration factors for bending (α_B, β_B) are defined as the ratio of the maximum equivalent stress (Von Mises) – occurring in the fillets under bending load – to the nominal bending stress related to the web cross-section (see 4-2-1-A5).

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

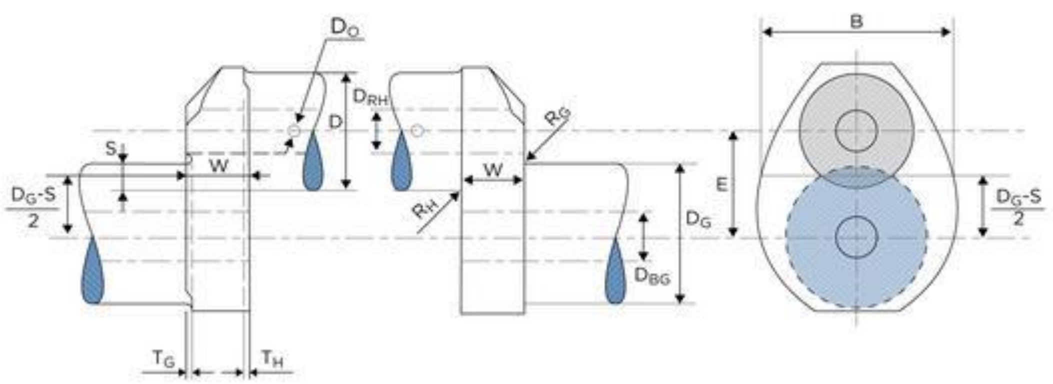
The stress concentration factors for torsion (α_T, β_T) are defined as the ratio of the maximum equivalent shear stress, occurring in the fillets under torsional load, to the nominal torsional stress related to the axially bored crankpin or journal cross-section (see 4-2-1-A5).

The stress concentration factors for bending (γ_B) and torsion (γ_T) are defined as the ratio of the maximum principal stress, occurring at the outlet of the crankpin oil-hole under bending and torsional loads, to the corresponding nominal stress related to the axially bored crankpin cross section (see 4-2-1-A6).

When reliable measurements and/or calculations are available, which can allow direct assessment of stress concentration factors, the relevant documents and their analysis method is to be submitted in order to demonstrate their equivalence with the Rules. This is always to be performed when dimensions are outside of any of the validity ranges for the empirical formulae presented in 4-2-1-A4/5.3, 4-2-1-A4/5.5 and 4-2-1-A4/5.7.

4-2-1-A7 and 4-2-1-A10 describe how FE analyses can be used for the calculation of the stress concentration factors. Avoid mixing equivalent (Von Mises) stresses and principal stresses.

FIGURE 5
Crank Dimensions



- Actual dimensions:

D = crankpin diameter, in mm

D_{BH} = diameter of axial bore in crankpin, in mm

D_O = diameter of oil bore in crankpin, in mm

R_H = fillet radius of crankpin, in mm

T_H = recess of crankpin fillet, in mm

D_G = journal diameter, in mm

D_{BG} = diameter of axial bore in journal, in mm

R_G = fillet radius of journal, in mm

T_G = recess of journal fillet, in mm

E = pin eccentricity, in mm

S = pin overlap, in mm

= $\frac{D + D_G}{2} - E$

W^* = web thickness, in mm

B^* = web width, in mm

* *Note:* In the case of 2 stroke semi-built crankshafts:

- When $T_H > R_H$, the web thickness is to be considered as equal to:

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

- Web width B is to be taken in way of crankpin fillet radius center according to

The following related dimensions will be applied for the calculation of stress concentration factors:

Crankpin fillet	*Journal fillet*
$r = R_H/D$	$r = R_G/D$

s = S/D

w = W/D crankshafts with overlap

= W_{red}/D crankshafts without overlap

b = B/D

d_o = D_O/D

d_G = D_{BG}/D

d_H = D_{BH}/D

t_H = T_H/D

t_G = T_G/D

Stress concentration factors are valid for the ranges of related dimensions for which the investigations have been carried out. Ranges are as follows:

$$s \leq 0.5$$

$$0.2 \leq w \leq 0.8$$

$$1.1 \leq b \leq 2.2$$

$$0.03 \leq r \leq 0.13$$

$$0 \leq d_G \leq 0.8$$

$$0 \leq d_H \leq 0.8$$

$$0 \leq d_o \leq 0.2$$

Low range of *s* can be extended down to large negative values provided that:

- If calculated $f(recess) < 1$ then the factor $f(recess)$ is not to be considered $(f(recess) = 1)$
- If $s < -0.5$ then $f(s, w)$, $f(r, s)$ and $f_B(s, w)$ are to be evaluated replacing actual value of s by -0.5.

5.3 Crankpin fillet

- The stress concentration factor for bending (α_B) is:

$$\alpha_B = 2.6914 \cdot f(s, w) \cdot f(w) \cdot f(b) \cdot f(r) \cdot f(d_G) \cdot f(d_H) \cdot f(recess)$$

where

$f(s, w)$ = $-4.1883 + 29.2004 \cdot w - 77.5925 \cdot w^2 + 91.9454 \cdot w^3 - 40.0416 \cdot w^4 + (1-s) \cdot (9.5440 - 58.3480 \cdot w + 159.3415 \cdot w^2 - 192.5846 \cdot w^3 + 85.2916 \cdot w^4) + (1-s)^2 \cdot (-3.8399 + 25.0444 \cdot w - 70.5571 \cdot w^2 + 87.0328 \cdot w^3 - 39.1832 \cdot w^4$

$f(w)$ = $2.1790 \cdot w^{0.7171}$

$f(b)$ = $0.6840 - 0.0077 \cdot b + 0.1473 \cdot b^2$

$f(r)$ = $0.2081 \cdot r^{(-0.5231)}$

$f(d_G)$ = $0.9993 + 0.27 \cdot d_G - 1.0211 \cdot d_G^2 + 0.5306 \cdot d_G^3$

$f(d_H)$ = $0.9978 + 0.3145 \cdot d_H - 1.5241 \cdot d_H^2 + 2.4147 \cdot d_H^3$

$f(recess)$ = $1 + (t_H + t_G) \cdot (1.8 + 3.2 \cdot s)$

- The stress concentration factor for torsion (α_T) is:

$$\alpha_T = 0.8 \cdot f(r, s) \cdot f(b) \cdot f(w)$$

where

$f(r,s)$ = $r^{[-0.322+0.1015\cdot(1-s)]}$

$f(b)$ = $7.8955-10.654\cdot b+5.3482\cdot b^2-0.857\cdot b^3$

$f(w)$ = $w^{(-0.145)}$

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

- The stress concentration factor for bending (β_B) is:

$$\beta_B = 2.7146\cdot f_B(s,w)\cdot f_B(w)\cdot f_B(b)\cdot f_B(r)\cdot f_B(d_G)\cdot f_B(d_H)\cdot f(recess)$$

where

$f_B(s,w)$ = $-1.7625+2.9821\cdot w-1.5276\cdot w^2+(1-s)\cdot(5.1169-5.8089\cdot w+3.1391\cdot w^2)+(1-s)^2\cdot(-2.1567+2.3297\cdot w-1.2952\cdot w^2)$

$f_B(w)$ = $2.2422\cdot w^{0.7548}$

$f_B(b)$ = $0.5616+0.1197\cdot b+0.1176\cdot b^2$

$f_B(r)$ = $0.1908\cdot r^{(-0.5568)}$

$f_B(d_G)$ = $1.0012-0.6441\cdot d_G+1.2265\cdot d_G^2$

$f_B(d_H)$ = $1.0022-0.1903\cdot d_H+0.0073\cdot d_H^2$

$f(recess)$ = $1+(t_H+t_G)\cdot(1.8+3.2\cdot s)$

- The stress concentration factor for compression (β_Q) due to the radial force is:

$$\beta_Q = 3.0128\cdot f_Q(s)\cdot f_Q(w)\cdot f_Q(b)\cdot f_Q(r)\cdot f_Q(d_H)\cdot f(recess)$$

where

$f_Q(s)$ = $0.4368+2.1630\cdot(1-s)-1.5212\cdot(1-s)^2$

$f_Q(w)$ = $\dfrac{w}{0.0637+0.9369\cdot w}$

$f_Q(b)$ = $-0.5+b$

$f_Q(r)$ = $0.5331\cdot r^{(-0.2038)}$

$f_Q(d_H)$ = $0.9937-1.1949\cdot d_H+1.7373\cdot d_H^2$

$f(recess)$ = $1+(t_H+t_G)\cdot(1.8+3.2\cdot s)$

- The stress concentration factor for torsion (β_T) is:

$$\beta_T = \alpha_T$$ if the diameters and fillet radii of crankpin and journal are the same

$$\beta_T = 0.8 \cdot f(r,s) \cdot f(b) \cdot f(w)$$ if crankpin and journal diameters and/or radii are of different sizes

where $f(r,s)$, $f(b)$ and $f(w)$ are to be determined in accordance with (see calculation of α_T), however, the radius of the journal fillet is to be related to the journal diameter :

$$r = \frac{R_G}{D_G}$$

5.7 Outlet of crankpin oil bore

- The stress concentration factor for bending (γ_B) is:

$$\gamma_B = 3–5.88 \cdot d_o + 34.6 \cdot d_o^2$$

- The stress concentration factor for torsion (γ_T) is:

$$\gamma_T = 4–6 \cdot d_o + 30 \cdot d_o^2$$

7 Additional Bending Stresses (2024)

In addition to the alternating bending stresses in fillets (see 4-2-1-A4/1.5 further bending stresses due to misalignment and bedplate deformation as well as due to axial and bending vibrations are to be considered by applying σ_{add} as given by the table below:

Type of engine	σ_{add} [N/mm^2]
Crosshead engines	30 (*)
Trunk piston engines	10

Notes:

* The additional alternating stress of 30 N/mm^2 is composed of two components

1 An additional alternating stress of 20 N/mm^2 resulting from axial vibration

2 An additional alternating stress of 10 N/mm^2 resulting from misalignment/bedplate deformation

A value of at least 20 N/mm^2 is to be used for the axial vibration component for assessment purposes where axial vibration calculation results of the complete dynamic system (engine/shafting/gearing/propeller) are not available. Where axial vibration calculation results of the complete dynamic system are available, the calculated figures may be used instead.

9 Calculation of Equivalent Alternating Stress

9.1 General

In the fillets, bending and torsion lead to two different biaxial stress fields which can be represented by a Von Mises equivalent stress with the additional assumptions that bending and torsion stresses are not time phased and the corresponding peak values occur at the same location (see 4-2-1-A5).

As a result, the equivalent alternating stress is to be calculated for the crankpin fillet as well as for the journal fillet by using the Von Mises criterion.

At the oil hole outlet, bending and torsion lead to two different stress fields which can be represented by an equivalent principal stress equal to the maximum of the principal stress resulting from combination of these two stress fields with the assumption that bending and torsion are time phased (see 4-2-1-A6).

The above two different ways of equivalent stress evaluation both lead to stresses which may be compared to the same fatigue strength value of crankshaft assessed according to Von Mises criterion.

9.2 Equivalent alternating stress

The equivalent alternating stress is calculated in accordance with the following equations.

- Related to the crankpin diameter:

$$\sigma_v = \pm\sqrt{(\sigma_{BH} + \sigma_{add})^2 + 3 \cdot \tau_H^2}$$

- For the journal fillet:

$$\sigma_v = \pm\sqrt{(\sigma_{BG} + \sigma_{add})^2 + 3 \cdot \tau_G^2}$$

- For the outlet of crankpin oil bore:

$$\sigma_v = \pm\frac{1}{3}\sigma_{BO} \cdot \left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\tau_O}{\sigma_{BO}}\right)^2}\right]$$

where

σ_v = equivalent alternating stress, in N/mm^2, for other parameters referred to in , and .

11 Calculation of Fatigue Strength (2024)

The fatigue strength is to be understood as that value of equivalent alternating stress (Von Mises) which a crankshaft can permanently withstand at the most highly stressed points. The fatigue strength may be evaluated by means of the following equations.

- Related to the crankpin diameter:

$$\sigma_{DW} = \pm K \cdot (0.42 \cdot \sigma_B + 39.3) \cdot \left[0.264 + 1.073 \cdot D^{-0.2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{R_X}}\right]$$

where

R_X = R_H in the fillet area

= $D_O/2$ in the oil bore area

- Related to the journal diameter:

$$\sigma_{DW} = \pm K \cdot (0.42 \cdot \sigma_B + 39.3) \cdot \left[0.264 + 1.073 \cdot D_G^{-0.2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{R_G}}\right]$$

where

σ_{DW}	=	allowable fatigue strength of crankshaft, in N/mm^2	
K	=	factor for different types of crankshafts without surface treatment. Values greater than 1 are only applicable to fatigue strength in fillet area.	
	=	1.05	for continuous grain flow forged or drop-forged crankshafts
	=	1.0	for free form forged crankshafts (without continuous grain flow) factor for cast steel crankshafts with cold rolling treatment in fillet area
	=	0.93	for cast steel crankshafts manufactured by companies using a cold rolling process approved by ABS
σ_B	=	minimum tensile strength of crankshaft material, in N/mm^2	

For other parameters refer to 4-2-1-A4/5.5.

When a surface treatment process is applied, it is subject to ABS technical assessment and approval. Guidance for calculation of surface treated fillets and oil bore outlets is presented in 4-2-1-A9.

These equations are subject to the following conditions:

- Surfaces of the fillet, the outlet of the oil bore and inside the oil bore (down to a minimum depth equal to 1.5 times the oil bore diameter) are to be smoothly finished.
- For calculation purposes R_H , R_G or R_X are to be taken as not less than 2 mm.

As an alternative, the fatigue strength of the crankshaft can be determined by experiment based either on full size crank throw (or crankshaft) or on specimens taken from a full size crank throw. For evaluation of test results, see 4-2-1-A8.

13 Acceptability Criteria

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

$$Q = \frac{\sigma_{DW}}{\sigma_v}$$

where

Q	=	acceptability factor

Adequate dimensioning of the crankshaft is ensured if the smallest of all acceptability factors satisfies the criteria:

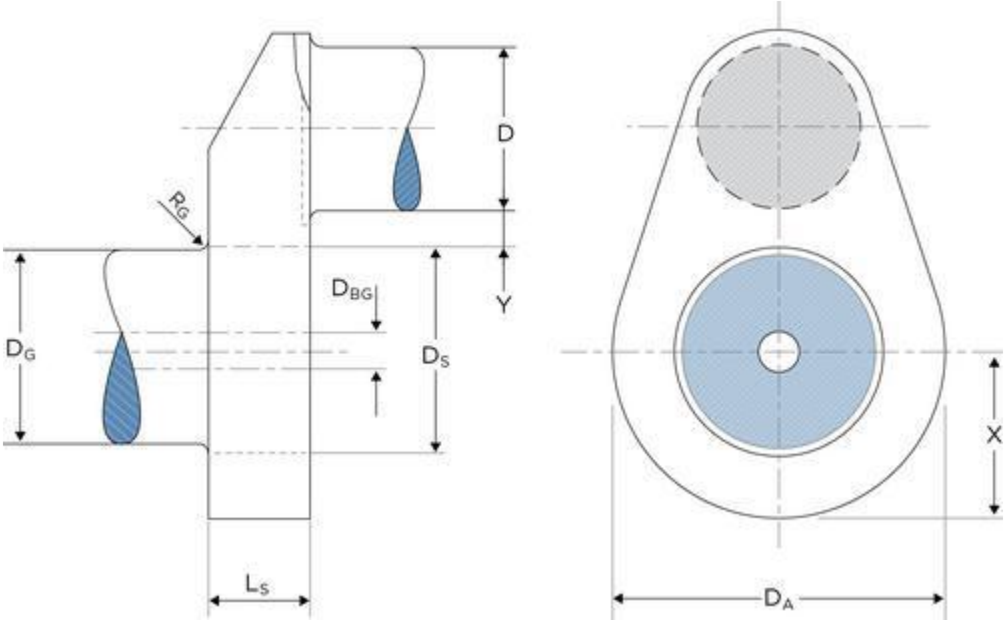
$$Q \geq 1.15$$

15 Calculation of Shrink-fits of Semi-built Crankshaft

15.1 General (2024)

All crank dimensions necessary for the calculation of the shrink-fit are shown in 4-2-1-A4/15.1 FIGURE 6.

FIGURE 6
Crank Throw of Semi-built Crankshaft



where

D_A = outside diameter of web, in mm, or twice the minimum distance *x* between center-line of journals and outer contour of web, whichever is less

D_S = shrink diameter, in mm

D_G = journal diameter, in mm

D_{BG} = diameter of axial bore in journal, in mm

L_S = length of shrink-fit, in mm

R_G = fillet radius of journal, in mm

Y = distance between the adjacent generating lines of journal and pin, in mm, $y \geq 0.05 \cdot D_S$

where Y is less than $0.1 \cdot D_S$, effect of the stress due to the shrink-fit on the fatigue strength at the crankpin fillet is subject to ABS technical assessment and approval.

With regard to the radius of the transition from the journal to the shrink diameter, the following is to be complied with:

$$R_G \geq 0.015 \cdot D_G$$

and

$$R_G \geq 0.5 \cdot (D_S – D_G)$$

where the greater value is to be considered.

The actual oversize Z of the shrink-fit is to be within the limits $Z_{\min}$ and Z_{max} calculated in accordance with 4-2-1-A4/15.5 and 4-2-1-A4/15.7.

If the condition in 4-2-1-A4/15.3 cannot be fulfilled, the calculation methods of $Z_{\min}$ and $Z_{\max}$ in 4-2-1-A4/15.5 and 4-2-1-A4/15.7 are not applicable due to multi-zone-plasticity problems.

In such case, $Z_{\min}$ and $Z_{\max}$ have to be established based on FEM calculations.

15.3 Maximum permissible hole in the journal pin

The maximum permissible hole diameter in the journal pin is calculated in accordance with the following equation:

$$D_{BG} = D_S \cdot \sqrt{1 - \frac{4000 \cdot S_R \cdot M_{\max}}{\mu \cdot \pi \cdot D_S^2 \cdot L_S \cdot \sigma_{SP}}}$$

where

S_R	=	safety factor against slipping, however a value not less than 2 is to be taken unless documented by experiments.
$M_{\max}$	=	absolute value of the maximum torque $M_{T\max}$, N-m, in accordance with 4-2-1-A4/3.3
μ	=	coefficient for static friction, however a value not greater than 0.2 is to be taken unless documented by experiments.
σ_{SP}	=	minimum yield strength of material for journal pin, in N/mm^2

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

15.5 Necessary minimum oversize of shrink-fit

Necessary minimum oversize of shrink-fit. The necessary minimum oversize is determined by the greater value calculated according to:

$$Z_{\min} \geq \frac{\sigma_{SW} \cdot D_S}{E_m}$$

and

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

where

$Z_{\min}$	=	minimum oversize, in mm
E_m	=	Young's modulus, in N/mm^2
σ_{SW}	=	minimum yield strength of material for crank web, in N/mm^2
Q_A	=	$\text{webratio}, Q_A = \frac{D_S}{D_A}$
Q_S	=	$\text{shaftratio}, Q_S = \frac{D_{BG}}{D_S}$

15.7 Maximum permissible oversize of shrink-fit

Maximum permissible oversize of shrink-fit. The maximum permissible oversize is calculated according to:

$$Z_{\max} \leq D_S \cdot \left(\frac{\sigma_{SW}}{E_m} + \frac{0.8}{1000} \right)$$

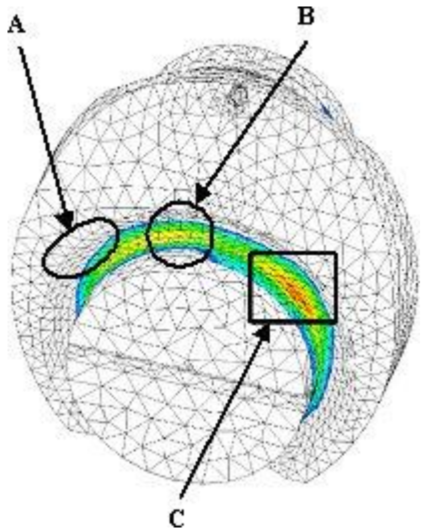
This condition serves to restrict the shrinkage induced mean stress in the fillet.

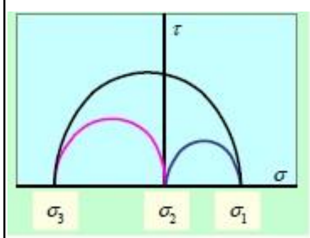
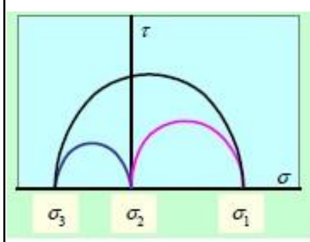
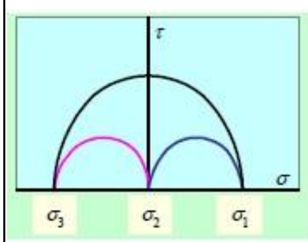
17 Other Reciprocating Components

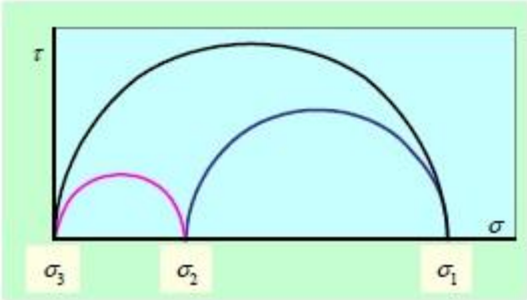
All other reciprocating components (e.g., connecting rod) are to have acceptability factors of at least 1.15. Tightening torques are to be submitted for pretensioned bolts/studs.

Appendix 5 Definition of Stress Concentration Factors in Crankshaft Fillets

Definition of Stress Concentration Factors in Crankshaft Fillets (2020)

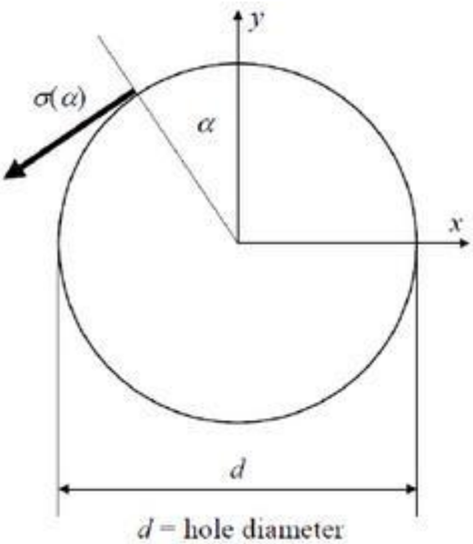


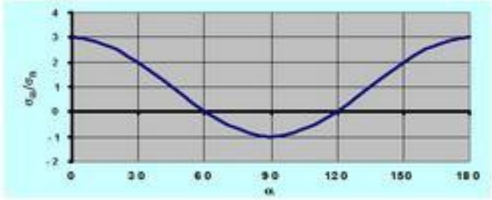
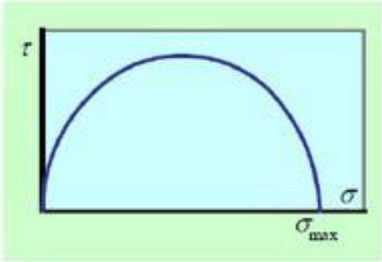
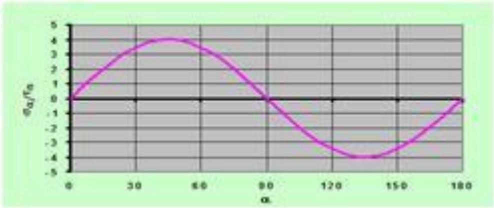
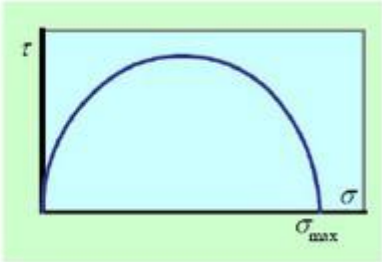
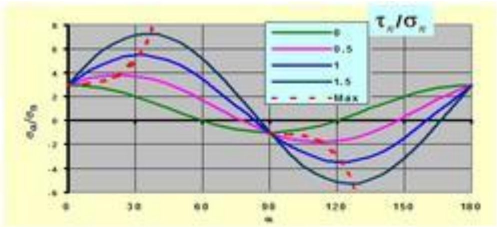
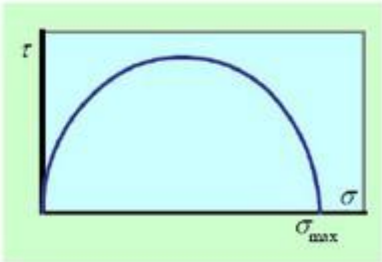
	Stress	Max $\|\sigma_3\|$	Max σ_1	
Torsional loading	Location of maximal stresses	**A**	**C**	**B**
	Typical principal stress system Mohr's circle diagram with σ_2= 0	 $\| \sigma_3 \| > \sigma_1$	 $\sigma_1 > \| \sigma_3 \|$	 $\sigma_1 \approx \| \sigma_3 \|$

	Equivalent stress and **S.C.F.**	$$\tau_{equiv} = \frac{\sigma_1 - \sigma_3}{2}$$ $$\mathbf{S.C.F.} = \frac{\tau_{equiv}}{\tau_n}\ \text{for}\, \alpha_T, \beta_T$$		
Bending loading	Location of maximal stresses	**B**	**B**	**B**
	Typical principal stress system Mohr's circle diagram with σ_3= 0	 $\sigma_2 \neq 0$		
	Equivalent stress and **S.C.F.**	$$\sigma_{equiv} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1.\sigma_2}$$ $$\mathbf{S.C.F.} = \frac{\sigma_{equiv}}{\sigma_n}\ \text{for}\, \alpha_B, \beta_B, \beta_Q$$		

Appendix 6 Stress Concentration Factors and Stress Distribution at the Edge of Oil Drillings

Stress Concentration Factors and Stress Distribution at the Edge of Oil Drillings (2020)



Stress type	Nominal stress tensor	Uniaxial stress distribution around the edge	Mohr's Circle diagram
Tension	$\begin{bmatrix} \sigma_n & 0 \\ 0 & 0 \end{bmatrix}$	$\sigma_\alpha = \sigma_n \gamma_B / 3 \left[1 + 2\cos(2\alpha)\right]$ 	 $\gamma_B = \sigma_{max}/\sigma_n \text{for} \alpha = k\pi$
Shear	$\begin{bmatrix} 0 & \tau_n \\ \tau_n & 0 \end{bmatrix}$	$\sigma_\alpha = \gamma_T \tau_n \sin(2\alpha)$ 	 $\gamma_T = \sigma_{max}/\tau_n \text{for} \alpha = \frac{\pi}{4} + k\frac{\pi}{2}$
Tension + Shear	$\begin{bmatrix} \sigma_n & \tau_n \\ \tau_n & 0 \end{bmatrix}$	$\sigma_\alpha = \frac{\gamma_B}{3} \sigma_n \left\{1 + 2\left[\cos(2\alpha) + \frac{3}{2}\frac{\gamma_T}{\gamma_B}\frac{\tau_n}{\sigma_n}\sin(2\alpha)\right]\right\}$ 	 $\sigma_{max} = \frac{\gamma_B}{3}\sigma_n \left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\gamma_T}{\gamma_B}\frac{\tau_n}{\sigma_n}\right)^2}\right]$ $\text{for} \alpha = \frac{1}{2} tg^{-1}\left(\frac{3\gamma_T\tau_n}{2\gamma_B\sigma_n}\right)$

Appendix 7 Alternative Method for Calculation of Stress Concentration Factors in the Web Fillet Radii of Crankshafts by Utilizing Finite Element Method

1 General

The objective of the analysis is to develop Stress Concentration Factors (SCF) by applying the Finite Element Method (FEM) as an alternative to the analytically calculated SCF's at the crankshaft fillets in 4-2-1-A4/5. The analytical method is based on empirical formulae developed from strain gauge measurements of various crank geometries and accordingly the application of these formulae is limited to those geometries.

The SCF's calculated in accordance with this Appendix are defined as the ratio of stresses calculated by FEM to nominal stresses in both journal and pin fillets. When used in connection with the analytical method in 4-2-1-A4/5 or this alternative method, von Mises stresses is to be calculated for bending and principal stresses for torsion.

The procedure as well as evaluation guidelines are valid for both solid cranks and semi-built cranks (with the exception of the journal fillets).

The analysis is to be conducted as a linear elastic FE analysis, and unit loads are to be applied for all load cases.

The calculation of SCF at the oil bores is not addressed by this Appendix.

The element accuracy of the FE solver used is to be checked (e.g. by modeling a simple geometry and comparing the stresses obtained by FEM with the analytical solution for pure bending and torsion).

The Boundary Element Method (BEM) may be used instead of FEM.

3 Model Requirements

The basic recommendations and perceptions for building the FE-model are presented in 4-2-1-A7/3.1. It is obligatory for the final FE-model to fulfill the requirement in 4-2-1-A7/3.5.

3.1 Element Mesh Recommendations

To fulfill the mesh quality criteria for the evaluation of SCF's, it is recommended to construct the FE model as follows:

i. The model consists of one complete crank, from the main bearing centerline to the opposite side main bearing centerline.

ii. Element types used in the vicinity of the fillets:

- 10 node tetrahedral elements
- 8 node hexahedral elements
- 20 node hexahedral elements

iii. Mesh properties in fillet radii. The following applies to ±90 degrees in circumferential direction from the crank plane:

iv. Maximum element size a = $r/4$ through the entire fillet as well as in the circumferential direction. When using 20 node hexahedral elements, the element size in the circumferential direction may be extended up to $5a$. In the case of multi-radii fillet r is the local fillet radius. (If 8 node hexahedral elements are used even smaller element size is required to meet the quality criteria.)

v. Recommended manner for element size in fillet depth direction

- First layer thickness equal to element size of a
- Second layer thickness equal to element to size of 2 a
- Third layer thickness equal to element to size of 3 a

vi. Minimum 6 elements across web thickness.

vii. The rest of the crank is to be suitable for numeric stability of the solver.

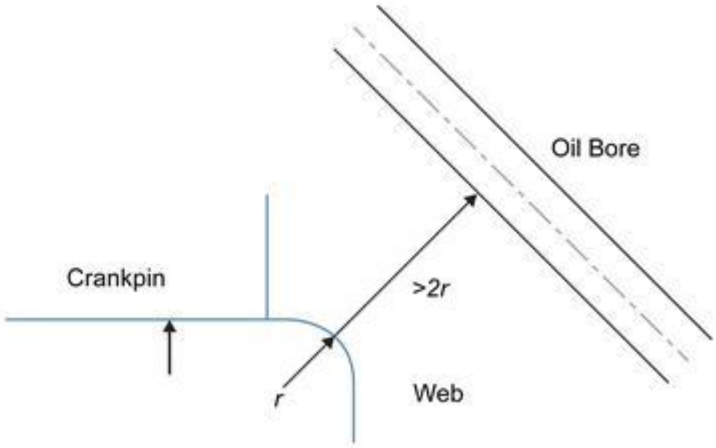
viii. Counterweights have to be modeled only when influencing the global stiffness of the crank significantly.

ix. Modeling of oil drillings is not necessary as long as the influence on global stiffness is negligible and the proximity to the fillet is more than $2r$, see .

x. Drillings and holes for weight reduction have to be modeled.

xi. Sub-modeling may be used provided the software requirements are fulfilled.

FIGURE 1
Oil Bore Proximity to Fillet



3.3 Materials

Material properties such as Young's Modulus (*E*) and Poisson's ratio (*ν*) are not considered. In FE analysis those material parameters are required, as strain is primarily calculated and stress is derived from strain using Young's Modulus and Poisson's ratio. Reliable values for material parameters have to be used, either as quoted in literature or as measured on representative material samples.

For steel the following is advised: *E*= 2.05·105 MPa and *ν* =0.3.

3.5 Element Mesh Quality Criteria

If the actual element mesh does not fulfill any of the following criteria at the examined area for SCF evaluation, then a second calculation with a refined mesh is to be performed.

3.5.1 Principal Stresses Criterion

The quality of the mesh is to be checked by noting the stress component normal to the surface of the fillet radius. Ideally, this stress should be zero. With principal stresses σ_1, σ_2, and σ_3 the following criterion is required:

min ($|\sigma_1|$, $|\sigma_2|$, $|\sigma_3|$) < 0.03 max ($|\sigma_1|$, $|\sigma_2|$, $|\sigma_3|$)

3.5.2 Averaged/Unaveraged Stresses Criterion

The criterion is based on observing the discontinuity of stress results over elements at the fillet for the calculation of SCF:

- Unaveraged nodal stress results calculated from each element connected to a node are to differ less than 5% from the 100% averaged nodal stress results at this node at the examined location.

5 Load Cases

To substitute the analytically determined SCF in 4-2-1-A4/5 the following load cases are to be calculated.

5.1 Torsion

Similar to the testing apparatus arrangements used for the investigations of SCF's of web fillet radii the structure is loaded in pure torsion. In the model surface warp at the end faces is suppressed. See 4-2-1-A7/5.1 FIGURE 2.

Torque is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is connected rigidly to all nodes of the end face.

Boundary and load conditions are valid for both in-line and V-type engines.

For all nodes in both the journal and crank pin fillet principal stresses are extracted and the equivalent torsional stress is calculated:

$$\tau_{equiv} = \max\left(\frac{|\sigma_1 - \sigma_2|}{2}, \frac{|\sigma_2 - \sigma_3|}{2}, \frac{|\sigma_1 - \sigma_3|}{2}\right)$$

The maximum value taken for the subsequent calculation of the SCF:

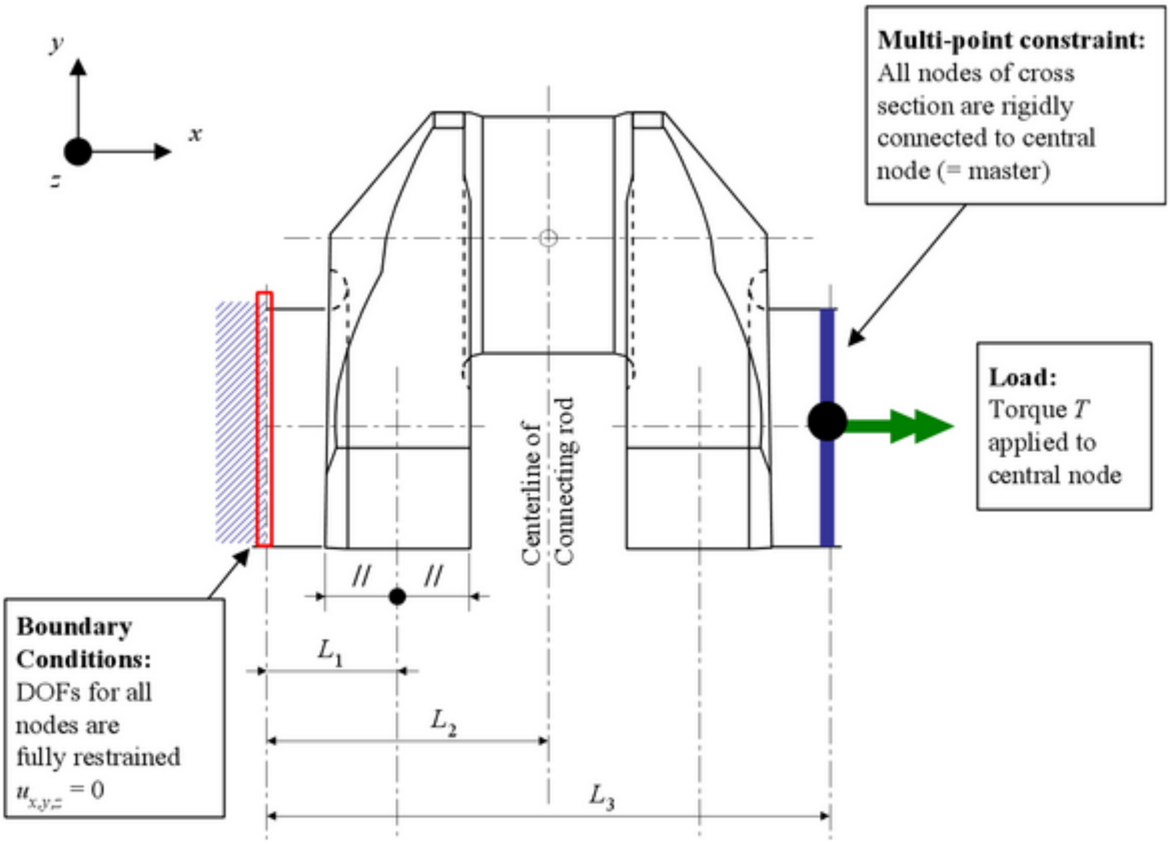
$$\alpha_T = \frac{\tau_{equiv,\alpha}}{\tau_N}$$

$$\beta_T = \frac{\tau_{equiv,\beta}}{\tau_N}$$

where τ_N is nominal torsional stress referred to the crank pin and respectively journal as per 4-2-1-A4/3 with the torsional torque T :

$$\tau_N = \frac{T}{W_p}$$

FIGURE 2
Boundary and Load Conditions for the Torsion Load Case



5.3 Pure Bending (4 Point Bending)

Similar to the testing apparatus arrangements used for the investigations of SCF's of web fillet radii the structure is loaded in pure bending. In the model surface warp at the end faces is suppressed. See 4-2-1-A7/5.3 FIGURE 3.

The bending moment is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is connected rigidly to all nodes of the end face.

Boundary and load conditions are valid for both in-line and V- type engines.

For all nodes in both the journal and pin fillet von Mises equivalent stresses σ_{equiv} are extracted. The maximum value is used to calculate the SCF according to:

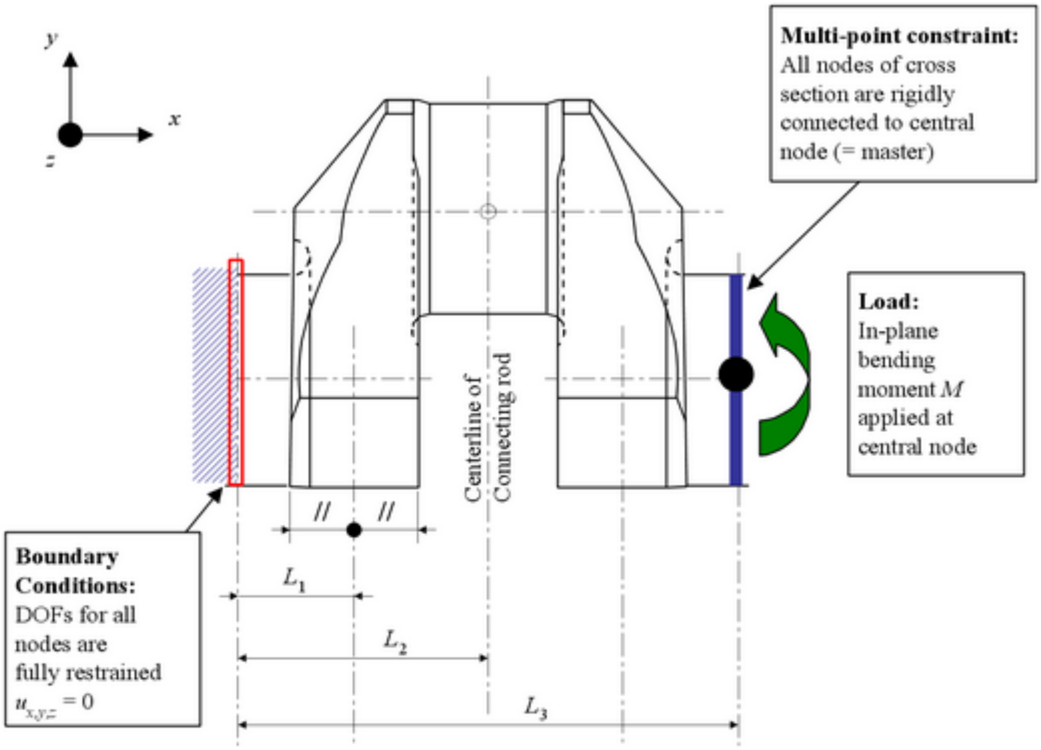
$$\alpha_{\beta} = \frac{\sigma_{equiv,\alpha}}{\sigma_N}$$

$$\beta_B = \frac{\sigma_{equiv,\beta}}{\sigma_N}$$

Nominal stress σ_N is calculated as per 4-2-1-A4/3 with the bending moment *M*:

$$\sigma_N = \frac{M}{W_{eqw}}$$

FIGURE 3
Boundary and Load Conditions for the Pure Bending Load Case



5.5 Bending With Shear Force (3 Point Bending)

This load case is calculated to determine the SCF for pure transverse force (radial force, β_Q) for the journal fillet.

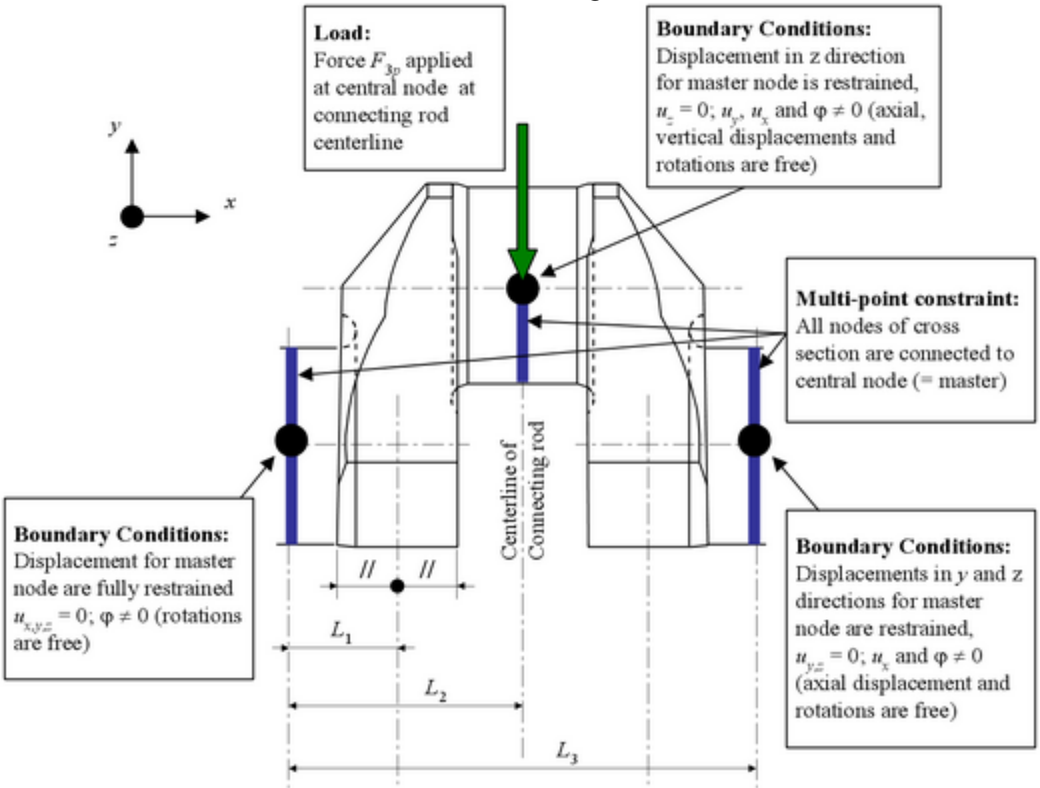
Similar to the testing apparatus arrangements used for the investigations of SCF's of web fillet radii, the structure is loaded in 3-point bending. In the model, surface warp at both end faces is suppressed. All nodes are connected rigidly to the center node; boundary conditions are applied to the center nodes. These nodes act as master nodes with 6 degrees of freedom. See 4-2-1-A7/5.5 FIGURE 4.

The force is applied to the central node located at the pin centerline of the connecting rod. This node is connected to all nodes of the pin cross sectional area. Warping of the sectional area is not suppressed.

Boundary and load conditions are valid for in-line and V-type engines. V-type engines can be modeled with one connecting rod force only. Using two connecting rod forces will make no significant change in the SCF.

The maximum equivalent von Mises stress σ_{3P} in the journal fillet is evaluated. The SCF in the journal fillet can be determined in two ways as shown below.

FIGURE 4
Boundary and Load Conditions for the 3-Point Bending Load Case of an Inline Engine



5.5.1 Method 1

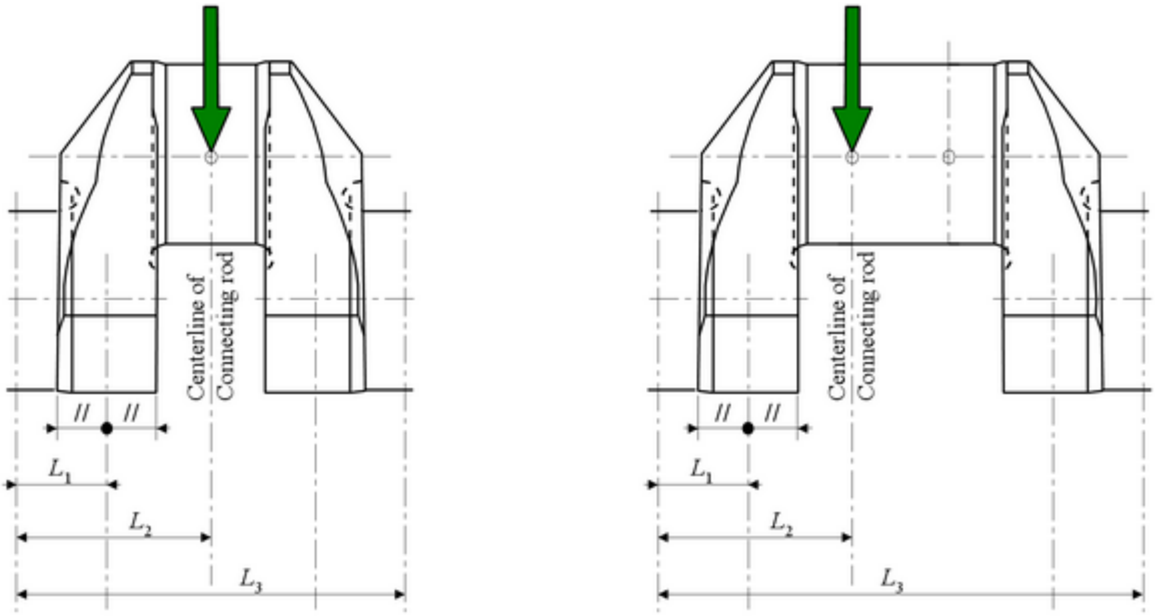
This method is based on the testing apparatus arrangements used for the investigations of SCF's of web fillet radii. The results from 3-point and 4-point bending are combined as follows:

$$\sigma_{3P} = \sigma_{N3P} \cdot \beta_B + \sigma_{Q3P} \cdot \beta_Q$$

where:

σ_{3P}	=	as found by the FE calculation.
σ_{N3P}	=	nominal bending stress in the web center due to the force F_{3P} [N] applied to the centerline of the actual connecting rod, See 4-2-1-A7/5.5.1 FIGURE 5.
β_B	=	as determined in paragraph 4-2-1-A7/5.3.
σ_{Q3P}	=	$\dfrac{Q_{3P}}{B \cdot W}$
Q_{3P}	=	radial (shear) force in the web due to the force F_{3P} [N] applied to the centerline of the actual connecting rod, see also 4-2-1-A4/1.1 FIGURE 3 and 4-2-1-A4/1.1 FIGURE 4.

FIGURE 5
Load Applications for In-line and V-type Engines



5.5.2 Method 2

This method is not based on the testing apparatus arrangements investigation. In a statically determined system with one crank throw supported by two bearings, the bending moment and radial (shear) force are proportional. Therefore the journal fillet SCF can be found directly by the 3-point bending FE calculation.

The SCF is then calculated according to:

$$\beta_{EQ} = \frac{\sigma_{3P}}{\sigma_{N3P}}$$

For symbols see 4-2-1-A7/5.5.1.

When using this method the radial force and stress determination in 4-2-1-A4 become superfluous. The alternating bending stress in the journal fillet as per 4-2-1-A4/1.5 is then evaluated:

$$\sigma_{BG} = \pm|\beta_{BQ} \cdot \sigma_{BFN}|$$

Note that the use of this method does not apply to the crank pin fillet and that this SCF is not to be used in connection with calculation methods other than those assuming a statically determined system as in 4-2-1-A4.

Appendix 8 Guidance for Evaluation of Fatigue Tests

1 Introduction

Fatigue testing can be divided into two main groups; testing of small specimens and full-size crank throws. Testing can be made using the staircase method or a modified version thereof which is presented in this document. Other statistical evaluation methods may also be applied.

1.1 Small Specimen Testing

For crankshafts without any fillet surface treatment, the fatigue strength can be determined by testing small specimens taken from a full-size crank throw. When other areas in the vicinity of the fillets are surface treated introducing residual stresses in the fillets, this approach cannot be applied.

One advantage of this approach is the rather high number of specimens which can be then manufactured. Another advantage is that the tests can be made with different stress ratios (R-ratios) and/or different modes (e.g., axial, bending and torsion), with or without a notch. This is required for evaluation of the material data to be used with critical plane criteria.

1.3 Full-size Crank Throw Testing

For crankshafts with surface treatment the fatigue strength can only be determined through testing of full size crank throws. For cost reasons, this usually means a low number of crank throws. The load can be applied by hydraulic actuators in a 3- or 4-point bending arrangement, or by an exciter in a resonance test rig. The latter is frequently used, although it usually limits the stress ratio to $R = -1$.

3 Evaluation of Test Results

3.1 Principles

Prior to fatigue testing the crankshaft is to be tested as required by quality control procedures (e.g., for chemical composition, mechanical properties, surface hardness, hardness depth and extension, fillet surface finish, etc.).

The test samples are to be prepared so as to represent the “lower end” of the acceptance range (e.g., for induction hardened crankshafts this means the lower range of acceptable hardness depth, the shortest extension through a fillet, etc.). Otherwise the mean value test results are to be corrected with a confidence interval: a 90% confidence interval may be used both for the sample mean and the standard deviation.

The test results, when applied in 4-2-1-A4, are to be evaluated to represent the mean fatigue strength, with or without taking into consideration the 90% confidence interval as mentioned above. The standard deviation should be considered by taking the 90% confidence into account. Subsequently the result to be used as the fatigue strength is then the mean fatigue strength minus one standard deviation.

If the evaluation aims to find a relationship between (static) mechanical properties and the fatigue strength, the relation is to be based on the real (measured) mechanical properties, not on the specified minimum properties.

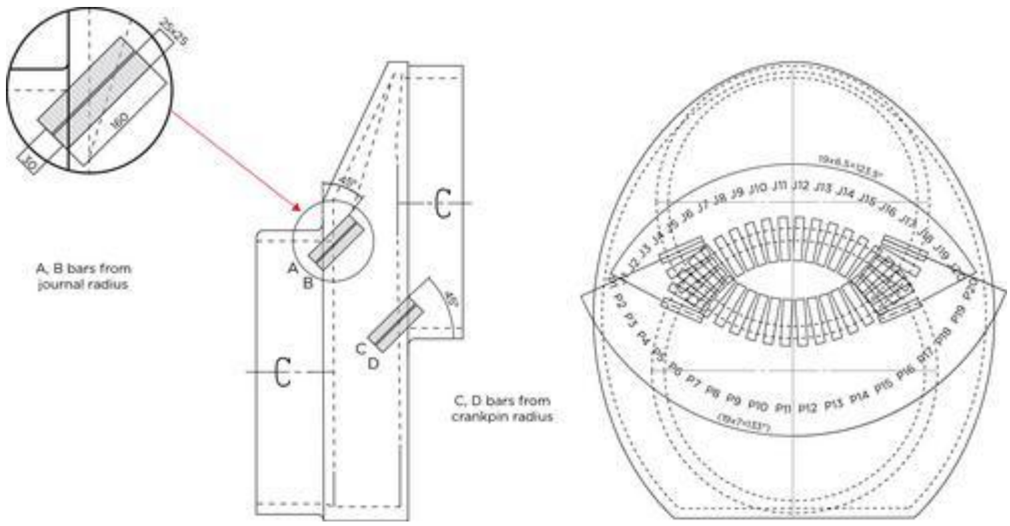
The calculation technique presented in 4-2-1-A8/11.5 was developed for the original staircase method. However, since there is no similar method dedicated to the modified staircase method the same is applied for both.

5 Small Specimen Testing

In this connection, a small specimen is considered to be one of the specimens taken from a crank throw. Since the specimens are to be representative for the fillet fatigue strength, they are to be taken out close to the fillets, as shown in 4-2-1-A8/5 FIGURE 1. It is to be made certain that the principal stress direction in the specimen testing is equivalent to the full-size crank throw. The verification is recommended to be done by utilizing the finite element method.

The (static) mechanical properties are to be determined as stipulated by the quality control procedures.

FIGURE 1
Specimen Locations in a Crank Throw



5.1 Determination of Bending Fatigue Strength

It is advisable to use un-notched specimens in order to avoid uncertainties related to the stress gradient influence. Push-pull testing method (stress ratio R = –1) is preferred, but for the purpose of critical plane criteria, other stress ratios and methods may be added.

In order to verify that the principal stress direction in push-pull testing represents the full-size crank throw principal stress direction and when no further information is available, the specimen is to be taken in 45 degrees angle as shown in 4-2-1-A8/5 FIGURE 1.

i. If the objective of the testing is to document the influence of high cleanliness, test samples taken from positions approximately 120 degrees in a circumferential direction may be used. See .
ii. If the objective of the testing is to document the influence of continuous grain flow (cgf) forging, the specimens are to be restricted to the vicinity of the crank plane.

5.3 Determination of Torsional Fatigue Strength

i. If the specimens are subjected to torsional testing, the selection of samples is to follow the same guidelines as for bending above. The stress gradient influence has to be considered in the evaluation.
ii. If the specimens are tested in push-pull and no further information is available, the samples are to be taken out at an angle of 45 degrees to the crank plane in order to verify collinearity of the principal stress direction between the specimen and the full-size crank throw. When taking the specimen at a distance from the (crank) middle plane of the crankshaft along the fillet, this plane rotates around the pin center point making it possible to resample the fracture direction due to torsion (the results are to be converted into the pertinent torsional values).

5.5 Other Test Positions

If the test purpose is to find fatigue properties and the crankshaft is forged in a manner likely to lead to cgf, the specimens may also be taken longitudinally from a prolonged shaft piece where specimens for mechanical testing are usually taken. The condition is that this prolonged shaft piece is heat treated as a part of the crankshaft and that the size is so as to result in a similar quenching rate as the crank throw.

When using test results from a prolonged shaft piece, it is to be considered how well the grain flow in that shaft piece is representative for the crank fillets.

5.7 Correlation of Test Results

The fatigue strength achieved by specimen testing is to be converted to correspond to the full-size crankshaft fatigue strength with an appropriate method (size effect).

When using the bending fatigue properties from tests mentioned in this section, it is to be kept in mind that successful continuous grain flow (cgf) forging leading to elevated values compared to other (non cgf) forging, will normally not lead to a torsional fatigue strength improvement of the same magnitude.

In such cases it is advised to either carry out also torsional testing or to make a conservative assessment of the torsional fatigue strength (e.g., by using no credit for cgf). This approach is applicable when using the Gough Pollard criterion. However, this approach is not recognized when using the von Mises or a multi-axial criterion such as Findley.

If the found ratio between bending and torsion fatigue differs significantly from $\sqrt{3}$, one is to consider replacing the use of the von Mises criterion with the Gough Pollard criterion. Also, if critical plane criteria are used, it is to be kept in mind that cgf makes the material inhomogeneous in terms of fatigue strength, meaning that the material parameters differ with the directions of the planes.

Any addition of influence factors is to be made with caution. If for example a certain addition for clean steel is documented, it may not necessarily be fully combined with a K-factor for cgf. Direct testing of samples from a clean and cgf forged crank is preferred.

7 Full Size Testing

7.1 Hydraulic Pulsation

A hydraulic test rig can be arranged for testing a crankshaft in 3-point or 4-point bending as well as in torsion. This allows for testing with any R-ratio.

Although the applied load should be verified by strain gauge measurements on plain shaft sections for the initiation of the test, it is not necessarily used during the test for controlling load. It is also pertinent to check fillet stresses with strain gauge chains. Furthermore, it is important that the test rig provides boundary conditions as defined in 4-2-1-A8/5.1, 4-2-1-A8/5.3, and 4-2-1-A8/5.5.

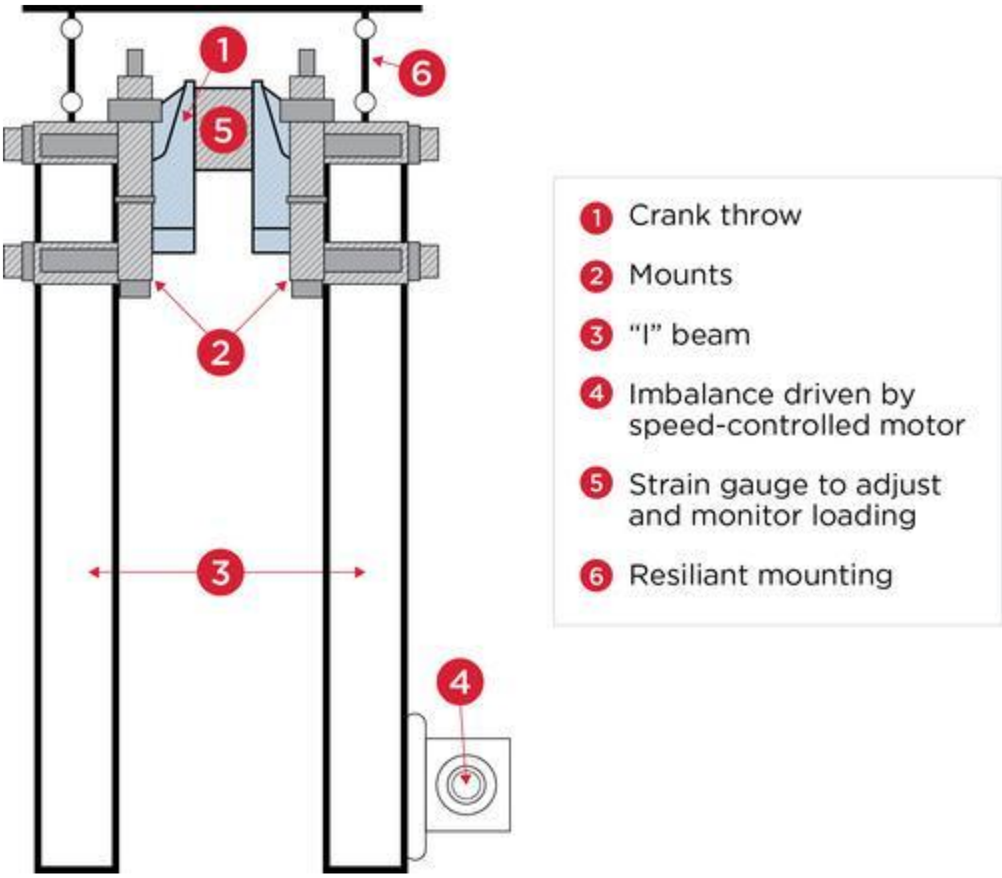
The (static) mechanical properties are to be determined as stipulated by the quality control procedures.

7.3 Resonance Tester (2020)

A rig for bending fatigue normally works with an R-ratio of –1. Due to operation close to resonance, the energy consumption is moderate. Moreover, the frequency is usually relatively high, meaning that 10^7 cycles can be reached within some days. 4-2-1-A8/7.3 FIGURE 2 shows a layout of the testing arrangement.

The applied load is to be verified by strain gauge measurements on plain shaft sections. It is also pertinent to check fillet stresses with strain gauge chains.

FIGURE 2
An Example of Testing Arrangement of the Resonance Tester for Bending Loading



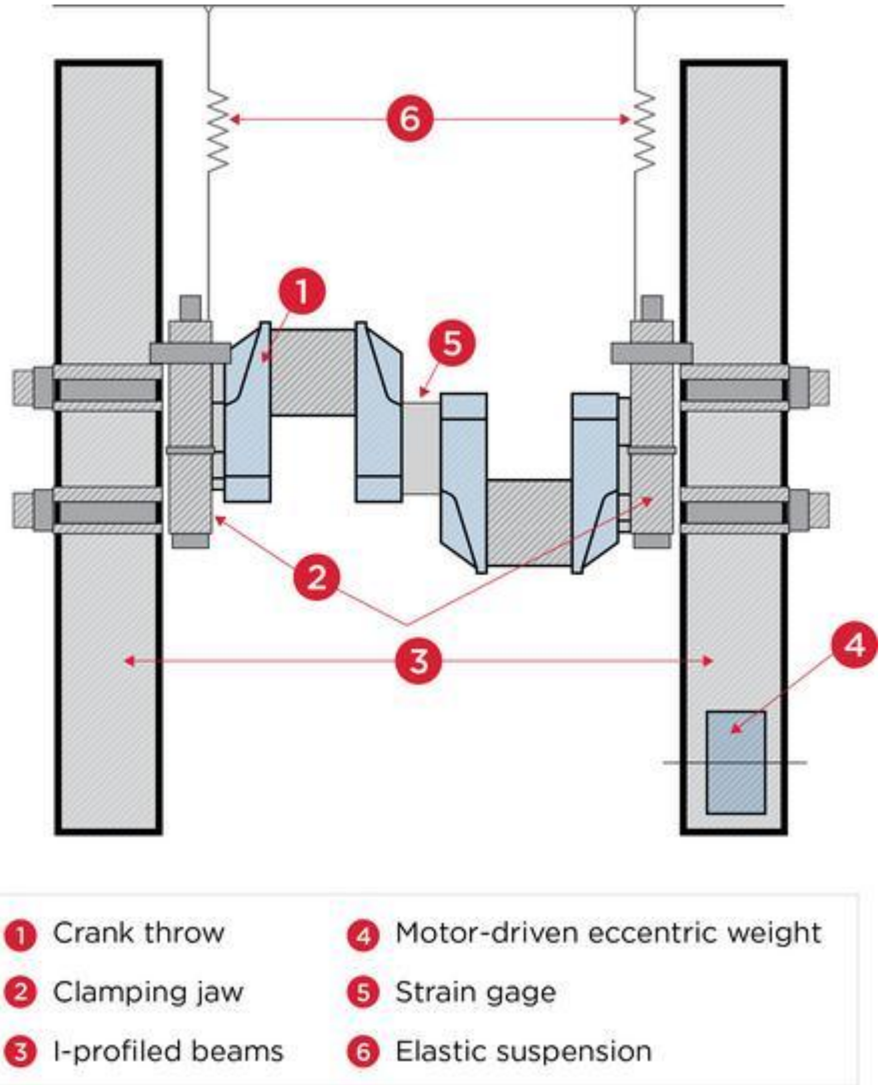
Clamping around the journals is to be arranged in a way that prevents severe fretting which could lead to a failure under the edges of the clamps. If some distance between the clamps and the journal fillets is provided, the loading is consistent with 4-point bending and thus representative for the journal fillets also.

In an engine, the crankpin fillets normally operate with an R-ratio slightly above –1 and the journal fillets slightly below –1. If found necessary, it is possible to introduce a mean load (deviate from R = –1) by means of a spring preload.

A rig for torsion fatigue can also be arranged as shown in 4-2-1-A8/7.3 FIGURE 3. When a crank throw is subjected to torsion, the twist of the crankpin makes the journals move sideways. If one single crank throw is tested in a torsion resonance test rig, the journals with their clamped-on weights will vibrate heavily sideways.

This sideways movement of the clamped-on weights can be reduced by having two crank throws, especially if the cranks are almost in the same direction. However, the journal in the middle will move more.

FIGURE 3
An Example of Testing Arrangement of the Resonance Tester for Torsion Loading with Double Crank Throw Section



Since sideways movements can cause some bending stresses, the plain portions of the crankpins should also be provided with strain gauges arranged to measure any possible bending that could have an influence on the test results.

Similarly to the bending case, the applied load is to be verified by strain gauge measurements on plain shaft sections. It is also pertinent to check fillet stresses with strain gauge chains as well.

7.5 Use of Results and Crankshaft Acceptability **(1 July 2024)**

In order to combine tested bending and torsion fatigue strength results in calculation of crankshaft acceptability, see 4-2-1-A4/13, the Gough-Pollard approach can be applied for the following cases:

At the crankpin fillet:

$$Q = \left(\sqrt{ \left(\frac{\sigma_{BH} + \sigma_{add}}{\sigma_{DWCT}} \right)^2 + \left(\frac{\tau_{BH}}{\tau_{DWCT}} \right)^2 } \right)^{-1}$$

where

σ_{DWCT}	=	fatigue strength by bending testing
τ_{DWCT}	=	fatigue strength by torsion testing

For other parameters see 4-2-1-A4/1.5, 4-2-1-A4/3.5 and 4-2-1-A4/7.

Related to the crankpin oil bore:

$$Q = \sigma_{DWOT} / \sigma_v$$

$$\sigma_v = \frac{1}{3}\sigma_{BO}\left|1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\sigma_{TO}}{\sigma_{BO}}\right)^2}\right|$$

where

σ_{DWOT}	=	fatigue strength by means of largest principal stress from torsion testing

At the journal fillet:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BG} + \sigma_{add}}{\sigma_{DWJT}}\right)^2 + \left(\frac{\tau_G}{\tau_{DWJT}}\right)^2}\right)^{-1}$$

where

σ_{DWJT}	=	fatigue strength by bending testing
τ_{DWJT}	=	fatigue strength by torsion testing

For other parameters see 4-2-1-A4/1.5, 4-2-1-A4/3.5 and 4-2-1-A4/7.

In case increase in fatigue strength due to the surface treatment is considered to be similar between the above cases, it is sufficient to test only the most critical location according to the calculation where the surface treatment had not been taken into account.

9 Use of Existing Results for Similar Crankshafts

For fillets or oil bores without surface treatment, the fatigue properties found by testing may be used for similar crankshaft designs providing:

i. Material:
   - Similar material type
   - Cleanliness on the same or better level
   - The same mechanical properties can be granted (size versus hardenability)

ii. Geometry:
   - Difference in the size effect of stress gradient is insignificant or it is considered
   - Principal stress direction is equivalent. See .

iii. Manufacturing:
   - Similar manufacturing process

Induction hardened or gas nitrided crankshafts will suffer fatigue either at the surface or at the transition to the core. The surface fatigue strength as determined by fatigue tests of full size cranks, may be used on an equal or similar design as the tested crankshaft when the fatigue initiation occurred at the surface. With the similar design, it is meant that a similar material type and surface hardness are used and the fillet radius and hardening depth are within approximately ± 30 % of the tested crankshaft.

Fatigue initiation in the transition zone can be either subsurface, i.e. below the hard layer, or at the surface where the hardening ends. The fatigue strength at the transition to the core can be determined by fatigue tests as described above, provided that the fatigue initiation occurred at the transition to the core. Tests made with the core material only will not be representative since the tension residual stresses at the transition are lacking.

Some recent research has shown that the fatigue limit can decrease in the very high cycle domain with subsurface crack initiation due to trapped hydrogen that accumulates through diffusion around some internal defect functioning as an initiation point. In these cases, it would be appropriate to reduce the fatigue limit by some percent per decade of cycles beyond 10^7. Based on the publication “Metal Fatigue: Effects of Small Defects and Non-metallic Inclusions” the reduction is suggested to be 5% per decade especially when the hydrogen content is considered to be high.

11 Calculation Technique

11.1 Staircase Method

In the original staircase method, the first specimen is subjected to a stress corresponding to the expected average fatigue strength. If the specimen survives 10^7 cycles, it is discarded and the next specimen is subjected to a stress that is one increment above the previous (i.e., a survivor is always followed by the next using a stress one increment above the previous). The increment should be selected to correspond to the expected level of the standard deviation.

When a specimen fails prior to reaching 10^7 cycles, the obtained number of cycles is noted and the next specimen is subjected to a stress that is one increment below the previous. With this approach, the sum of failures and run-outs is equal to the number of specimens.

This original staircase method is only suitable when a high number of specimens are available. Through simulations it has been found that the use of about 25 specimens in a staircase test leads to a sufficient accuracy in the result.

11.3 Modified Staircase Method

When a limited number of specimens are available, it is advisable to apply the modified staircase method. Here the first specimen is subjected to a stress level that is most likely well below the average fatigue strength. When this specimen has survived 10^7 cycles, this same specimen is subjected to a stress level one increment above the previous. The increment should be selected to correspond to the expected level of the standard deviation. This is continued with the same specimen until failure.

Then the number of cycles is recorded and the next specimen is subjected to a stress that is at least 2 increments below the level where the previous specimen failed.

With this approach, the number of failures usually equals the number of specimens.

The number of run-outs, counted as the highest level where 10^7 cycles were reached, also equals the number of specimens.

The acquired result of a modified staircase method should be used with care, since some results available indicate that testing a runout on a higher test level, especially at high mean stresses, tends to increase the fatigue limit. However, this “training effect” is less pronounced for high strength steels (e.g., UTS > 800 MPa).

If the confidence calculation is desired or necessary, the minimum number of test specimens is 3.

11.5 Calculation of Sample Mean and Standard Deviation

A hypothetical example of tests for 5 crank throws is presented further in the subsequent text. When using the modified staircase method and the evaluation method of Dixon and Mood, the number of samples will be 10, meaning 5 run-outs and 5 failures, i.e.:

Number of samples: $n = 10$

Furthermore, the method distinguishes between:

Less frequent event is failures $C = 1$

Less frequent event is run-outs $C = 2$

The method uses only the less frequent occurrence in the test results, i.e. if there are more failures than run-outs, then the number of run-outs is used, and vice versa.

In the modified staircase method, the number of run-outs and failures are usually equal. However, the testing can be unsuccessful (e.g., the number of run-outs can be less than the number of failures if a specimen with 2 increments below the previous failure level goes directly to failure). On the other hand, if this unexpected premature failure occurs after a rather high number of cycles, it is possible to define the level below this as a run-out.

Dixon and Mood's approach, derived from the maximum likelihood theory, which also may be applied here, especially on tests with few samples, presented some simple approximate equations for calculating the sample mean and the standard deviation from the outcome of the staircase test. The sample mean can be calculated as follows:

$$\overline{S_a} = S_{a0} + d \cdot \left(\frac{A}{F} - \frac{1}{2}\right) \text{when} C = 1$$

$$\overline{S_a} = S_{a0} + d \cdot \left(\frac{A}{F} + \frac{1}{2}\right) \text{when} C = 2$$

The standard deviation can be found by:

$$s = 1.62 \cdot d \cdot \left(\frac{F \cdot B - A^2}{F^2} + 0.029\right)$$

where

S_{a0} = lowest stress level for the less frequent occurrence

d = stress increment

F = $\sum f_i$

A = $\sum i \cdot f_i$

B = $\sum i^2 \cdot f_i$

i = stress level numbering

f_i = number of samples at stress level i

The formula for the standard deviation is an approximation and can be used when:

$$\frac{F \cdot B - A^2}{F^2} > 0.3 \text{and} 0.5s < d < 1.5s$$

If any of these two conditions are not fulfilled, a new staircase test should be considered or the standard deviation should be taken quite large in order to be on the safe side.

If increment d is greatly higher than the standard deviation s, the procedure leads to a lower standard deviation and a slightly higher sample mean, both compared to values calculated .

Respectively, if increment d is much less than the standard deviation s, the procedure leads to a higher standard deviation and a slightly lower sample mean.

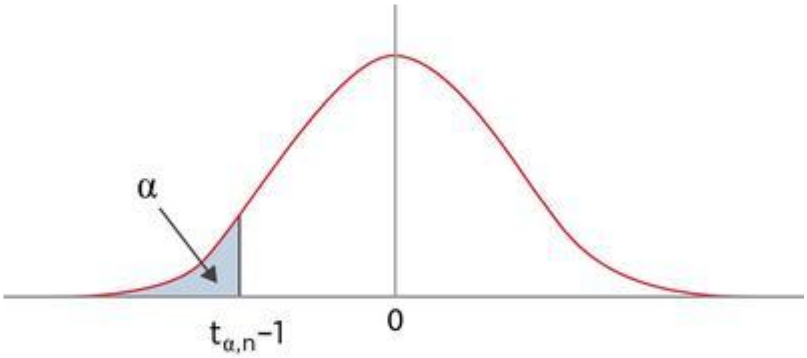
11.7 Confidence Interval for Mean Fatigue Limit

If the staircase fatigue test is repeated, the sample mean and the standard deviation will most likely be different from the previous test. Therefore, it is necessary to assure with a given confidence that the repeated test values will be above the chosen fatigue limit by using a confidence interval for the sample mean.

The confidence interval for the sample mean value with unknown variance is known to be distributed according to the *t*-distribution (also called student's *t*-distribution) which is a distribution symmetric around the average.

The confidence level normally used for the sample mean is 90%, meaning that 90% of sample means from repeated tests will be above the value calculated with the chosen confidence level. 4-2-1-A8/11.7 FIGURE 4 shows the t-value for (1 – α) 100% confidence interval for the sample mean.

FIGURE 4
Student's *t*-Distribution



If S_a is the empirical mean and s is the empirical standard deviation over a series of n samples, in which the variable values are normally distributed with an unknown sample mean and unknown variance, the (1 – α) 100% confidence interval for the mean is:

$$P\left(S_a - t_{\alpha,n-1}\cdot\frac{s}{\sqrt{n}} < S_{aX\%}\right) = 1-\alpha$$

The resulting confidence interval is symmetric around the empirical mean of the sample values, and the lower endpoint can be found as:

$$S_{aX\%} = S_a - t_{\alpha,n-1}\cdot\frac{s}{\sqrt{n}}$$

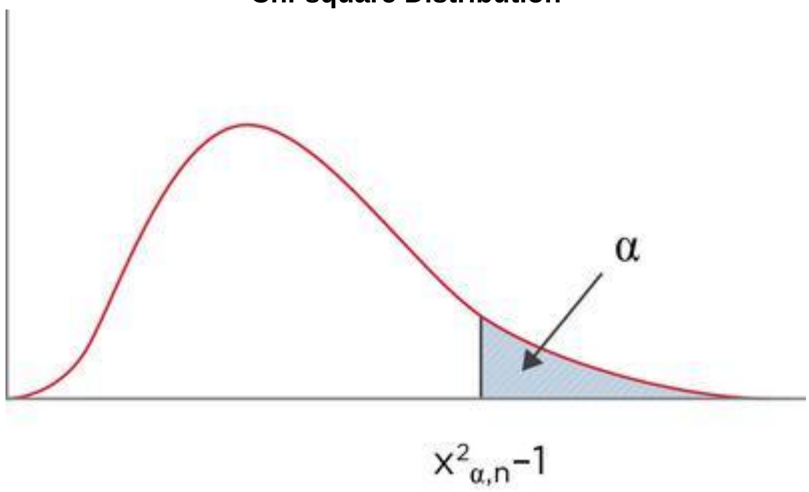
which is the mean fatigue limit (population value) to be used to obtain the reduced fatigue limit where the limits for the probability of failure are taken into consideration.

11.9 Confidence Interval for Standard Deviation

The confidence interval for the variance of a normal random variable is known to possess a chi-square distribution with n – 1 degrees of freedom.

The confidence level on the standard deviation is used to verify that the standard deviations for repeated tests are below an upper limit obtained from the fatigue test standard deviation with a confidence level. 4-2-1-A8/11.9 FIGURE 5 shows the chi-square for (1 – α) 100% confidence interval for the variance.

FIGURE 5
Chi-square Distribution



An assumed fatigue test value from n samples is a normal random variable with a variance of σ^2 and has an empirical variance s^2 . Then a (1 – α) 100% confidence interval for the variance is:

$$P\left(\frac{(n-1)s^2}{\sigma^2} < \chi^2_{\alpha,n-1}\right) = 1 - \alpha$$

A (1 – α) 100% confidence interval for the standard deviation is obtained by the square root of the upper limit of the confidence interval for the variance and can be found by:

$$S_{X\%} = \sqrt{\frac{n-1}{\chi^2_{\alpha,n-1}}} \cdot s$$

This standard deviation (population value) is to be used to obtain the fatigue limit, where the limits for the probability of failure are taken into consideration.

Appendix 9 Guidance for Calculation of Surface Treated Fillets and Oil Bore Outlets

1 Introduction

This Appendix deals with surface treated fillets and oil bore outlets. The various treatments are explained and some empirical formulae are given for calculation purposes. Conservative empiricism has been applied intentionally, in order to be on the safe side from a calculation standpoint. Measurements should be used if available. In the case of a wide scatter (e.g., for residual stresses) the values should be chosen from the end of the range that would be on the safe side for calculation purposes.

3 Surface Treatment

"Surface treatment" is a term covering treatments such as thermal, chemical or mechanical operations, leading to inhomogeneous material properties – such as hardness, chemistry or residual stresses – from the surface to the core.

3.1 Surface Treatment Methods

The following list covers possible treatment methods and how they influence the properties that are decisive for the fatigue strength.

Surface Treatment Methods and the Characteristics They Affect

Treatment Method	*Affecting*
Induction hardening	Hardness and residual stresses
Nitriding	Chemistry, hardness and residual stresses
Case hardening	Chemistry, hardness and residual stresses
Die quenching (no temper)	Hardness and residual stresses
Cold rolling	Residual stresses
Stroke peening	Residual stresses
Shot peening	Residual stresses
Laser peening	Residual stresses
Ball coining	Residual stresses

It is important to note that since only induction hardening, nitriding, cold rolling and stroke peening are considered relevant for marine engines, other methods as well as combination of two or more of the above are not dealt with in this document. In addition, die quenching can be considered in the same way as induction hardening.

5 Calculation Principles

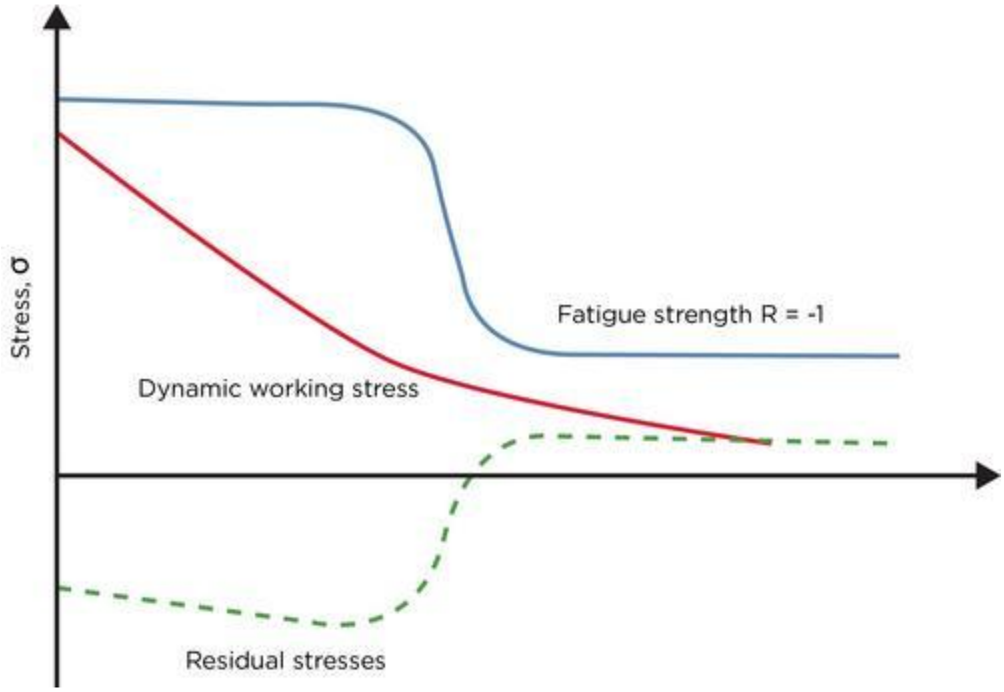
The basic principle is that the alternating working stresses are to be below the local fatigue strength (including the effect of surface treatment) wherein non-propagating cracks may occur, see also 4-2-1-A9/11.1 for details. This is then divided by a certain safety factor. This applies through the entire fillet or oil bore contour as well as below the surface to a depth below the treatment-affected zone (i.e., to cover the depth all the way to the core).

Consideration of the local fatigue strength is to include the influence of the local hardness, residual stress and mean working stress. The influence of the "giga-cycle effect", especially for initiation of subsurface cracks, should be covered by the choice of safety margin.

It is of vital importance that the extension of hardening/peening in an area with concentrated stresses be duly considered. Any transition where the hardening/peening is ended is likely to have considerable tensile residual stresses. This forms a 'weak spot' and is important if it coincides with an area of high stresses.

Alternating and mean working stresses are to be known for the entire area of the stress concentration as well as to a depth of about 1.2 times the depth of the treatment. 4-2-1-A9/5 FIGURE 1 indicates this principle in the case of induction hardening. The base axis is either the depth (perpendicular to the surface) or along the fillet contour.

FIGURE 1
Stresses as Functions of Depth, General Principles



The acceptability criterion should be applied stepwise from the surface to the core as well as from the point of maximum stress concentration along the fillet surface contour to the web.

5.1 Evaluation of Local Fillet Stresses

It is necessary to have knowledge of the stresses along the fillet contour as well as in the subsurface to a depth somewhat beyond the hardened layer. Normally, this will be found via FEA as described in Appendix 4-2-1-A7. However, the element size in the subsurface range will have to be the same size as at the surface. For crankpin hardening only the small element size will have to be continued along the surface to the hard layer.

If no FEA is available, a simplified approach may be used. This can be based on the empirically determined stress concentration factors (SCFs), as in 4-2-1-A4/5 if within its validity range, and a relative stress gradient inversely proportional to the fillet radius. Bending and torsional stresses are to be addressed separately. The combination of these is addressed by the acceptability criterion.

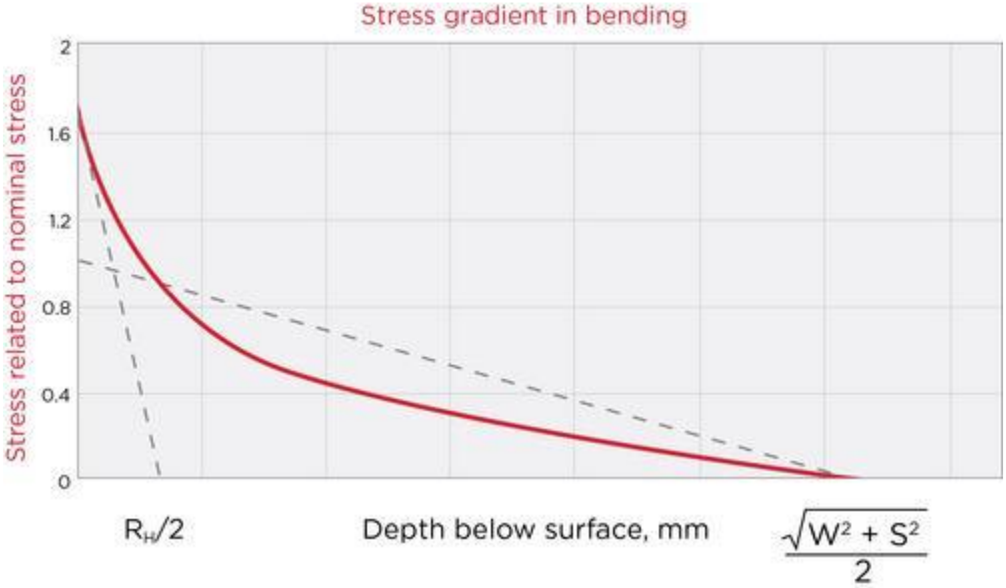
The subsurface transition-zone stresses, with the minimum hardening depth, can be determined by means of local stress concentration factors along an axis perpendicular to the fillet surface. These functions $\alpha_{B-local}$ and $\alpha_{T-local}$ have different shapes due to the different stress gradients.

The SCFs α_B and α_T are valid at the surface. The local $\alpha_{B-local}$ and $\alpha_{T-local}$ drop with increasing depth. The relative stress gradients at the surface depend on the kind of stress raiser, but for crankpin fillets they can be simplified to $2/R_H$ in bending and $1/R_H$ in torsion. The journal fillets are handled analogously by using R_G and D_G . The nominal stresses are assumed to be linear from the surface to a midpoint in the web between the crankpin fillet and the journal fillet for bending and to the crankpin or journal center for torsion.

The local SCFs are then functions of depth t according to the following formula as shown in 4-2-1-A9/5.1 FIGURE 2 for bending:

$$\alpha_{B-local} = (\alpha_B - 1) \cdot e^{\frac{-2 \cdot t}{R_H}} + 1 - \left(\frac{2 \cdot t}{\sqrt{W^2 + S^2}} \right)^{\frac{0.6}{\sqrt{\alpha_B}}}$$

FIGURE 2
Bending SCF in the Crankpin Fillet as a Function of Depth



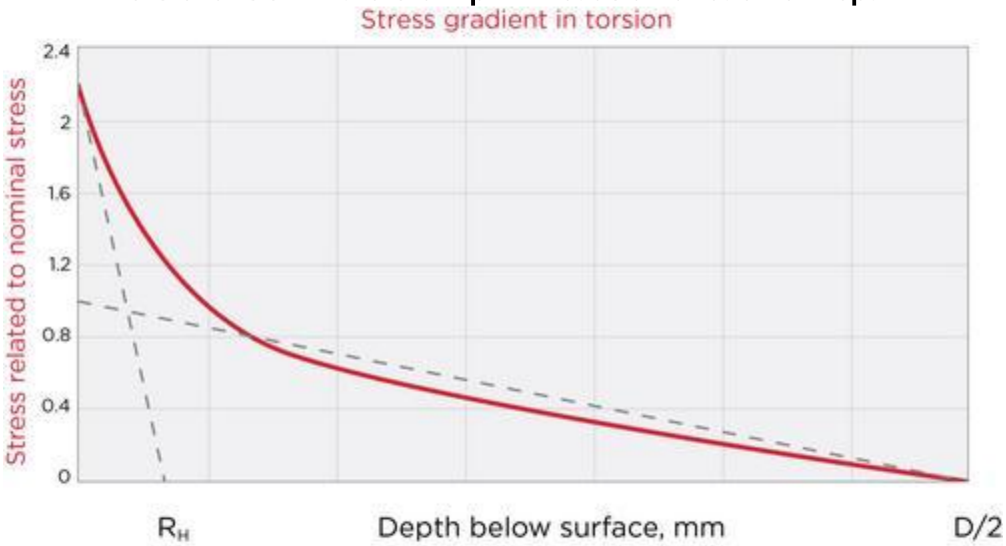
Note:

The corresponding SCF for the journal fillet can be found by replacing R_H with R_G .

and respectively for torsion in the following formula and 4-2-1-A9/5.1 FIGURE 3:

$$\alpha_{T-local} = (\alpha_T - 1) \cdot e^{\frac{-t}{R_H}} + 1 - \left(\frac{2 \cdot t}{D}\right)^{\frac{1}{\sqrt{\alpha_T}}}$$

FIGURE 3
Torsional SCF in the Crankpin Fillet as a Function of Depth



Note:

The corresponding SCF for the journal fillet can be found by replacing R_H with R_G and D with D_G .

If the pin is hardened only and the end of the hardened zone is closer to the fillet than three times the maximum hardness depth, FEA should be used to determine the actual stresses in the transition zone.

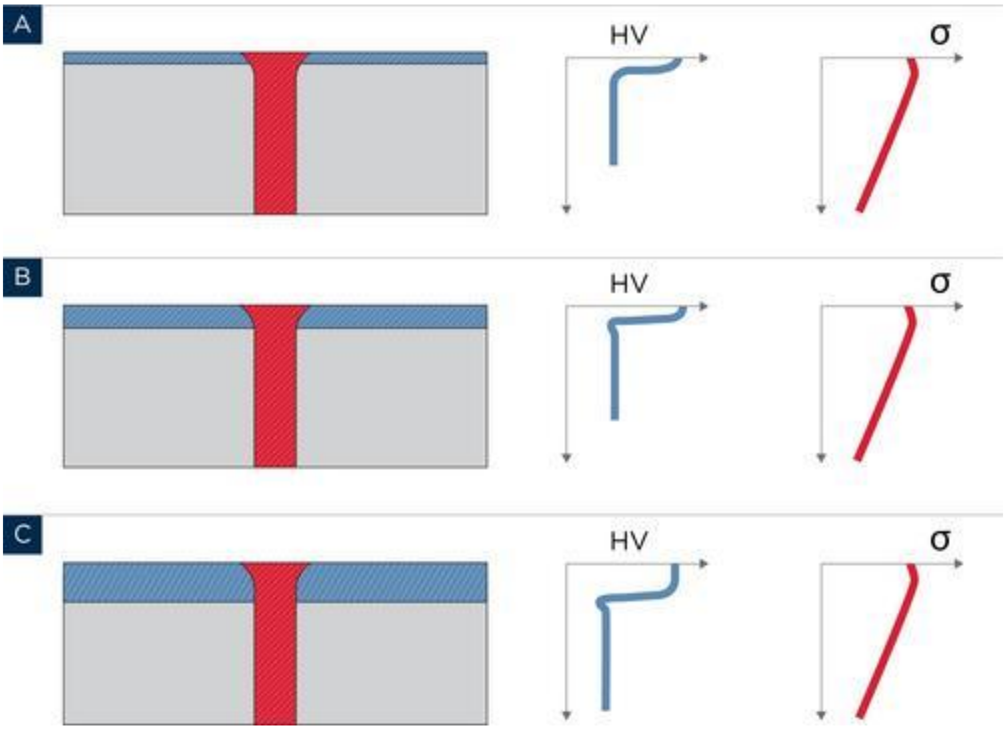
5.3 Evaluation of Oil Bore Stresses (2020)

Stresses in the oil bores can be determined also by FEA. The element size should be less than $1/8$ of the oil bore diameter D_o and the element mesh quality criteria should be followed as prescribed in Appendix 4-2-1-A7. The fine element mesh should continue well beyond a radial depth corresponding to the hardening depth.

The loads to be applied in the FEA are the torque – see 4-2-1-A7/5.1 – and the bending moment, with four-point bending as in 4-2-1-A7/5.3.

If no FEA is available, a simplified approach may be used. This can be based on the empirically determined SCF from 4-2-1-A4/5 if within its applicability range. Bending and torsional stresses at the point of peak stresses are combined as in 4-2-1-A4/9.

FIGURE 4
Stresses and Hardness in Induction Hardened Oil Holes



4-2-1-A9/5.3 FIGURE 4 indicates a local drop of the hardness in the transition zone between a hard and soft material. Whether this drop occurs depends also on the tempering temperature after quenching in the QT process.

The peak stress in the bore occurs at the end of the edge rounding. Within this zone the stress drops almost linearly to the center of the pin. As can be seen from 4-2-1-A9/5.3 FIGURE 4, for shallow (A) and intermediate (B) hardening, the transition point practically coincides with the point of maximal stresses. For deep hardening the transition point comes outside of the point of peak stress and the local stress can be assessed as a portion $(1 - 2t_H/D)$ of the peak stresses where t_H is the hardening depth.

The subsurface transition-zone stresses (using the minimum hardening depth) can be determined by means of local stress concentration factors along an axis perpendicular to the oil bore surface. These functions $\gamma_{B-local}$ and $\gamma_{T-local}$ have different shapes, because of the different stress gradients.

The stress concentration factors γ_B and γ_T are valid at the surface. The local SCFs $\gamma_{B-local}$ and $\gamma_{T-local}$ drop with increasing depth. The relative stress gradients at the surface depend on the kind of stress raiser, but for crankpin oil bores they can be simplified to $4/D_o$ in bending and $2/D_o$ in torsion. The local SCFs are then functions of the depth *t*:

$$\gamma_{B-local} = (\gamma_B - 1) \cdot e^{\frac{-4 \cdot t}{D_o}} + 1$$

$$\gamma_{T-local} = (\gamma_T - 1) \cdot e^{\frac{-2 \cdot t}{D_o}} + 1$$

5.5 Acceptability Criteria

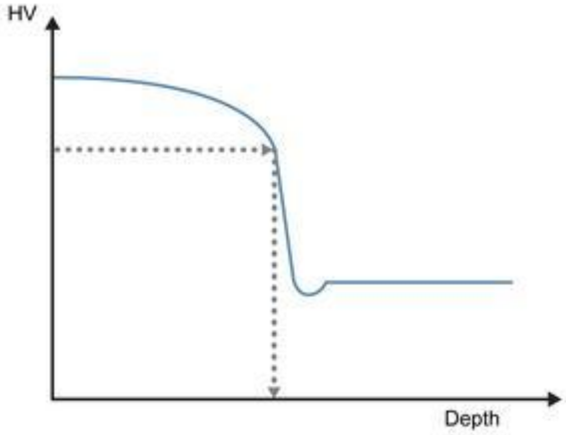
Acceptance of crankshafts is based on fatigue considerations; 4-2-1-A4/13 compares the equivalent alternating stress and the fatigue strength ratio to an acceptability factor of $Q \geq 1.15$ for oil bore outlets, crankpin fillets and journal fillets. This is to be extended to cover also surface treated areas independent of whether surface or transition zone is examined.

7 Induction Hardening

The hardness specification is to specify the surface hardness range (i.e., minimum and maximum values), the minimum and maximum extension in or through the fillet and also the minimum and maximum depth along the fillet contour. The referenced Vickers hardness is considered to be HV0.5 ~ HV5.

The induction hardening depth is defined as the depth where the hardness is 80% of the minimum specified surface hardness.

FIGURE 5
Typical Hardness as a Function of Depth

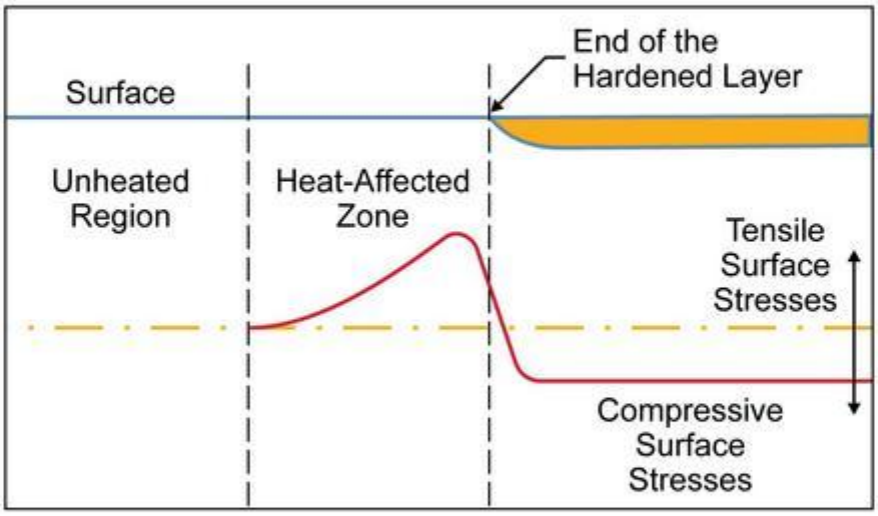


Note:

The arrows indicate the defined hardening depth. Note the indicated potential hardness drop at the transition to the core. This can be a weak point as local strength may be reduced and tensile residual stresses may occur.

In the case of crankpin or journal hardening only, the minimum distance to the fillet is to be specified due to the tensile stress at the heat-affected zone as shown in 4-2-1-A9/7 FIGURE 6.

FIGURE 6
Residual Stresses along the Surface of a Pin and Fillet



If the hardness-versus-depth profile and residual stresses are not known or specified, one may assume the following:

i. The hardness profile consists of two layers (see):
    - Constant hardness from the surface to the transition zone
    - Constant hardness from the transition zone to the core material
ii. Residual stresses in the hard zone of 200 MPa (compression)
iii. Transition-zone hardness as 90% of the core hardness unless the local hardness drop is avoided
iv. Transition-zone maximum residual stresses (von Mises) of 300 MPa tension

If the crankpin or journal hardening ends close to the fillet, the influence of tensile residual stresses has to be considered. If the minimum distance between the end of the hardening and the beginning of the fillet is more than 3 times the maximum hardening depth, the influence may be disregarded.

7.1 Local Fatigue Strength

Induction-hardened crankshafts will suffer fatigue either at the surface or at the transition to the core. The fatigue strengths, for both the surface and the transition zone, can be determined by fatigue testing of full size cranks as described in Appendix 4-2-1-A8. In the case of a transition zone, the initiation of the fatigue can be either subsurface (i.e. below the hard layer) or at the surface where the hardening ends. Tests made with the core material only will not be representative since the tensile residual stresses at the transition are lacking.

Alternatively, the surface fatigue strength can be determined empirically as follows where *HV* is the surface Vickers hardness. The following formula provides a conservative value, with which the fatigue strength is assumed to include the influence of the residual stress. The resulting value is valid for a working stress ratio of $R = -1$:

$$\sigma_{Fsurface} = 400 + 0.5 \cdot (HV - 400)\text{Mpa}$$

It has to be noted also that the mean stress influence of induction-hardened steels may be significantly higher than that for QT steels.

The fatigue strength in the transition zone, without taking into account any possible local hardness drop, is to be determined by the equation introduced in 4-2-1-A4/11.

For journal and respectively to crankpin fillet applies:

$$\sigma_{Ftransition,cpin} = \pm K \cdot (0.42 \cdot \sigma_B + 39.3) \cdot \left[0.264 + 1.073 \cdot Y^{-0.2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{X}}\right]$$

where

Y = D_G for journal fillet

= D for crankpin fillet

= D for oil bore outlet

X = R_G for journal fillet

= R_H for crankpin fillet

= $D_o/2$ for oil bore outlet

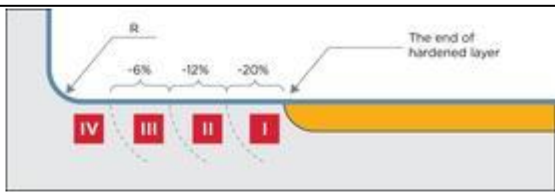
The influence of the residual stress is not included in the above formula.

For the purpose of considering subsurface fatigue, below the hard layer, the disadvantage of tensile residual stresses has to be considered by subtracting 20% from the value determined above. This 20% is based on the mean stress influence of alloyed quenched and tempered steel having a residual tensile stress of 300 MPa.

When the residual stresses are known to be lower, also the smaller value of subtraction is to be used. For low-strength steels the percentage chosen should be higher.

For the purpose of considering surface fatigue near the end of the hardened zone (i.e., in the heat-affected zone shown in 4-2-1-A9/7 FIGURE 6), the influence of the tensile residual stresses can be considered by subtracting a certain percentage, in accordance with 4-2-1-A9/7.1 TABLE 1, from the value determined by the above formula.

TABLE 1
Influence of Tensile Residual Stresses at a Given Distance from the End of the Hardening Towards the Fillet

i. 0 to 1.0 of the max. hardening depth: 20% ii. 1.0 to 2.0 of the max. hardening depth: 12% iii. 2.0 to 3.0 of the max. hardening depth: 6% iv. 3.0 or more of the max. hardening depth: 0%	

9 Nitriding

The hardness specification is to include the surface hardness range (min and max) and the minimum and maximum depth. Only gas nitriding is considered. The referenced Vickers hardness is considered to be HV0.5.

The depth of the hardening is defined in different ways in the various standards and the literature. The most practical method to use in this context is to define the nitriding depth t_N as the depth to a hardness of 50 HV above the core hardness.

The hardening profile should be specified all the way to the core. If this is not known, it may be determined empirically via the following formula:

$$HV(t) = HV_{core} + (HV_{surface} - HV_{core}) \cdot \left(\frac{50}{HV_{surface} - HV_{core}} \right)^{\left(\frac{t}{t_N}\right)^2}$$

where

t = local depth

$HV(t)$ = hardness at depth t

HV_{core} = core hardness (minimum)

$HV_{surface}$ = surface hardness (minimum)

t_N = nitriding depth as defined above (minimum)

9.1 Local Fatigue Strength (2020)

It is important to note that in nitrided crankshaft cases, fatigue is found either at the surface or at the transition to the core. This means that the fatigue strength can be determined by tests as described in Appendix 4-2-1-A8.

Alternatively, the surface fatigue strength (principal stress) can be determined empirically and conservatively as follows. This is valid for a surface hardness of 600 HV or greater:

$$\sigma_{Fsurface} = 450\mathrm{MPa}$$

Note that this fatigue strength is assumed to include the influence of the surface residual stress and applies for a working stress ratio of $R = -1$.

The fatigue strength in the transition zone can be determined by the equation introduced in 4-2-1-A4/11. For crankpin and respectively to journal applies:

$$\sigma_{Ftransition,cpin} = \pm K \cdot (0.42 \cdot \sigma_B + 39.3) \cdot \left[0.264 + 1.073 \cdot Y^{-0.2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{X}}\right]$$

where

Y = D_G for journal fillet

= D for crankpin fillet

= D for oil bore outlet

X = R_G for journal fillet

= R_H for crankpin fillet

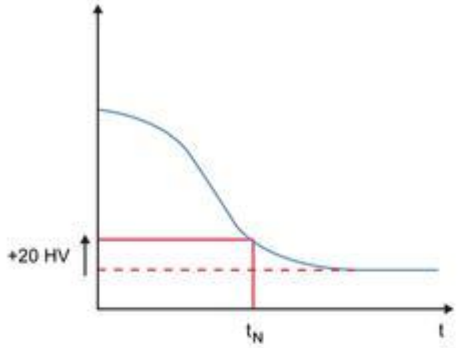
= $D_o/2$ for oil bore outlet

Note that this fatigue strength is not assumed to include the influence of the residual stresses.

In contrast to induction-hardening the nitrided components have no such distinct transition to the core. Although the compressive residual stresses at the surface are high, the balancing tensile stresses in the core are moderate because of the shallow depth. For the purpose of analysis of subsurface fatigue the disadvantage of tensile residual stresses in and below the transition zone may be even disregarded in view of this smooth contour of a nitriding hardness profile.

Although in principle the calculation should be carried out along the entire hardness profile, it can be limited to a simplified approach of examining the surface and an artificial transition point. This artificial transition point can be taken at the depth where the local hardness is approximately 20 HV above the core hardness. In such a case, the properties of the core material should be used. This means that the stresses at the transition to the core can be found by using the local SCF formulae mentioned earlier when inserting $t = 1.2t_N$.

FIGURE 7
Sketch of the Location for the Artificial Transition Point in the Depth Direction



11 Cold Forming

The advantage of stroke peening or cold rolling of fillets is the compressive residual stresses introduced in the high-loaded area. Even though surface residual stresses can be determined by X-ray diffraction technique and subsurface residual stresses can be determined through neutron diffraction, the local fatigue strength is virtually non-assessable on that basis since suitable and reliable correlation formulae are hardly known.

Therefore, the fatigue strength has to be determined by fatigue testing; see also Appendix 4-2-1-A8. Such testing is normally carried out as four-point bending, with a working stress ratio of $R = -1$. From these results, the bending fatigue strength – surface- or subsurface-initiated depending on the manner of failure – can be determined and expressed as the representative fatigue strength for applied bending in the fillet.

In comparison to bending, the torsion fatigue strength in the fillet may differ considerably from the ratio $\sqrt{3}$ (utilized by the von Mises criterion). The forming-affected depth that is sufficient to prevent subsurface fatigue in bending, may still allow subsurface fatigue in torsion. Another possible reason for the difference in bending and torsion could be the extension of the highly stressed area.

The results obtained in a full-size crank test can be applied for another crank size provided that the base material (alloyed Q+T) is of the similar type and that the forming is done so as to obtain the similar level of compressive residual stresses at the surface as well as through the depth. This means that both the extension and the depth of the cold forming is to be proportional to the fillet radius.

11.1 Stroke Peening by Means of a Ball

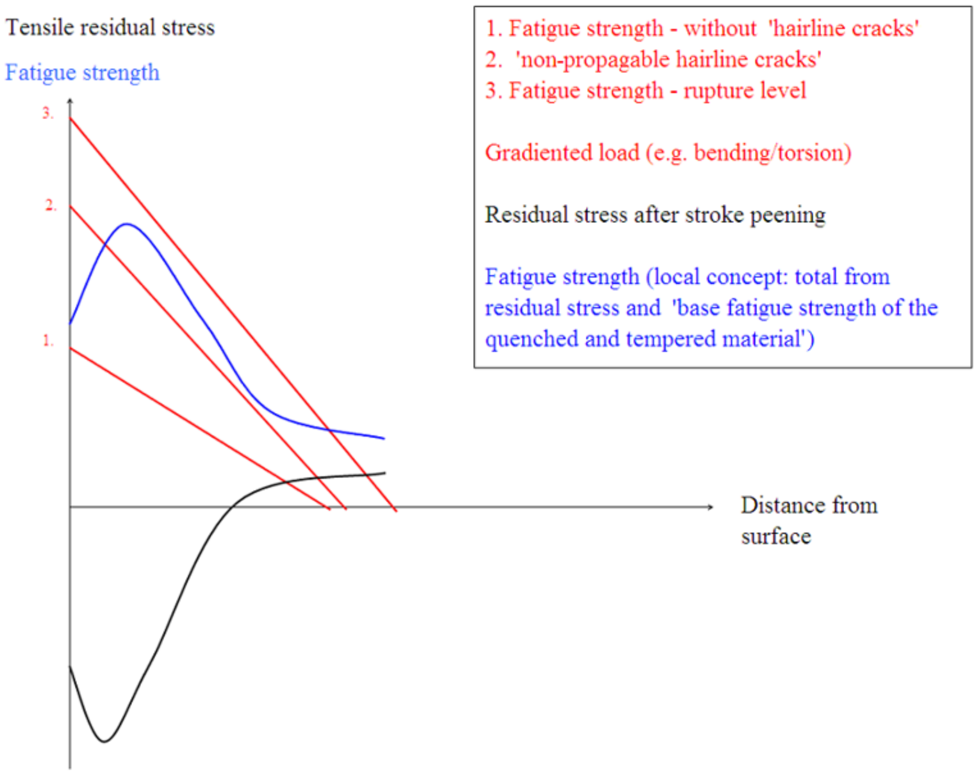
The fatigue strength obtained can be documented by means of full size crank tests or by empirical methods if applied on the safe side. If both bending and torsion fatigue strengths have been investigated and differ from the ratio $\sqrt{3}$, the von Mises criterion should be excluded.

If only bending fatigue strength has been investigated, the torsional fatigue strength should be assessed conservatively. If the bending fatigue strength is concluded to be $x\%$ above the fatigue strength of the non-peened material, the torsional fatigue strength should not be assumed to be more than 2/3 of $x\%$ above that of the non-peened material.

As a result of the stroke peening process the maximum of the compressive residual stress is found in the subsurface area. Therefore, depending on the fatigue testing load and the stress gradient, it is possible to have higher working stresses at the surface in comparison to the local fatigue strength of the surface. Because of this phenomenon small cracks may appear during the fatigue testing, which will not be able to propagate in further load cycles and/or with further slight increases of the testing load because of the profile of the compressive residual stress. Put simply, the high compressive residual stresses below the surface “arrest” small surface cracks.

This is illustrated in 4-2-1-A9/11.1 FIGURE 8 as gradient load 2.

FIGURE 8
Working and Residual Stresses below the Stroke-peened Surface



Note:

Straight lines 1~ 3 represent different possible load stress gradients .

In fatigue testing with full-size crankshafts these small "hairline cracks" should not be considered to be the failure crack. The crack that is technically the fatigue crack leading to failure, and that therefore shuts off the test-bench, should be considered for determination of the failure load level. This also applies if induction-hardened fillets are stroke-peened.

In order to improve the fatigue strength of induction-hardened fillets it is possible to apply the stroke peening process in the crankshafts' fillets after they have been induction-hardened and tempered to the required surface hardness. If this is done, it might be necessary to adapt the stroke peening force to the hardness of the surface layer and not to the tensile strength of the base material. The effect on the fatigue strength of induction hardening and stroke peening the fillets is to be determined by a full-size crankshaft test.

11.1.1 Use of Existing Results for Similar Crankshafts

The increase in fatigue strength, which is achieved by applying stroke peening, may be utilized in another similar crankshaft if all of the following criteria are fulfilled:

- Ball size relative to fillet radius within ± 10% in comparison to the tested crankshaft
- At least the same circumferential extension of the stroke peening
- Angular extension of the fillet contour relative to fillet radius within ± 15% in comparison to the tested crankshaft and located to cover the stress concentration during engine operation
- Similar base material (e.g., alloyed quenched and tempered)
- Forward feed of ball of the same proportion of the radius
- Force applied to ball proportional to base material hardness (if different)
- Force applied to ball proportional to square of ball radius

11.3 Cold Rolling

The fatigue strength can be obtained by means of full size crank tests or by empirical methods, if these are applied so as to be on the safe side. If both, bending and torsion fatigue strengths have been investigated, and differ from the ratio $\sqrt{3}$, the von Mises criterion should be excluded.

If only bending fatigue strength has been investigated, the torsional fatigue strength should be assessed conservatively. If the bending fatigue strength is concluded to be $x\%$ above the fatigue strength of the non-rolled material, the torsional fatigue strength should not be assumed to be more than $^2/_3$ of $x\%$ above that of the non-rolled material.

11.3.1 Use of Existing Results for Similar Crankshafts

The increase in fatigue strength, which is achieved applying cold rolling, may be utilized in another similar crankshaft if all of the following criteria are fulfilled:

- At least the same circumferential extension of cold rolling
- Angular extension of the fillet contour relative to fillet radius within $\pm$ 15% in comparison to the tested crankshaft and located to cover the stress concentration during engine operation
- Similar base material (e.g., alloyed quenched and tempered)
- Roller force to be calculated so as to achieve at least the same relative (to fillet radius) depth of treatment

Appendix 10 Guidance for Calculation of Stress Concentration Factors in the Oil Bore Outlets of Crankshafts through Utilization of the Finite Element Method

1 General

The objective of the analysis described in this document is to substitute the analytical calculation of the stress concentration factor (SCF) at the oil bore outlet with suitable finite element method (FEM) calculated figures. The former method is based on empirical formulae developed from strain gauge readings or photo-elasticity measurements of various round bars. Because use of these formulae beyond any of the validity ranges can lead to erroneous results in either direction, the FEM-based method is highly recommended.

The SCF calculated according to the rules set forth in this document is defined as the ratio of FEM-calculated stresses to nominal stresses calculated analytically. In use in connection with the present method in 4-2-1-A4/5, principal stresses are to be calculated.

The analysis is to be conducted as linear elastic FE analysis, and unit loads of appropriate magnitude are to be applied for all load cases.

It is advisable to check the element accuracy of the FE solver in use (e.g., by modeling a simple geometry and comparing the FEM-obtained stresses with the analytical solution).

A boundary element method (BEM) approach may be used instead of FEM.

3 Model Requirements

The basic recommendations and assumptions for building of the FE-model are presented in 4-2-1-A10/3.1. The final FE-model is to meet one of the criteria in 4-2-1-A10/3.5.

3.1 Element Mesh Recommendations

For the mesh quality criteria to be met, construction of the FE model for the evaluation of stress concentration factors according to the following recommendations is advised:

i. The model consists of one complete crank, from the main bearing center line to the opposite side's main bearing center line.
ii. The following element types are used in the vicinity of the outlets:
    - 10-node tetrahedral elements
    - 8-node hexahedral elements
    - 20-node hexahedra elements
iii. The following mesh properties for the oil bore outlet are used:
    - Maximum element size $a = r/4$ through the entire outlet fillet as well as in the bore direction (if 8-node hexahedral elements are used, even smaller elements are to meet the quality criterion)
iv. Recommended manner for element size in the fillet depth direction
    - First layer's thickness equal to element size of a
    - Second layer's thickness equal to element size of $2a$
    - Third layer's thickness equal to element size of $3a$
v. The rest of the crank should be suitable for numeric stability of the solver
vi. Drillings and holes for weight reduction have to be modelled
vii. Submodeling may be used as long as the software requirements are fulfilled.

3.3 Material

4-2-1-A4/5 does not consider material properties such as Young's modulus (E) and Poisson's ratio (ν). In the FE analysis, these material parameters are required, as primarily strain is calculated and stress is derived from strain through the use of Young's modulus and Poisson's ratio. Reliable values for material parameters have to be used, either as quoted in the literature or measured from representative material samples.

For steel, the following is advised: $E = 2.05 \cdot 10^5 \mathrm{MPa}$ and $\nu = 0.3$.

3.5 Element Mesh Quality Criteria

If the actual element mesh does not fulfil any of the following criteria in the area examined for SCF evaluation, a second calculation, with a finer mesh is to be performed.

3.5.1 Principal Stresses Criterion

The quality of the mesh should be verified through checking of the stress component normal to the surface of the oil bore outlet radius. With principal stresses σ_1 , σ_2 and σ_3 the following criterion is to be met:

$$\min(|\sigma_1|, |\sigma_2|, |\sigma_3|) < 0.03\max(|\sigma_1|, |\sigma_2|, |\sigma_3|)$$

3.5.2 Averaged/Unaveraged Stresses Criterion

The criterion is based on observation of the discontinuity of stress results over elements at the fillet for the calculation of the SCF:

- Unaveraged nodal stress results calculated from each element connected to a node i should differ less than 5% from the 100% averaged nodal stress results at this node i at the location examined.

5 Load Cases and Assessment of Stress

For substitution of the analytically determined SCF in 4-2-1-A4/5, the following load cases are to be calculated.

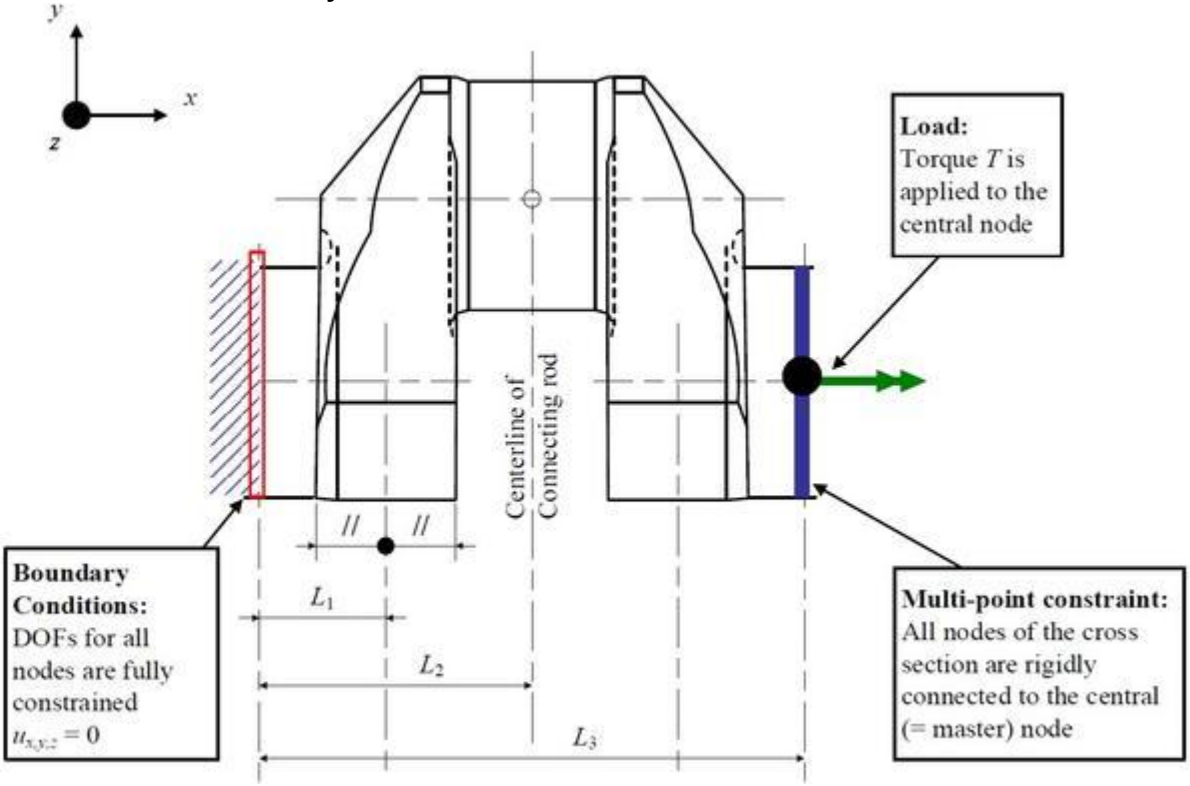
5.1 Torsion

The structure is loaded in pure torsion. The surface warp at the end faces of the model is suppressed.

Torque is applied to the central node, on the crankshaft axis. This node acts as the master node with six degrees of freedom, and is connected rigidly to all nodes of the end face.

The boundary and load conditions as shown in 4-2-1-A10/5.1 FIGURE 1 are valid for both in-line- and V- type engines.

FIGURE 1
Boundary and Load Conditions for the Torsion Load Case



For all nodes in an oil bore outlet, the principal stresses are obtained and the maximum value is taken for subsequent calculation of the SCF:

$$\gamma_T = \frac{\max(|\sigma_1|, |\sigma_2|, |\sigma_3|)}{\tau_N}$$

where the nominal torsion stress τ_N referred to the crankpin is evaluated per 4-2-1-A4/3.3 with torque T :

$$\tau_N = \frac{T}{W_p}$$

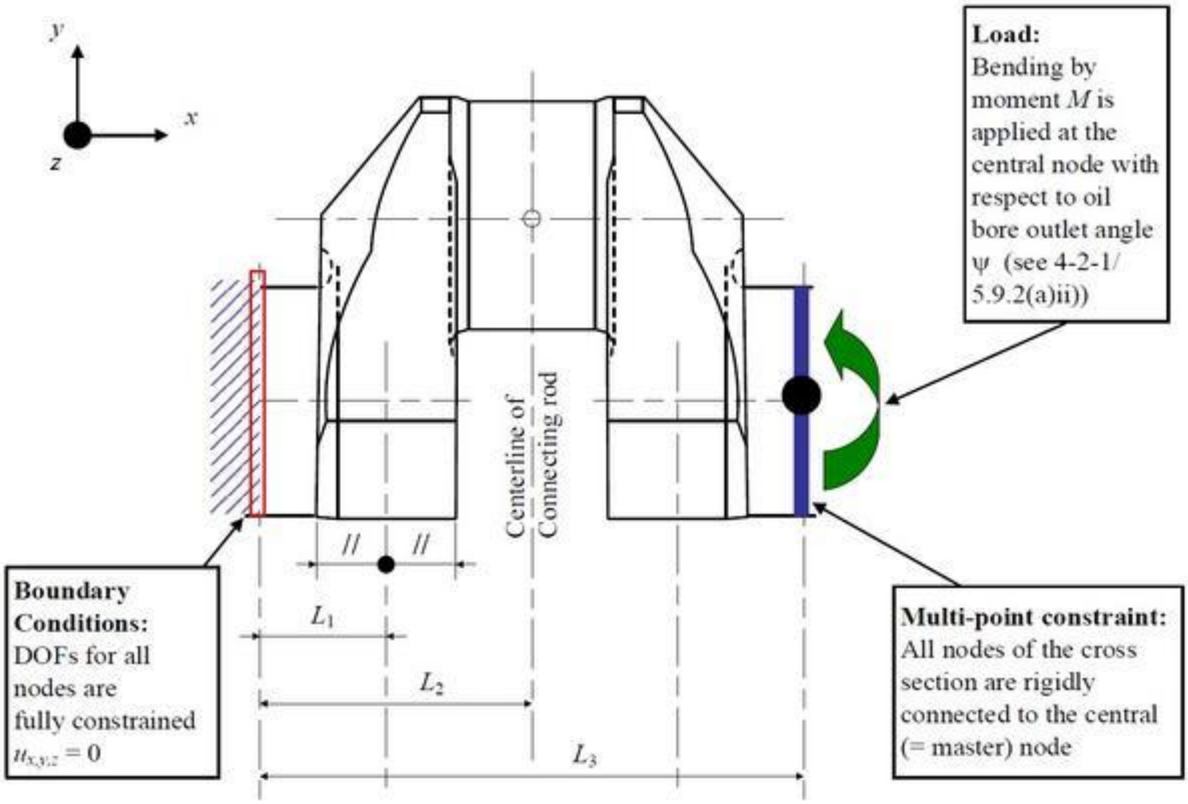
5.3 Bending

The structure is loaded in pure bending. The surface warp at the end faces of the model is suppressed.

The bending moment is applied to the central node on the crankshaft axis. This node acts as the master node, with six degrees of freedom, and is connected rigidly to all nodes of the end face.

The boundary and load conditions as shown in 4-2-1-A10/5.3 FIGURE 2 are valid for both in-line- and V- type engines.

FIGURE 2
Boundary and Load Conditions for the Pure Bending Load Case



For all nodes in the oil bore outlet, principal stresses are obtained and the maximum value is taken for subsequent calculation of the SCF:

$$\gamma_B = \frac{\max(|\sigma_1|, |\sigma_2|, |\sigma_3|)}{\sigma_N}$$

where the nominal bending stress σ_N referred to the crankpin is calculated per4-2-1-A4/1.3.ii. with bending moment M:

$$\sigma_N = \frac{M}{W_e}$$

Appendix 11 Guidance for Spare Parts

1 General (2025)

While spare parts are not required for purposes of classification, the below is provided as a guidance for vessels intended for unrestricted service.

3 Spare Parts for Main Propulsion Diesel Engines (2025)

3.1 Introduction (2025)

As main propulsion machinery, equipment, systems, and technologies emerge to address the ever developing and evolving needs of shipping, their complexity and diversity will increase. In such an operating environment, the application of rigid recommendations for spare parts, such as those defined in a traditional list-based approach, may not always be appropriate.

A risk assessment for the spare parts to be carried on board the vessel is recommended for providing the vessel with flexible and adaptable means to satisfy the need for spare parts required to perform associated maintenance, with the intent of avoidance of sudden operational failures to equipment, components and systems which may result in hazardous situations or unsafe events.

The ISM Code and IACS Recommendation No. 74 and No. 127 contain guidance upon which a risk assessment may be based.

In this context, "main propulsion diesel engines" refers to engines providing propulsion power irrespective of the configuration of the propulsion system (e.g., direct drive, geared, hybrid, diesel electric, etc.) and includes their control systems, both local and remote, their alarm systems, and their safety systems.

3.3 Risk Assessment Approach to Determining Spare Parts Provision **(2025)**

3.3.1 Identification of Essential Engine Components

A risk assessment at the component level (e.g., FMEA, FMECA, FTA, ETA, etc.) would normally be undertaken for each type of engine to identify components, the failure of which, could potentially result in engine damage, unsafe engine operation, or a reduction in engine power output.

The risk assessment may consider both the likelihood and consequence of component failure. Failure likelihood is to be based upon OEM data (known reliability values, MTBF and similar statistics, as well as OEM recommendations), as well as vessel configuration and operator experience (redundancy, relevant service history for the model and operating profile, service-specific failure rates).

The risk assessment is to consider each fuel on which the engine is designed to operate independently, and therefore, for the purposes of determining spare parts, fuel changeover is not to be considered a mitigation for component failure.

The risk assessment may be carried out in accordance with recognized national or international standards.

The risk assessment report can be included in the documentation submitted for Type Approval of the engine.

3.3.2 Determination of Recommended Spare Parts

Determination of recommended spare parts for each type of engine would normally take into account the results of the risk assessment together with any evidence of component failure rates such as known reliability (e.g., relevant service history, MTBF data, etc.)

The recommended spare parts are to be parts (or sets of parts) suitable for exchange onboard by the vessel's crew and with available onboard tooling and consumables.

The recommended spare parts can be listed and included in the engine user documentation (e.g., operating and/or maintenance manual, product guide, project guide etc.).

The recommended spare parts list can be included in the documentation submitted for Type Approval of the engine.

3.3.3 Recommended Number of Spare Parts to be Supplied

For each type of engine, at least one recommended spare part (or set of spare parts) is to be supplied for each different type of part determined by 4-2-1-A11/3.3.2 above, unless the risk assessment concludes otherwise.

For spare parts periodically exchanged in normal operation (e.g., exhaust valves), at least two spare parts (or sets of spare parts) are to be supplied for each type of part determined by 4-2-1-A11/3.3.2 above, unless the risk assessment concludes otherwise.

Spare parts supplied may be verified and documented by means of Society Certificate (SC), Work Certificate (W) or Test Report (TR), in accordance with Section 4-2-1.

3.3.4 Spare Parts Inventory to be Carried On Board

For determination of the spare parts inventory to be carried on board, a vessel specific risk assessment is to be undertaken (e.g., HAZID) to establish any need to supplement the engine spares supplied with additional spare parts.

The risk assessment is to establish the numbers or quantity of each type of spare parts (or sets of spare parts) required, the types of spare parts required, and the scope of spare parts required taking into account the following considerations:

- Vessel type and operational profile
- Number and types of engines installed, their arrangement, and any redundancy
- Engine and component service experience and service history
- Maintenance policy and maintenance regime
- Manufacturer's recommendations for maintenance and/or repair
- Tools required for fitting spare parts
- Spare parts required to be carried by regulations

3.5 Traditional Approach to Determining Spare Parts Provision **(2025)**

In cases where a risk assessment approach has not been taken, the table below provides a generic example of the typical minimum recommended spare parts for conventionally fueled main internal combustion engines. This example has been developed to deal with cases of such vessels complying with the international regulations effective at the time of approval of Rev.1 of IACS Recommendation 26 and would normally be taken into account when spare parts to be provided on board the vessel and their actual number should be determined. The table is not intended to replace any guidance set by the engine manufacturers with regard to recommended spares for their equipment.

Item		Spare Part	Number Recommended
1.	Main bearings	Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts	1
2.	Main thrust block	Pads for one face of Michell type thrust block, or	1 set
		Complete white metal thrust shoe of solid ring type, or	1
		Inner and outer race with rollers, where roller thrust bearings are fitted	1
3.	Cylinder liner	Cylinder liner, complete with joint rings and gaskets	1
4.	Cylinder cover	Cylinder cover, complete with all valves, joint rings and gaskets.	1
		Cylinder cover bolts and nuts, for one cylinder	1/2 set
5.	Cylinder valves	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder	2 sets
		Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder	1 set
		Starting air valve, complete with casing, seat, springs and other fittings	1
		Fuel valves of each size and type fitted, complete with all fittings, for one engine	1 set [(a)]
6.	Connecting rod bearings	Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder	1 set
		Top end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder	1 set
7.	Pistons	Crosshead type: Piston of each type fitted, complete with piston rod, stuffing box, skirt, rings, studs and nuts	1
		Trunk piston type: Piston of each type fitted, complete with skirt, rings, studs, nuts, gudgeon pin and connecting rod.	1
8.	Piston rings	Piston rings, for one cylinder	1 set

Item		Spare Part	Number Recommended
9.	Piston cooling	Telescopic cooling pipes, fittings and seals or their equivalent, for one cylinder unit	1 set
10.	Cylinder lubricators	Lubricator, complete, of the largest size, with its chain drive or gear wheels, or equivalent spare part kit	1
11.	Fuel injection pumps	Fuel pump complete or when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valve springs, etc.), or equivalent high pressure fuel pump (e.g. common rail pump or servo pump essential for operation of fuel injection system)	1
12.	Fuel injection piping	High pressure double wall fuel pipe of each size and shape fitted, complete with couplings	1 set
13.	Scavenge blowers (including turbo chargers)	Rotors, rotor shafts, bearings, nozzle rings and gear wheels or equivalent working parts if other types	1 set [(b)]
14.	Scavenging system	Suction and delivery valves for one pump of each type fitted	1 set
15.	Reduction and/or reverse gear	Complete bearing bush, of each size fitted in the gear case assembly	1 set
		Roller or ball race, of each size fitted in the gear case assembly	1 set
16	Control, alarm, and safety system	Parts essential for safe engine operation	1 set

Footnotes:

a) *(i)* Engines with one or two fuel valves per cylinder: one set of fuel valves, complete.

(ii) Engines with three or more fuel valves per cylinder: two fuel valves complete per cylinder, and a sufficient number of valve parts, excluding the body, to form, with those fitted in the complete valves, a full engine set.

b) The spare parts may be omitted where it has been demonstrated, at the Builder's test bench for one engine of the type concerned, that the engine can be maneuvered satisfactorily with one blower out of action.
The requisite blanking and blocking arrangements for running with one blower out of action are to be available on board.

Notes:

1 The availability of other spare parts, such as gears and chains for camshaft drive, are to be specially considered and decided upon by the vessel operator.

2 It is assumed that the new crew has on board the necessary tools and equipment.

3 When the recommended spares are utilized, it is recommended that new spares are supplied as soon as possible.

4 In case of multi-engine installations, the minimum recommended spares are only necessary for one engine.

5 Spare Parts for Auxiliary Diesel Engines

5.1 Introduction **(1 July 2025)**

Recognizing the complexity and diversity of machinery, equipment and systems providing essential services, a recommended list of spare parts may not always be relevant. In such circumstances, a risk-based approach should be taken in order to determine the spare parts to be carried on board. Such a risk-based approach is described in 4-2-1A11/3.3 for internal combustion engines. However, the approach described is equally relevant to other machinery, equipment, and systems.

5.3 Traditional Approach to Determining Spare Parts Provision **(1 July 2025)**

In cases where a risk assessment approach has not been taken, the following list is provided as guidance for auxiliary diesel engines on vessels intended for unrestricted service. Depending on the design of the engine, spare parts other than those listed below, such as electronic control cards, may be considered. The table is not intended to replace any guidance provided by manufacturers or suppliers regarding recommended spare parts.

Item		Spare Part	Number Recommended
1.	Main bearings	Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts	1
2.	Cylinder valves	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder	2 sets
		Air inlet valves, complete with casings, seats, springs, and other fittings for one cylinder	1 set
		Starting air valve, complete with casing, seat, springs and other fittings	1
		Fuel valves of each size and type fitted, complete, with all fittings, for one engine	1/2 set
3.	Connecting rod bearings	Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder	1 set
		Trunk piston type: gudgeon pin with bush for one cylinder	1 set
4.	Piston rings	Piston rings, for one cylinder	1 set
5.	Piston cooling	Telescopic cooling pipes and fittings or their equivalent, for one cylinder unit	1 set
6.	Fuel injection pumps	Fuel pump complete or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valve springs, etc.), or equivalent high pressure fuel pump (e.g. common rail pump or servo pump essential for operation of fuel injection system)	1
7.	Fuel injection piping	High-pressure double wall fuel pipe of each size and shape fitted, complete with couplings	1
8.	Gaskets and packings	Special gaskets and packings of each size and type fitted, for cylinder covers and cylinder liners for one cylinder	1 set
9.	Control, alarm, and safety system	Parts essential for safe engine operation	1 set

Notes:

1 The availability of other spare parts are to be specially considered and decided upon by the vessel operator.

2 It is assumed that the new crew has on board the necessary tools and equipment.

3 When the recommended spares are utilized, it is recommended that new spares are supplied as soon as possible.

4 Where the number of generators of adequate capacity fitted for essential services exceeds the required number, spare parts may be omitted.

Section 4 Steam Turbines
Appendix 1 Guidance for Spare Parts

1 General (1 July 2025)

Recognizing the complexity and diversity of machinery, equipment and systems providing essential services, a recommended list of spare parts may not always be relevant. In such circumstances, a risk-based approach should be taken in order to determine the spare parts to be carried on board.

Such a risk-based approach is described in 4-2-1-A11/3.3 for internal combustion engines. However the approach described is equally relevant to other machinery, equipment, and systems.

1.1 Traditional Approach to Determining Spare Parts Provision

While spare parts are not required for purposes of classification, in cases where a risk assessment approach is not followed, the spare parts list below is provided as a guidance for vessels intended for unrestricted service. Depending on the turbine design, spare parts other than those listed below, such as electronic control cards, should be considered.

3 Spare Parts for Propulsion *Steam Turbines* (1 July 2025)

a. One (1) set of springs for governor, relief, and maneuvering valves

b. Sufficient packing rings with springs to repack one gland of each kind and size
c. One (1) set of thrust pads or rings, also springs where fitted, for each size turbine-thrust bearing
d. Bearing bushings sufficient to replace all the bushings on every turbine rotor, pinion, and gear for main propulsion, spare bearing bushings sufficient to replace all the bushings on each non-identical auxiliary-turbine rotor, pinion, and gear having sleeve-type bearings or complete assemblies consisting of outer and inner races and cages complete with rollers or balls where these types of bearings are used
e. One (1) set of bearing shoes for one face, for one single-collar type main thrust bearing where fitted. Where the ahead and astern pads differ, pads for both faces are to be provided.
f. One (1) set of strainer baskets or inserts for filters of special design of each type and size, for oil filters.
g. Necessary special tools.

Notes:

1. The availability of other spare parts should be specially considered and decided upon by the vessel operator.
2. It is assumed that the crew has on board the necessary tools and equipment.
3. When the recommended spares are utilized, it is recommended that new spares are supplied as soon as possible.
4. In the case of multi-turbine installations, the minimum recommended spare parts are only necessary for one turbine.

5 Spare Parts for Steam Turbines Driving Electric Generators (1 July 2025)

a)	Main bearings	Bearing bushes or roller bearings of each size and type fitted for the shafts of the turbine rotor and of the reduction gearing, if any, for one engine	1 set
b)	Turbine thrust bearing	Pads for one face of tilting pad type thrust, with liners, or rings for turbine adjusting block with assorted liners, for one engine	1 set
c)	Turbine shaft sealing rings	Carbon sealing rings where fitted, with springs for each size and type of gland, for one engine	1 set
d)	Oil filters	Strainer baskets or inserts, for filters of special design, of each type and size	1 set

Notes:

1. The availability of other spare parts should be specially considered and decided upon by the vessel operator.
2. It is assumed that the crew has on board the necessary tools and equipment.
3. When the recommended spares are utilized, it is recommended that new spares are supplied as soon as possible.
4. Where the number of generators of adequate capacity fitted for essential services exceeds the required number, spare parts may be omitted.

Offshore Rules (OR) (Jan 2026)

Part 4 Machinery and Systems

Chapter 1 Machinery, Equipment and Systems

Section 1 General

1 Objective

1.1 Goals

The machinery, equipment and systems covered in this Chapter are to be designed, constructed, operated, and maintained to:

Goal No.	Goal
POW 1	provide safe and reliable storage and supply of fuel/energy/power.

Goal No.	Goal
PROP 2	provide redundancy and/or reliability to maintain propulsion.
SAFE 1	promote the occupational health and safety of personnel onboard.

The goals in the cross-referenced Rules/Regulations are also to be met.

1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of the machinery equipment and systems are to be in accordance with the following functional requirements:

Functional Requirement	Functional Requirement
Propulsion, Maneuvering, Station Keeping (PROP)	
PROP-FR1 (POW)	Machinery and systems are to operate under all anticipated environmental and operating conditions, including weather, vibration, inclination, and low and high temperature.
Safety of Personnel (SAFE)	
SAFE-FR1	Materials that harm human health are not to be used in machinery.

The Functional Requirements in the cross-referenced Rules/Regulations are also to be met.

1.3 Compliance

A unit is considered to comply with the Goals and Functional Requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

Part 4 contains requirements for marine systems. Requirements associated with the unit function (i.e., hydrocarbon production) are contained in Part 8.

2 Requirements for Classification

Part 4 contains general requirements for machinery, equipment and systems (Chapter 1) and the design requirements for piping systems (Chapter 2) and electrical systems (Chapter 3).

Part 5 contains the design requirements for safety systems, including fire extinguishing systems.

Part 6 contains the design, testing and survey requirements for the certification of equipment, machinery and system components at vendor’s shop.

Part 7A, 7B or 7C contains the survey requirements during construction of units at builder’s yard (Chapter 1) and the requirements for periodical surveys after construction (Chapter 2).

Part 8 contains specific classification requirements for each type of offshore units as well as for specific machinery, equipment and system installed onboard for the intended offshore services.

3 Definitions

3.1 Control Station

A location where controllers or actuators are fitted,along with monitoring devices, as appropriate, for purposes of effecting desired operation of specific machinery.

Control Station is defined solely for purposes of passive fire protection as intended by the IMO MODU Code, in 5-1-1/3.9.2.1.

Centralized Control Station is defined in Part 4, Chapter 9 "Remote Propulsion Control and Automation" of the ABS *Rules for Building and Classing Marine Vessels (Marine Vessel Rules)* to refer to the space or the location where the following functions are centralized:

- Controlling propulsion and auxiliary machinery,

- Monitoring propulsion and auxiliary machinery, and
- Monitoring the propulsion machinery space.

3.3 Machinery Space

*Machinery Space*s are machinery spaces of category A and other spaces containing propulsion machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation, and air-conditioning machinery and similar spaces, and trunks to such spaces.

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

i. Internal combustion machinery used for main propulsion; or
ii. Internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 KW (500 hp); or
iii. Any oil-fired boiler or oil fuel unit; or
iv. Any oil-fired equipment other than boiler, such as inert gas generator, incinerator, or waste disposal units, etc.

Commentary:

Item iv applies only to fire safety requirements similar to SOLAS Chapter II-2. See IMO MSC/Circ.847.

End of Commentary

3.5 Essential Services

Essential services are:

i. Those services considered necessary for:
    - Continuous operation to maintain propulsion and steering in self-propelled units (primary essential services);
    - Systems of the unit whose loss or failure would create an immediate danger to the unit (primary essential services);
    - Non-continuous operation to maintain propulsion and steering in self-propelled units and a minimum level of safety for the unit's navigation and systems (secondary essential services)
ii. Emergency services as described in (each service is either primary essential or secondary essential depending upon its nature, as described above); and
iii. Other special characteristics (e.g., special services) of the unit whose loss or failure would create a potential danger to the unit (secondary essential services).

Examples of primary essential services and secondary essential services are as listed in 4-1-1/TABLE 3 and 4-1-1/ TABLE 4, respectively.

3.7 Hazardous Areas

See 4-3-6/2.1 for definition. For hazardous area classification of specific areas, refer to:

- Helicopter refueling facilities, see 4-3-6/6.5.

- Paint stores, see 4-3-6/6.1.
- Battery Rooms, see 4-3-6/6.3.
- Oxygen-acetylene Storage Rooms, see 4-3-6/6.7.

- Areas related to Drilling Activities, see 8-2-1/13.

3.9 Dead Ship Condition

Dead ship condition means a condition under which:

i. The main propulsion plant, boilers and auxiliary machinery are not in operation due to the loss of the main source of electrical power, and
ii. In restoring propulsion, no stored energy for starting the propulsion plant, the main source of electrical power and other essential auxiliary machinery is assumed to be available.

3.11 Blackout

Blackout situation means the loss of the main source of electrical power resulting in the main and auxiliary machinery being out of operation.

3.13 Piping Systems

For definitions related to piping systems, refer to 4-2-1/3.

3.15 Electrical Installations

For definitions related to electrical installations, refer to 4-3-1/3.

3.17 Fail Safe

Fail Safe means that the component or system is designed to return to a predetermined position upon failure. The predetermined position is to maintain the system in a safe condition.

5 Machinery Plans

5.1 Submission of Plans

Machinery and systems plans required by the Rules are to be submitted electronically by the manufacturer, designer or shipyard to ABS. Where so stated in the shipbuilding contract, the Owner may require the shipyard to provide copies of approved plans and related correspondence. A fee will be charged for the review of plans which are not covered by a contract of classification with the shipyard.

All plans are to be submitted and approved before proceeding with the work.

5.3 Plans

Machinery and systems plans required to be submitted for review and approval by ABS are listed in each of the sections in Part 4. Equipment plans are to contain performance data and operational particulars; standard of compliance where standards are used in addition to, or in lieu of, the Rules; construction details such as dimensions, tolerances, welding details, welding procedures, material specifications, etc.; and engineering calculations or analyses in support of the design. System plans are to contain a bill of material with material specifications or particulars, a legend of symbols used, system design parameters, and are to be in a schematic format. Booklets containing standard shipyard practices of piping and electrical installations are required to supplement schematic system plans.

5.5 Additional Notations

In the case of units for which additional class notations covered by other ABS Rules and Guides have been requested, machinery and systems plans related to the services covered by the additional class notations are required to be submitted for review and approval by ABS as indicated in the corresponding Rules and Guides.

5.7 Repair and Modification of Machinery

When repairs or modifications are made to ABS approved systems and equipment, documentation identifying the changes, as well as any documentation that supersedes or replaces previously approved documentation is required to be submitted for ABS review and approval by the equipment designer or responsible party. Repairs and modifications are to be carried out to the satisfaction of the Surveyor. If the service or product bulletin indicates modification or alterations to the component that would impact the Class approval, these details are to be submitted to ABS Engineering for review and approval.

7 Miscellaneous Requirements for Machinery

7.1 Inclinations

All machinery, components and systems for essential services, as defined in 4-1-1/3.5, are to be designed to operate under the inclinations as indicated for each of the conditions listed in 4-1-1/TABLE 1.

TABLE 1
Angle of Inclination

Condition	Static	Dynamic
Column-Stabilized Units	15° in any direction	22.5° in any direction
Self-Elevating Units	10° in any direction	15° in any direction
Surface Units	15° list and 5° trim simultaneously	22.5° rolling and 7.5° pitching simultaneously

7.3 Dead Ship Start

Means are to be provided to bring the machinery into operation from a "dead ship" condition, as defined in 4-1-1/3.9. See 4-3-2/3.1.4 and 4-3-3/3.27 for the required starting arrangements.

7.5 Unattended Machinery Spaces

Controls necessary for safe operation are to be provided for machinery in spaces which are not normally manned. Relevant data is to be submitted to permit the assessment of the effect of such controls on the safety of the unit. See 4-2-4/3.7 for bilge alarm systems and 5-3-1/11 for fire precautions for such spaces.

7.7 Ambient Temperature

For units of unrestricted service, ambient temperature, as indicated in 4-1-1/TABLE 2, is to be considered in the selection and installation of machinery, equipment and components. For drilling units of restricted or specific service, the ambient temperature appropriate for the specific nature is to be considered. See 3A-1-4/2.9.

Systems and equipment used solely for specific operations associated with class notations are to follow temperature requirements as outlined within the applicable recognized standards to which they are designed and constructed in accordance with 8-1-1/3.

Machinery, equipment and components related to marine equipment on the open deck for units with unrestricted service are to be rated for a minimum air temperature equal to the Design Service Temperature (DST) for the unit.

Control, monitoring and safety devices/systems of equipment for essential services (item (l) of 4-1-1/TABLE 3 and 4-1-1/TABLE 4), when located on the open deck are to be rated for a Minimum Air Temperature (MAT) of 15°C below the DST. If operation of the equipment is not anticipated at temperatures below the DST, these devices/systems need not be operable below DST but physical components are not to be damaged if exposed to temperatures down to the MAT.

TABLE 2
Ambient Temperatures for Machinery, Equipment and Appliances in Units of Unrestricted Service

Air		
Installations, Components	*Location, Arrangement* (1, 2)	*Temperature Range (°C)*
Machinery and electrical installations	Enclosed Spaces – General	0 to +45°C
	Components mounted on machinery associated with high temperature	According to specific machinery and installation
	In spaces subject to higher temperature (details to be submitted)	According to the actual maximum ambient temperature
	In spaces with temperature lower than +45°C (details to be submitted)	According to the actual ambient temperature subject to minimum +40
	Open Deck (3)	–25 to +45°C
Water		
Coolant		*Temperature (°C)*

Seawater	+32°C

Notes:

1. Electronic equipment is to be suitable for operations up to 55°C. See also 4-3-1/17.3.
2. For environmentally controlled spaces, see 4-3-1/17.3.
3. The minimum air temperature need not be less than the service temperature identified for the unit (see 3A-1-4/1.9 and 3A-1-2/1) and documented in the unit's Operating Manual as per 1B-2-3/1 of the ABS *Rules for Conditions of Classification – Offshore Units (Part 1B)*, except for control, monitoring, and safety devices/systems of equipment associated with essential services which are to be based on Minimum Atmospheric Temperature (MAT) as indicated in 4-1-1/7.7.

7.9 Materials Containing Asbestos

Installation of materials which contain asbestos is prohibited.

7.11 Materials and Welding for Machinery Components

Materials used in the construction of the machinery of units are to be in accordance with the ABS *Rules for Materials and Welding (Part 2)*.

For welding procedures and details for machinery components, see Section 2-4-2.

TABLE 3
Primary Essential Services

(a)	Steering gears
(b)	Pumps for controllable pitch propellers
(c)	Scavenging air blower, fuel oil supply pumps, fuel valve cooling pumps, lubricating oil pumps and cooling water pumps for main and auxiliary engines, turbines and shafting necessary for propulsion
(d)	Ventilation necessary to maintain propulsion
(e)	Forced draft fans, feed water pumps, water circulating pumps, vacuum pumps and condensate pumps for steam plants on steam turbine units, and also for auxiliary boilers where steam is used for equipment supplying primary essential services
(f)	Oil burning installations for steam plants on steam turbine units and for auxiliary boilers where steam is used for equipment supplying primary essential services
(g)	Azimuth thrusters which are the sole means for propulsion/steering with lubricating oil pumps, cooling water pumps, etc.
(h)	Electrical equipment for electric propulsion plant with lubricating oil pumps and cooling water pumps
(i)	Electric generators and associated power sources supplying primary essential equipment
(j)	Hydraulic pumps supplying primary essential equipment
(k)	Viscosity control equipment for heavy fuel oil
(l)	Control, monitoring and safety devices/systems of equipment for primary essential services
(m)	Fire pumps and other fire extinguishing medium pumps.
(n)	Navigation lights, aids and signals.
(o)	Internal safety communication equipment.
(p)	Lighting system.
(q)	Services considered necessary to maintain dangerous spaces in a safe condition
(r)	Blow-out preventer control systems
(s)	Well control systems
(t)	Dynamic positioning systems
(u)	Ventilation systems necessary to maintain a safe atmosphere
(v)	Elevating (jacking) systems
(w)	Ballast control systems (on column stabilized units)

TABLE 4
Secondary Essential Services

(a)	Windlass
(b)	Fuel oil transfer pumps and fuel oil treatment equipment
(c)	Lubrication oil transfer pumps and lubrication oil treatment equipment
(d)	Pre-heaters for heavy fuel oil
(e)	Starting air and control air compressors
(f)	Bilge, ballast and heeling pumps
(g)	Ventilating fans for engine and boiler rooms
(h)	Fire and gas detection and alarm system
(i)	Electrical equipment for watertight and fire-tight closing appliances
(j)	Electric generators and associated power sources supplying secondary essential equipment
(k)	Hydraulic pumps supplying secondary essential equipment
(l)	Control, monitoring and safety devices/systems of equipment for secondary essential services
(m)	Inerting systems
(n)	Ambient temperature control equipment required by 4-3-1/17.3
(o)	Watertight Doors (see 3A-3-2/5)

Section 2 Machinery and Equipment

1 Prime Movers

1.1 Application

Prime movers (diesel engines, gas turbines, steam turbines) having a rated power of 100 kW (135 hp) and over, intended for essential services (see 4-1-1/3.5) or for services related to additional optional notations requested for the unit, are to be designed, constructed, tested, certified and installed in accordance with the requirements of Part 4, Chapter 2 of the ABS *Rules for Building and Classing Marine Vessels (Marine Vessel Rules)*.

Prime movers having a rated power of less than 100 kW (135 hp) are not required to comply with Part 4, Chapter 2 of the *Marine Vessel Rules*, but are to be designed, constructed and equipped in accordance with good commercial and marine practice. Acceptance of such engines will be based on manufacturer's affidavit, verification of engine nameplate data, and subject to a satisfactory performance test after installation conducted in the presence of the Surveyor. Automatic air intake shut-off valves or equivalent arrangements are to be provided in accordance with 8-2-1/11.

Prime movers having a rated power of 100 kW (135 hp) and over, intended for services not considered essential (see 4-1-1/3.5) and not related to additional optional notations requested for the unit, are not required to be designed, constructed and certified by ABS in accordance with the requirements of Part 4, Chapter 2 of the *Marine Vessel Rules*. However, they are to comply with safety features, such as crankcase explosion relief valve, overspeed protection, etc., as provided in 4-2-1/7 of the *Marine Vessel Rules*, as applicable. After installation, they are subject to a satisfactory performance test conducted in the presence of the Surveyor. Automatic air intake shut-off valves or equivalent arrangements are to be provided in accordance with 8-2-1/11.

Drilling, hydrocarbon production, and other types of units where large amounts of flammable gases may be present, are to be fitted with automatic air intake shut off valves. Automatic air intake shut-off valves or equivalent arrangements are to be provided in accordance with 8-2-1/11.

3 Propulsion, Maneuvering and Dynamic Positioning Systems

Self-propelled units and those receiving notations related to propulsion assist thrusters and athwartship thrusters are to be fitted to thrusters that comply with the following:

- Main propulsion thrusters Section 4-3-5 of the *Marine Vessel Rules*
- Waterjets Section 4-3-6 of the *Marine Vessel Rules*

- Podded Propulsors Section 4-3-8 of the *Marine Vessel Rules*
- Contra-Rotating Propellers Section 4-3-9 of the *Marine Vessel Rules*

Dynamic positioning systems, including their thrusters, are to comply with the ABS *Guide for Dynamic Positioning Systems*.

5 Moving Cantilevers, Skid Beams and Moveable Structures

A description of equipment for moving cantilevers, skid beams or moveable substructures, including piping and electrical systems, details of mechanical components, including hold-down devices and applicable strength calculations, is to be submitted for review.

7 Electrical Machinery and Equipment

For electrical machinery and equipment, refer to Section 4-3-4.

9 Certification of Machinery and Equipment

For certification of machinery and equipment required at vendor's plant, refer to Part 6.

11 Unattended Machinery Spaces

Controls necessary for safe operation are to be provided for machinery spaces which are not normally manned. Relevant data is to be submitted to permit the assessment of the effect of such controls on the safety of the unit. See 4-2-4/3.7 for bilge alarm systems and 5-3-1/13 for fire precautions for such spaces.

For self-propelled units where it is intended that propulsion machinery space be periodically unattended and that propulsion machinery be controlled primarily from the navigation bridge, ✠*ACCU* notation will be assigned upon verification of compliance with Section 4-9-6 of the *Marine Vessel Rules*.

For non-self-propelled units where it is intended that the machinery space(s) and the local centralized control and monitoring station(s) (if provided) be periodically unmanned, and that the machinery/ systems be controlled and monitored from a remote control and monitoring center located outside the machinery space(s), ✠*AMCCU* notation will be assigned upon verification of compliance with the Section 3 of the ABS *Guide for Automatic or Remote Control and Monitoring for Machinery and Systems (other than Propulsion) on Offshore Installations*.

✠ *ACCU* and ✠*AMCCU* notations are not mandatory and will be assigned upon request.

13 Propulsion Redundancy

Units equipped with propulsion and steering systems designed to provide enhanced reliability and availability through functional redundancy may be granted the optional notation as specified in 4-3-7/3 of the *Marine Vessel Rules,* as appropriate, when the unit is designed, built and surveyed in accordance with Section 4-3-7 of the *Marine Vessel Rules*.

It is a prerequisite that the units are also to be classed to ✠*ACCU* notation, in accordance with Part 4, Chapter 9 of the *Marine Vessel Rules*.