



RULES FOR BUILDING AND CLASSING

STEEL VESSELS 2018

PART 4 VESSEL SYSTEMS AND MACHINERY

**American Bureau of Shipping
Incorporated by Act of Legislature of
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Rule Change Notice (2018)

The effective date of each technical change since 1993 is shown in parenthesis at the end of the subsection/paragraph titles within the text of each Part. Unless a particular date and month are shown, the years in parentheses refer to the following effective dates:

(2000) and after	1 January 2000 (and subsequent years)	(1996)	9 May 1996
(1999)	12 May 1999	(1995)	15 May 1995
(1998)	13 May 1998	(1994)	9 May 1994
(1997)	19 May 1997	(1993)	11 May 1993

Listing by Effective Dates of Changes from the 2017 Rules

Notice No. 1 (effective on 1 July 2017) to the 2017 Rules, which is incorporated in the 2018 Rules, is summarized below.

EFFECTIVE DATE 1 July 2017 – shown as (1 July 2017)
(based on the contract date for new construction between builder and Owner)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
4-2-1/13.9.2iv)	<No Title>	To include the alternative of normal continuous cruise power, in line with IACS UR M51 Rev.4, Feb. 2015. (Incorporates Notice No. 1)
4-2-1/Table 1	Required Material and Nondestructive Tests of Diesel Engine Parts	To clarify the scope of hydraulic testing for high pressure fuel injection pipes including common fuel rail and high pressure common servo oil systems, in line with IACS UR M72 rev. 1 Mar. 2016. (Incorporates Notice No. 1)
4-2-1/Table 2	Test Pressures for Parts of Internal-combustion Engines	To clarify the scope of hydraulic testing for high pressure fuel injection pipes including common fuel rail and high pressure common servo oil systems, in line with IACS UR M72 rev. 1 Mar. 2016. (Incorporates Notice No. 1)
4-2-2/1.1	Application	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)
4-2-2/1.3.1	Turbocharger	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)
4-2-2/1.3.3 (New)	Generic Range	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)
4-2-2/1.5.1ii)	<No Title>	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)
4-2-2/3.3	Category A and B Turbochargers	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)
4-2-2/3.5	Category C Turbochargers	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)
4-2-2/3.7.3	Certification Under Quality Assurance Assessment PQA (IACS UR Z26 Alternative Certification Scheme)	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)
4-2-2/5.1	General	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)
4-2-2/5.3	Containment	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)
4-2-2/5.7	Type Testing (applicable to category B and C turbochargers)	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)
4-2-2/7	Piping Systems for Turbochargers	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
4-2-2/8 (New)	Alarms and Monitoring	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)
4-2-2/11.1	Shop Inspection and Tests	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)
4-2-2/11.1.1	Material Tests	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)
4-2-2/11.1.5	Shop Trial	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)
4-2-2/11.3	Certification of Turbochargers	To clarify the categorization of turbochargers and the application of Type Approval. (Incorporates Notice No. 1)
4-3-4/13.1.9 (New)	System Response Under Failure	To detect failure in the steering gear control system and provide the operator with sufficient information to decide what action is required for the different failure scenarios, in line with IACS UR E25 June 2016. (Incorporates Notice No. 1)
4-3-4/Table 1	Steering Gear Instrumentation	To detect failure in the steering gear control system and provide the operator with sufficient information to decide what action is required for the different failure scenarios and to require a deviation alarm in addition to basic failure detection, in line with IACS UR E25 June 2016. (Incorporates Notice No. 1)
4-3-5/1.1	Application	To clarify the various terms used for steering systems and their associated equipment, in line with IACS UI SC242 Rev.1, Apr. 2016. (Incorporates Notice No. 1)
4-3-5/1.5.6 (New)	Steering System	To clarify the various terms used for steering systems and their associated equipment, in line with IACS UI SC242 Rev.1, Apr. 2016. (Incorporates Notice No. 1)
4-3-5/5.12.2(b)iii)	<No Title>	To clarify that the capacity requirements apply regardless whether the steering systems are arranged with common or dedicated power units that the requirements of 4-3-4/11.1 apply to each steering system in ships fitted with multiple steering systems, in line with IACS UI SC242 Rev.1, Apr. 2016. (Incorporates Notice No. 1)
4-3-5/5.12.4 (New)	Electric and Electrohydraulic Steering Systems	To clarify that the capacity requirements apply regardless whether the steering systems are arranged with common or dedicated power units that the requirements of 4-3-4/11.1 apply to each steering system in ships fitted with multiple steering systems, in line with IACS UI SC242 Rev.1, Apr. 2016. (Incorporates Notice No. 1)
4-3-5/7.5 (New)	Failure Detection and Response	To detect failure in the steering gear control system and provide the operator with sufficient information to decide what action is required for the different failure scenarios, in line with IACS UR E25 June 2016. (Incorporates Notice No. 1)
4-3-7/15.11	Instrumentation	To detect failure in the steering gear control system and provide the operator with sufficient information to decide what action is required for the different failure scenarios, in line with IACS UR E25 June 2016. (Incorporates Notice No. 1)
4-6-2/5.7.3(c)	Fire Resistance	To clarify the cases in which flexible hoses need not be of fire-resistant type. (Incorporates Notice No. 1)
4-6-2/5.9.1(c) (Deleted)	Operational Conditions	To minimize the use of slip-on joints for pipe connection except for cases where compensation of axial pipe deformation is necessary and to clarify the requirements, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)
4-6-2/5.9.1(e)	Fire Testing	To clarify the requirements, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)
4-6-2/5.9.1(f)	Locations	To clarify the requirements, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)
4-6-2/5.9.1(h) (Deleted)	Application	To clarify the requirements, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
4-6-2/5.9.1(g)	Joints	To clarify the requirements, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)
4-6-2/5.9.1(i)	Slip-on Joints	To minimize the use of slip-on joints for pipe connection except for cases where compensation of axial pipe deformation is necessary and to clarify the requirements, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)
4-6-2/5.9.1(j)	Application	To clarify the requirements, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)
4-6-2/5.9.2(e)ii)	Selection of Test Specimen	To clarify the requirements, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)
4-6-2/5.9.2(e)v)1(a)	<No Title>	To clarify the requirements, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)
4-6-2/5.9.2(e)v)2	Vibration (Fatigue) Test	To clarify the requirements, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)
4-6-2/5.9.2(e)v)4	Burst Pressure Test	To clarify the requirements, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)
4-6-2/5.9.2(e)v)5	Pull-out Test	To clarify the requirements, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)
4-6-2/5.9.2(e)v)6	Fire Endurance Test	To clarify the requirements, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)
4-6-2/5.9.2(e)v)7	Vacuum Test	To clarify the requirements, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)
4-6-2/Table 9	Examples of Mechanical Joints	To update the figures for “Machine Grooved Type” and “Slip Type” slip-on joints, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)
4-6-2/Table 10	Application of Mechanical Joints	To clarify the restrictions for on slip-on joints and flexible hoses used for L.O. lines and other flammable oils, and installed on open decks, in line with IACS UR P2 Rev.2, Mar. 2016. (Incorporates Notice No. 1)
4-8-2/7.21	Harmonics	To specify that the harmonic distortion calculation report is to be kept on board for exceptions to the 8% limit in cases where all installed equipment and systems have been designed for higher THD levels, in line with IACS UR E24 June 2016. (Incorporates Notice No. 1)
4-8-2/9.22 (New)	Harmonic Distortion for Ship Electrical Distribution System including Harmonic Filters	To introduce requirements for survey of harmonic filters and harmonic distortion levels, in line with IACS UR E24 June 2016. (Incorporates Notice No. 1)
4-8-2/9.23	Protection of Harmonic Filter Circuits Associated with Electric Propulsion	To introduce requirements for survey of harmonic filters and harmonic distortion levels, in line with IACS UR E24 June 2016. (Incorporates Notice No. 1)
4-8-3/9.1	Standard of Compliance	To identify the standards that have been withdrawn or replaced by new ones and to consider approaches for cables not manufactured to IEC standards identified, in line with IACS UR E7 Rev.4 Apr. 2016. (Incorporates Notice No. 1)
4-9-6/Table 1A	Instrumentation and Safety System Functions in Centralized Control Station – Slow Speed (Crosshead) Diesel Engines	To require turbocharger speed alarm for Categories B and C turbochargers, in line with IACS UR M35 rev. 7 Mar. 2016. (Incorporates Notice No. 1)
4-9-6/Table 1B	Instrumentation and Safety System Functions in Centralized Control Station – Medium and High Speed (Trunk Piston) Diesel Engines	To require turbocharger speed alarm for Categories B and C turbochargers, in line with IACS UR M35 rev. 7 Mar. 2016. (Incorporates Notice No. 1)
4-9-6/Table 4B	Instrumentation and Safety System Functions in Centralized Control Station – Generator Prime Mover for Electric Propulsion	To require turbocharger speed alarm for Categories B and C turbochargers, in line with IACS UR M35 rev. 7 Mar. 2016. (Incorporates Notice No. 1)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
4-9-6/Table 6	Instrumentation and Safety System Functions in Centralized Control Station – Auxiliary Turbines and Diesel Engines	To require turbocharger speed alarm for Categories B and C turbochargers, in line with IACS UR M35 rev. 7 Mar. 2016. (Incorporates Notice No. 1)

EFFECTIVE DATE 1 January 2018 – shown as (2018)
(based on the contract date for new construction between builder and Owner)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
4-3-1/5.13	Alternative Gear Rating Standards	To refer to the latest edition of the standards.
4-3-2/7.3.2(a)v)	Geared Systems	To clarify how the misalignment is to be verified and to require that verification and adjustment procedure be reviewed if the calculated misalignment is not submitted.
4-3-2/7.3.2(b)	Hull Deflections Accounted for in the Analysis	To clarify that the fully laden draft of a vessel is not with the aft peak tank full.
4-3-2/11.1.2(e)iv)	<No Title>	To clarify the draft of a vessel for shaft alignment analysis is accounted for in the hull deflection.
4-3-2/11.1.2(f) (New)	Geared Systems	To clarify how the misalignment is to be verified and to require that verification and adjustment procedure be reviewed if the calculated misalignment is not submitted.
4-3-4/1.11	Plans and Particulars to be Submitted	To clarify the requirements for automatic isolating systems.
4-3-4/25.1.2ii)	<No Title>	To clarify the requirements for automatic isolating systems.
4-4-1/1.1	Application	To clarify the requirements for accumulators of extruded seamless construction.
4-4-1/17.3.2	Diameter Over 457 mm (18 in.)	To clarify that the diameter is the inside diameter.
4-4-1/17.3.3	Diameter Over 305 mm (12 in.)	To clarify that the diameter is the inside diameter.
4-4-1/17.3.4	Diameter 305 mm (12 in.) or Less	To clarify that the diameter is the inside diameter.
4-6-4/5.7.4(c)	Sludge Piping	To align the requirement with Regulation 12 of MARPOL Annex 1, as amended by Resolution MEPC. 266(68).
4-6-4/9.5.5	Fuel Oil Tank Overflows	To align the requirements with ABS practice.
4-6-4/13.1.1	Application	To clarify the requirements for fuel tanks used for separating machinery spaces from cargo and slop tanks, in line with IACS UR M76, Apr. 2016.
4-6-4/17.5	Class Notation – POT	To clarify that the protection requirements for lubrication oil tanks as required in 4-6-4/17.5 is not applicable to lubrication oil tanks with a capacity not greater than 30 m ³ .
4-6-5/15 (New)	Storage and Use of SCR Reductants	To provide requirements for Selective Catalytic Reduction (SCR) systems, in line with IACS UR M77 Sept. 2016.
4-6-7/3.5.4	Hydraulic Accumulators	To clarify the requirements for accumulators of extruded seamless construction.
4-6-7/7.3.2	Ventilation of Storage Room	To clarify that the requirements are applied to acetylene gas (as flammable gas) only.
4-6-7/7.3.3	Electrical Installation in Storage Room	To clarify that the requirements are applied to acetylene gas (as flammable gas) only.
4-6-7/7.5.4	Gas Cylinders	To clarify that the requirements are applied to acetylene gas (as flammable gas) only.
4-7-2/1.9.4(a)	Escapes	To clarify the requirements for internal dimensions and ladders, in line with IMO MSC.Circ1511 and IACS UI SC277.
4-7-2/1.13.1.iii) (New)	Emergency Generator Spaces	To align the requirements with ABS practice.
4-7-3/3.1.2	Distribution Piping and Nozzles	To clarify the requirements for the pressure rating of the distribution pipe.
4-7-3/3.1.5	Medium Release Warning Alarm	To align the requirements with IACS UI SC132 (Rev.4).

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
4-7-3/3.1.9iii) (New)	<No Title>	To provide a cross reference to the additional clarification in 4-7-3/13.7.1(b).
4-7-3/11.3.1(f)i)	<No Title>	To clarify the acceptability for individually identifiable fire detectors without individual short circuit isolator, in line with 2.1.6.1 of FSS Code in IMO Resolution MSC.311(88)
4-7-3/13.7.1(b)	Location	To align the requirements for the location of the control panel with Chapter 10, paragraph 2.4.1.2 of the FSS Code (as amended by resolution MSC.292(87) as interpreted by IMO MSC.1/Circ. 1487 and IACS UI SC 260 (Rev. 1).
4-8-1/Table 2	Secondary Essential Services	To clarify when a reliquefaction system and/or gas combustion unit is considered an essential system.
4-8-2/5.3.1	General	To explicitly prohibit the installation of other unrelated equipment in the emergency generator room.
4-8-2/7.7.1(c)	Current Carrying Capacity Correction	To clarify the application of the reduction factor of 0.85 where more than six cables are expected to operate simultaneously and are laid close together in a bunch in such a way that are an absence of free air circulation around them.
4-8-2/7.13.1	Main Lighting System	To align the requirement with other ABS Rules.
4-8-3/5.3.2(e)	Clearance and Creepage	To align the requirement with IEC 60092-302 and IEC 61892-3.
4-8-3/Table 2	Minimum Degree of Protection	To permit plugs and socket outlets installed in hazardous areas, in line with IEC 61892-7 Para. 8.11.1 and IEC 60079-14 Para. 5.13.
4-8-3/Table 5	Equipment and Instrumentation for Switchboards	To provide a reference to the requirements for high voltage systems.
4-8-3/Table 6	Maximum Current Carrying Capacity for Cables	To clarify the application of the reduction factor of 0.85 where more than six cables are expected to operate simultaneously and are laid close together in a bunch in such a way that are an absence of free air circulation around them.
4-8-4/21.3	Cable Current Carrying Capacity	To clarify the application of the reduction factor of 0.85 where more than six cables are expected to operate simultaneously and are laid close together in a bunch in such a way that are an absence of free air circulation around them.
4-8-4/27.5.4	Oxygen-acetylene Storage Room	To restrict the use of copper in acetylene atmospheres due to the potential formation of acetylides on the surface that can be ignited by friction or impact.
4-8-5/3.3.2	Earth Fault Detection and Indication	To clarify the requirements for audible and visual indication of earth faults for high voltage systems.
4-9-1/5.1.19 (New)	Worst Case Execution Time (WCET)	To define terms used in 4-9-1/7.3.9, in line with ISO 17894:2005 and IEC 61508-3.
4-9-1/5.1.20 (New)	Worst Case Response Time (WCRT)	To define terms used in 4-9-1/7.3.9, in line with ISO 17894:2005 and IEC 61508-3.
4-9-1/7.3.9	Programmable Electronic System (PES)	To mitigate the danger of critical alarms missing their deadlines.
4-9-2/7.3	Audible Alarms	To require a visual alarm for cases where the audible alarm may not be heard due to high noise levels in the machinery space.
4-9-5/15.3.1	Bilge Level	To clarify the number of bilge level switches/sensors required for vessels with ACC or ACCU notation, in line with IAC UR M27.
4-9-6/21.3vi)	<No Title>	To align the requirements for a high-expansion foam fire extinguishing system with IACS UI SC262.
4-9-6/21.3vii)	<No Title>	To require that weathertight doors fitted in the engine casing bulkhead also be a type of self-closing door or could be closed from fire control station, to prevent the release of CO ₂ from the unintentional remaining opened doors when fixed CO ₂ system in engine room is active, and to align the requirements for a high-expansion foam fire extinguishing system with IACS UI SC262.

Vessel Systems and Machinery

CONTENTS

CHAPTER 1	General.....	1
Section 1	Classification of Machinery	2
CHAPTER 2	Prime Movers.....	18
Section 1	Diesel Engines	25
	Appendix 1 – Plans and Data for Diesel Engines	74
	Appendix 2 – Definition of Stress Concentration Factors in Crankshaft Fillets.....	94
	Appendix 3 – Stress Concentration Factors and Stress Distribution at the Edge of Oil Drillings	96
	Appendix 4 – Guidance for Spare Parts	98
	Appendix 5 – Type Testing Procedure for Crankcase Explosion Relief Valves	101
	Appendix 6 – Type Testing Procedure for Crankcase Oil Mist Detection/Monitoring and Alarm Arrangements.....	107
	Appendix 7 – Alternative Method for Calculation of Stress Concentration Factors in the Web Fillet Radii of Crankshafts by Utilizing Finite Element Method	112
Section 2	Turbochargers.....	119
Section 3	Gas Turbines	126
	Appendix 1 – Plans and Data for Gas Turbines.....	136
Section 4	Steam Turbines.....	138
	Appendix 1 – Guidance for Spare Parts	149
CHAPTER 3	Propulsion and Maneuvering Machinery	150
Section 1	Gears	159
	Appendix 1 – Rating of Cylindrical and Bevel Gears	169
	Appendix 2 – Guidance for Spare Parts	226
	Appendix 3 – Gear Parameters.....	227
Section 2	Propulsion Shafting.....	236
	Appendix 1 – Special Approval of Alloy Steel Used for Intermediate Shaft Material	259
Section 3	Propellers.....	262
Section 4	Steering Gears.....	276
Section 5	Thrusters.....	295
Section 6	Propulsion Redundancy.....	305

Section 7	Podded Propulsion Units	313
Section 8	Contra-Rotating Propellers	320
CHAPTER 4	Boilers, Pressure Vessels and Fired Equipment	324
Section 1	Boilers and Pressure Vessels and Fired Equipment	327
	Appendix 1 – Rules for Design.....	348
CHAPTER 5	Deck and Other Machinery	378
Section 1	Anchor Windlass	379
CHAPTER 6	Piping Systems.....	383
Section 1	General Provisions.....	391
Section 2	Metallic Piping	399
Section 3	Plastic Piping	434
Section 4	Ship Piping Systems and Tanks	450
Section 5	Piping Systems for Internal Combustion Engines	487
Section 6	Piping Systems for Steam Plants	501
Section 7	Other Piping Systems	515
CHAPTER 7	Fire Safety Systems	524
Section 1	General Provisions.....	530
Section 2	Provisions for Specific Spaces	535
Section 3	Fire-extinguishing Systems and Equipment	555
	Appendix 1 – IMO MSC.1/Circ.1271	587
	Appendix 2 – IMO MSC/Circ.1165	607
	Appendix 3 – IMO Resolution A.800(19), as Amended by MSC.265(84)	638
	Appendix 4 – IMO MSC/Circ.1388	678
CHAPTER 8	Electrical Systems.....	680
Section 1	General Provisions.....	687
Section 2	System Design	695
Section 3	Electrical Equipment	722
Section 4	Shipboard Installation and Tests	761
	Appendix 1 – Type Test Procedure for Plastic Cable Tray and Protective Casing.....	782
Section 5	Special Systems	786
CHAPTER 9	Automation	808
Section 1	General Provisions.....	815
Section 2	Essential Features Requirements.....	822
Section 3	Computer-based Systems	832
	Appendix 1 – Definitions and Notes Relating to SDLC and Hardware Test and Evidence Documentation in 4-9-3/Tables 2 and 3	843

Section 4	Integrated Automation System	848
Section 5	ACC Notation	850
Section 6	ACCU Notation	858
Section 7	Special Systems	879
Section 8	Equipment.....	883
Section 9	Installation, Tests and Trials	895

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PART

4

CHAPTER 1 General

CONTENTS

SECTION 1	Classification of Machinery	2
1	General	2
1.1	Organization of Part 4	2
1.3	Requirements for Classification	2
1.5	Classification Notations	3
1.7	Alternative Standards	4
1.9	Definitions	4
3	Certification of Machinery	5
3.1	Basic Requirements	5
3.3	Type Approval Program	5
3.5	Non-mass Produced Machinery	6
3.7	Details of Certification of Some Representative Products	6
5	Machinery Plans	6
5.1	Submission of Plans	6
5.3	Plans	6
7	Miscellaneous Requirements for Machinery	6
7.1	Construction Survey Notification	6
7.3	Machinery Equations	7
7.5	Astern Propulsion Power	7
7.7	Dead Ship Start	7
7.9	Inclinations	7
7.11	Ambient Temperature	7
7.13	Machinery Space Ventilation	7
7.15	Materials Containing Asbestos	7
9	Sea Trials	8
TABLE 1	Certification Details – Prime Movers	9
TABLE 2	Certification Details – Propulsion, Maneuvering and Mooring Machinery	10
TABLE 3	Certification Details – Electrical and Control Equipment	11
TABLE 4	Certification Details – Fire Safety Equipment	13
TABLE 5	Certification Details – Boilers, Pressure Vessels and Fired Equipment	14
TABLE 6	Certification Details – Piping System Components	15
TABLE 7	Design Angles of Inclination	16
TABLE 8	Ambient Temperatures for Unrestricted Service	17
FIGURE 1	Organization of Part 4	2

PART

4

CHAPTER 1 General

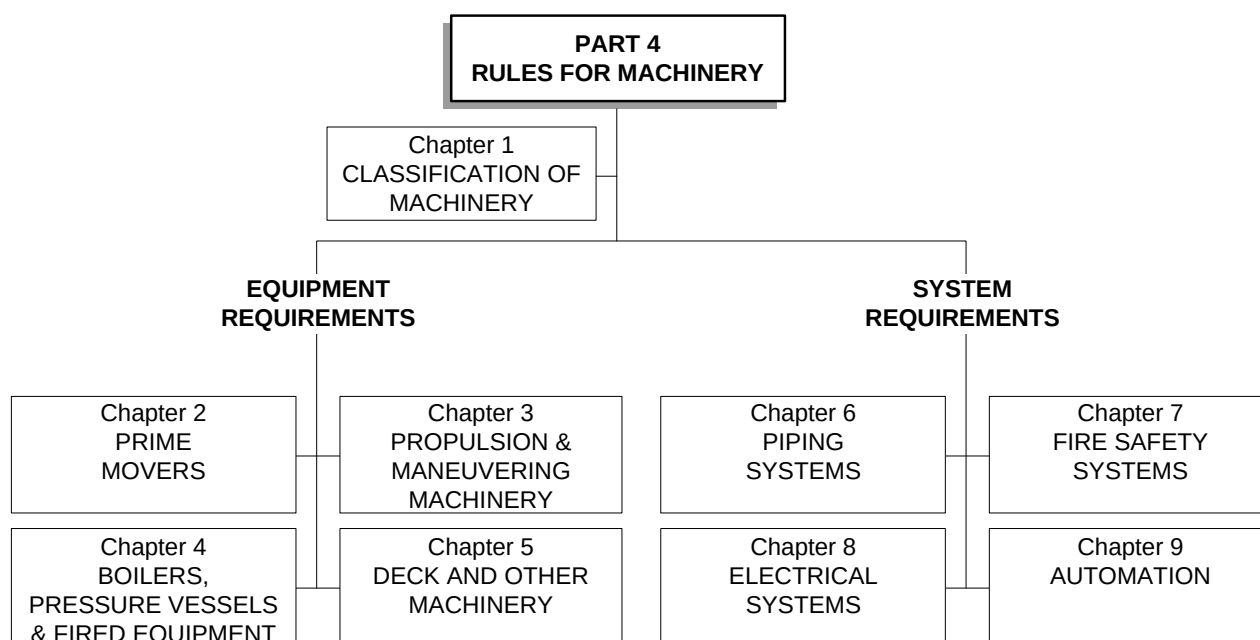
SECTION 1 Classification of Machinery

1 General

1.1 Organization of Part 4

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

FIGURE 1
Organization of Part 4



1.3 Requirements for Classification

1.3.1 Scopes of Part 4 and Part 5C

Part 4 provides the minimum requirements for machinery of self-propelled vessels of 90 meters in length and over. Compliance with Part 4 is a condition for classification of all such vessels, and for assigning the appropriate machinery class notations indicated in 4-1-1/1.5. Additional requirements for machinery, which are specific for each vessel type, are provided in Part 5C. Compliance with the provisions of Part 5C is a condition for assigning the vessel type class notation specified therein, such as **Oil Carrier, Passenger Vessel, Liquefied Gas Carrier**, etc.

1.3.2 Fundamental Intent of Machinery Rules

1.3.2(a) Propulsion and maneuvering capability. Part 4 of the Rules is intended to assure the propulsion and maneuvering capability of the vessel through specification of pertinent design, testing and certification requirements for propulsion, maneuvering and other equipment and their associated systems. See 4-1-1/Figure 1 for equipment and systems included in the scope.

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.

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

Classification notations are assigned to a vessel to indicate compliance with particular portions of the Rules. The following classification notations define 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 provisions of Section 4-9-5 are to be complied with. Upon verification of compliance, **ACC** will be assigned.

ACCU 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 provisions of Section 4-9-6 are to be complied with. Upon verification of compliance, **ACCU** will be assigned.

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 signifies compliance with applicable requirements of Section 4-3-5.

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 signifies compliance with applicable requirements of Section 4-3-5.

DPS-0, -1, -2, 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. **DPS** is assigned only when requested by the owners and signifies compliance with the *ABS Guide for Dynamic Positioning Systems*.

The above class notations, where preceded by the symbol ☒ (Maltese cross; e.g., ☒ **AMS**), signify that compliance with these Rules was 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

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. This, however, is subject to such standards being determined by ABS as being not less effective than the Rules. Where applicable, requirements may be imposed by ABS in addition to those contained in the alternative standard to assure that the intent of the Rules is 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 1-1-1/1.

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

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

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

Centralized Control Station is used in Part 4, Chapter 9 “Automation” 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 Space

Machinery Space is any space that contains propulsion machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, air conditioning and ventilation machinery, refrigerating machinery, stabilizing machinery or other similar machinery, including the trunks to the space. Machinery space is to include “machinery space of category A”, which, as defined in 4-7-1/11.15, is a space and trunks to that space which contains:

- Internal combustion machinery used for main propulsion; or
- Internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW (500 hp); or
- Any oil-fired boiler (including similar oil-fired equipment such as inert gas generators, incinerators, waste disposal units, etc.) or oil fuel unit (see definition in 4-7-1/11.19).

1.9.3 Essential Services (2004)

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

1.9.4 Hazardous Area

Areas where flammable or explosive gases, vapors or dust are normally present or likely to be present are known as hazardous areas. Hazardous areas are, however, more specifically defined for certain machinery installations, storage spaces and cargo spaces that present such hazard, e.g.:

- Helicopter refueling facilities, see 4-8-4/27.3.3;
- Paint stores, see 4-8-4/27.3.3;
- Cargo oil tanks and other spaces of oil carriers; see 5C-1-7/31.5;
- Ro-ro cargo spaces; see 5C-10-4/3.7.2.

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 saltwater, that possess in their original stage 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 (2004)

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, the stored energy for starting the propulsion plant, the main source of electrical power and other essential auxiliary machinery is assumed to not be available.

1.9.7 Blackout (2004)

Blackout situation means the loss of the main source of electrical power resulting in the main and auxiliary machinery to be out of operation.

3 Certification of Machinery

3.1 Basic Requirements

The Rules define, to varying degrees, the extent of evaluation required for products, machinery, equipment and their components based on the level of criticality of each of those items. 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 may be accepted based on the manufacturers' documentation on design and quality.

In general, 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 must be verified during installation, tests or trials.

3.3 Type Approval Program (2003)

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 for at the request of the designer or manufacturer. . The ABS Type Approval Program generally covers Product Type Approval (1-1-4/7.7.3), but is also applicable for a more expeditious procedure towards Unit-Certification, as specified in 1-1-4/7.7.2.

See the "ABS Type Approval Program" in Appendix 1-1-A3.

3.5 Non-mass Produced Machinery (2003)

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 4-1-1/3.1. 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 4-1-1/Table 1 through 4-1-1/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 Some Representative Products

4-1-1/Table 1 through 4-1-1/Table 6 provide abbreviated certification requirements of representative machinery based on the basic requirements of the Rules for machinery. The tables also provide the applicability of the Type Approval Program for each of these machinery items.

For easy reference, 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, fired equipment
- Piping system components

5 Machinery Plans

5.1 Submission of Plans (2011)

Machinery and systems plans required by the Rules are generally to be submitted electronically by the manufacturer, designer or shipbuilder to ABS. However, hard copies will also be accepted. After review and approval of the plans, one copy will be returned to the submitter, one copy will be retained for the use of the ABS Surveyor, and one copy will be retained by ABS for record. Where so stated in the shipbuilding contract, the Owner may require the builder 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 shipbuilder.

In general, all plans are to be submitted and approved before proceeding with the work.

5.3 Plans

Machinery plans required to be submitted for review and approval by ABS are listed in each of the sections in Part 4. In general, 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 generally required to supplement schematic system plans.

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 of the necessary information for the identification of the items to be surveyed.

7.3 Machinery Equations

The equations for rotating parts of the machinery in Part 4 of the Rules are based upon strength considerations only and their application does not relieve the manufacturer from responsibility for the presence of dangerous vibrations and other considerations in the installation at speeds within the operating range.

7.5 Astern Propulsion Power (2005)

7.5.1 General

Sufficient power for going astern is to be provided to secure proper control of the vessel in all normal circumstances. The astern power of the main propelling machinery is to be capable of maintaining in free route astern at least 70% of the ahead rpm corresponding to the maximum continuous ahead power. For main propulsion systems with reversing gears, controllable pitch propellers or electric propulsion drive, running astern is not to lead to overload of the propulsion machinery. The ability of the machinery 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.

7.5.2 Steam Turbine Propulsion

Where steam turbines are used for main propulsion, they are to be capable of maintaining in free route astern at least 70% of the ahead revolutions 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 (2005)

Means are to be provided to bring the machinery into operation from a "dead ship" condition, as defined in 4-1-1/1.9.6. See 4-8-2/3.1.3 and 4-8-4/1.13 for the required starting arrangements.

7.9 Inclinations

Machinery installations are to be designed to ensure proper operations under the conditions as shown in 4-1-1/Table 7.

7.11 Ambient Temperature

For vessels of unrestricted service, ambient temperature, as indicated in 4-1-1/Table 8, is to be considered in the selection and installation of machinery, equipment and appliances. For vessels of restricted or special service, the ambient temperature appropriate to the special nature is to be considered.

7.13 Machinery Space Ventilation (2002)

Suitable ventilation is to be provided for machinery spaces so as to simultaneously allow 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. In general, 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 3-2-17/9.3.

However, where due to the vessel size and arrangement this is not practicable, lesser heights for machinery space and emergency generator room ventilator coamings may be accepted with provision of weathertight closing appliances in accordance with 3-2-17/9.3.3 in combination with other suitable arrangements to ensure 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.

7.15 Materials Containing Asbestos (2011)

Installation of materials which contain asbestos is prohibited.

9 Sea Trials

A final underway 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 in order to demonstrate its reliability and sufficiency to function satisfactorily under operating conditions and its freedom from dangerous vibration and other detrimental operating phenomena 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 under way 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: 4-9-9/5
- Shipboard trials for diesel engines: 4-2-1/15

The viscosity of the fuel used on the sea trial will be entered in the classification report.

Based on the sea trials, the following information is to be provided on board:

- Stopping time (see also 4-1-1/7.5),
- Vessel headings and distances recorded on sea trials, and
- For vessels with multiple propellers, ability to navigate and maneuver with one or more propellers inoperative.

Reference may 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*.

TABLE 1
Certification Details – Prime Movers (2017)

<i>Prime Movers</i>	<i>ABS Approval Tier</i>	<i>Rule Reference</i>
Section 1: Diesel Engines		
1. (2017) Diesel 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, 4-2-1/13.1–13.9, 4-2-1/13.13, 4-2-1/15
2. (2017) Diesel engines that are mass produced per 4-2-1/13.11	4/5	4-2-1/13.11, 4-2-1/13.13, 4-2-1/15
3. Diesel engines < 100 kW (135 hp)	1	4-2-1/1.1
4. (2017) Diesel 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
Section 2: Turbochargers		
5. Turbochargers for engines ≥ 100 kW (135 hp), intended for propulsion and aux. services essential for propulsion, maneuvering and safety of the vessel	5	4-2-2/1.1, 4-2-2/5.3, 4-2-2/11.1–11.5
6. (2017) Turbochargers that are mass produced per 4-2-2/11.3.2(b)	4/5	4-2-2/5.3, 4-2-2/11.1–11.5
7. Turbochargers for engines < 100 kW (135 hp)	1	4-2-2/1.1
Section 3: Gas Turbines		
8. 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
9. 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
10. Gas turbines < 100 kW (135 hp)	1	4-2-3/1.1
11. (2017) 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
Section 4: Steam Turbines		
12. 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, 4-2-4/13.1–13.5
13. Steam turbines that are mass produced per 4-2-4/13.3.2(b)	4	4-2-4/13.1–13.5
14. Steam turbines < 100 kW (135 hp)	1	4-2-4/1.1
15. (2017) 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 (2017)

<i>Propulsion, Maneuvering and Mooring Machinery</i>	<i>ABS Approval Tier</i>	<i>Rule Reference</i>
Section 1: Propulsion Shafting		
1. (2017) Propulsion shafts, couplings, 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
2. (2017) Cardan shafts	4/5	4-3-2/5.21, 4-3-2/5.19
3. (2017) Coupling bolts constructed to a recognized standard	1	N/A
Section 2: Gears and Clutches		
4. Gears and clutches $\geq$ 5590 kW (7500 hp)	5	4-3-1/9.7.1
5. Gears and clutches $\geq$ 100 kW (135 hp)	4/5	4-3-1/1.1, 4-3-1/9.7.2(c)
6. Gears and clutches $<$ 100 kW (135 hp)	1	4-3-1/9.7.2(d)
Section 3: Propellers		
7. Propellers, fixed and controllable pitch	5	4-3-3/7.3
8. (2017) Propulsion thrusters	4/5	4-3-5
9. (2016) Podded propulsion units	5	4-3-7 and 3-2-14/25
Section 4: Steering		
10. Steering gears	5	4-3-4/19.1–19.7
11. (2017) Thrusters with optional notations (APS , DPS or PAS notation)	4/5	4-3-5/1.3 and 4-3-5/13, <i>DPS Guide</i>
12. Other thrusters 375 kW (500 hp) or less	1	4-3-5/3.3.2
Section 5: Anchoring and Mooring		
13. (2017) Anchor windlass	4/5	4-5-1/7
14. Mooring winches	1	4-5-1/1.3

TABLE 3
Certification Details – Electrical and Control Equipment (2017)

<i>Electrical and Control Equipment</i>	<i>ABS Approval Tier</i>	<i>Rule Reference</i>
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 LNG cargo or vapor handling services. (See 5C-8-10/2.12)	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 LNG cargo or vapor handling services. (See 5C-8-10/2.12)	1	4-8-3/3
5. Propulsion generators and motors	5	4-8-3/3, 4-8-5/5.17.5, 4-8-5/3.13.1 (high voltage)
6. (2017) 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 LNG cargo or vapor handling services. (See 5C-8-10/2.12)	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/Table 7 of aggregate load ≥ 100 kW (135 hp)	5	4-8-3/5.11.1
10. (2017) Motor controllers for steering gear	5	4-8-3/5.11.1
11. Motor control centers ≥ 100 kW (135 hp) for LNG cargo or vapor handling services. (See 5C-8-10/2.12)	4/5	4-8-3/5.11.1
12. Battery charger units of 25 kW and over, and discharging boards for essential services (see 4-8-1/7.3.3), emergency and transitional source of power (See 4-8-3/5.9)	4/5	4-8-3/5.11.1
13. Uninterruptible power system (UPS) units of 50 kVA and over for essential services (see 4-8-1/7.3.3), and for services indicated in 4-8-3/Table 7, emergency source or transitional source of power	4/5	4-8-3/5.11.1
14. Distribution boards associated with the charging or discharging of the battery system for emergency source and transitional source of power	4/5	4-8-3/5.11.1
15. Distribution boards associated with the 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/Table 7 and emergency source or transitional source of power	4/5	4-8-3/5.11.1
16. (2017) Power transformers for Essential Service and for emergency source of power and converters of low voltage	1	4-8-3/7, 4-8-3/8
17. Non-sparking fans (See 4-8-3/11)	2	4-8-3/11
18. (2017) Plastic Cable Tray and Protective Casing (See 4-8-4/21.9.4 and Appendix 4-8-4A1)	2	4-8-4/21.9.4, 4-8-4A1
19. (2017) Power transformers and converters for high voltage systems exceeding 100 kVA	5	4-8-5/3.7.5(e)
20. (2017) Cables	1	4-8-5/3.13.3 (high voltage), 4-8-3/9.17
21. (2016) Propulsion cables	4/5	4-8-5/5.17.2
22. Circuit breakers and fuses	1	4-8-3/5.3.3, 4-8-3/5.3.4
23. (2017) Certified safe equipment	2	4-8-3/13.1
24. (2017) Governors	2	4-2-1/7.3.3iii), 4-9-8/13
25. (2017) Cable penetration devices	2	4-8-1/5.3.1
26. (2017) Semiconductor converters for propulsion	4/5	4-8-5/5.17.8
27. Generator prime mover remote control system	4/5	4-9-8/13
28. Remote auxiliary machinery control system	4/5	4-9-8/13

TABLE 3 (continued)
Certification Details – Electrical and Control Equipment (2017)

<i>Electrical and Control Equipment</i>	<i>ABS Type Approval Tier</i>	<i>Rule Reference</i>
29. Centralized control and monitoring console	4/5	4-9-8/13
30. Control, monitoring and safety system devices, including computers, programmable logic controllers, etc., for DPS, ACC and ACCU notations	4/5	4-9-3/9.3.4, 4-9-3/11.9, 4-9-8/13.1
31. Complete assembly or subassembly units for DPS, ACC and ACCU notations	4/5	4-9-3/9.3.4, 4-9-3/11.9, 4-9-8/13.1
32. Steering control system	5	4-3-4/13, 4-9-3/9.3.4, 4-9-3/11.9
33. Boiler control system (4-9-1/7.3)	5	4-4-1/11.5, 4-9-3/9.3.4, 4-9-3/11.9
34. CPP control system	5	4-9-3/9.3.4, 4-9-3/11.9
35. Computer-based System (Cat. II or III) for other than DPS, ACC or ACCU notation	5	4-9-3/9.3.4, 4-9-3/11.9

TABLE 4
Certification Details – Fire Safety Equipment (2017)

<i>Fire Safety Equipment</i>	<i>ABS Approval Tier</i>	<i>Rule Reference</i>
Section 1: Fire Detection and Alarm System Components		
1. (2017) Fire detection and alarm system components	2	4-7-3/11
Section 2: Fixed Fire Extinguishing System Components		
2. (2017) Fixed fire extinguishing system components	2	4-7-3/3
3. (2017) Fixed gas systems	2	4-7-3/3
4. (2017) Fixed foam systems	2	4-7-3/5 (IMO MSC/circ. 1165R)
5. (2017) Fixed water spray and water-mist systems	2	4-7-3/7
Section 3: Fireman's Outfit, Hoses, and Portable Extinguishers		
6. (2017) Fireman's outfit ⁽¹⁾	3	4-7-3/15.5
7. (2017) Fire hoses ⁽¹⁾	3	4-7-3/1.13
8. (2017) Portable fire extinguishers ⁽¹⁾	3	4-7-3/15.1

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 (2017)

<i>Boilers, Pressure Vessels and Fired Equipment</i>	<i>ABS Approval Tier</i>	<i>Rule Reference</i>
Section 1: Group I		
1. Group I boilers and pressure vessels	5	4-4-1/7
Section 2: Group II		
2. (2017) Fired Pressure Vessels	4/5	4-4-1/7
3. Non-fired pressure vessels	4/5	4-4-1/7
Section 3: Inert Gas Generators & Incinerators		
4. (2017) Inert gas generators, incinerators	2	4-4-1/1, 4-4-1/15

TABLE 6
Certification Details – Piping System Components (2017)

<i>Piping System Components</i>	<i>ABS Approval Tier</i>	<i>Rule Reference</i>
1. Pumps related to propulsion diesel engines (bore >300 mm) (11.8 in.) and gas turbines and gears—fuel, cooling water, lube. Oil services	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	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	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	4/5	4-6-1/7.3.1, 4-6-1/7.5.3
5. (2017) Air compressors	1	4-6-5/9.3.3
6. (2017) Gas Compressors associated with liquefied gas carriers	4/5	5C-8-5/13.1.3
7. (2017) Refrigerated Cargo Compressor	5	6-2-6/25.1
8. (2017) Liquefied Gas Cargo Pumps	4/5	4-6-1/7.3.1v), 5C-8-5/13.1.3 (IACS)
9. (2017) Steel pipes, classes I and II (except hydraulic piping)	4/5	4-6-1/7.1.1, 4-6-1/7.5.1, 5C-8-5/12.1
10. (2017) Steel pipes, class III	1	4-6-1/7.1.1, 4-6-1/7.5.1, 5C-8-5/12.1
11. (2017) Pipe fittings—flanges, elbows, tees, flexible joints, etc., and valves; classes I & II designed to a recognized standard	4/5	4-6-1/7.1.1, 4-6-1/7.5.2, 5C-8-5/12.1, 5C-8-5/13.1
12. (2017) Pipe fittings—flanges, elbows, tees, flexible joints, etc., and valves; class III	2	4-6-1/7.1.1, 4-6-1/7.5.2, 5C-8-5/12.1, 5C-8-5/13.1
13. (2017) Level 1 and 2 Plastic pipes and pipe joints with ISO9001 certifications	2	4-6-3/9, IACS UR P4
14. Level 1 and 2 Plastic pipes and pipe joints w/o ISO9001 certifications	5	4-6-3/9, IACS UR P4
15. Level 3 Plastic pipes and pipe joints	1	4-6-3/9, IACS UR P4
16. Hoses (Does not cover fire hoses. For fire hoses, see 4-1-1/Table 4)	2	4-6-2/5.7
17. Vent heads, pressure vacuum valves	2	4-6-2/7
18. Gauges, detectors and transmitters	2	4-6-2/9.11
19. Fluid power cylinders and systems, including valve actuators, excluding steering actuators	2	4-6-7/3.5

TABLE 7
Design Angles of Inclination

	<i>Angle of Inclination, degrees ⁽¹⁾</i>			
	<i>Athwartship</i>		<i>Fore-and-Aft</i>	
Installations, components	Static	Dynamic	Static	Dynamic
Propulsion and auxiliary machinery	15	22.5	5 ⁽⁴⁾	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 Up to an angle of inclination of 45 degrees, switches and controls are to remain in their last set position.
- 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.
- 4 (2004) 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 3-1-1/3.1.

TABLE 8
Ambient Temperatures for Unrestricted Service (2014)

Air		
<i>Installations, Components</i>	<i>Location, Arrangement ^(1, 2)</i>	<i>Temperature Range (°C)</i>
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	–25 to +45
Water		
<i>Coolant</i>		<i>Temperature (°C)</i>
Seawater		+32

Notes:

- 1 Electronic equipment is to be suitable for operations up to 55°C.
- 2 (2014) For environmentally controlled spaces, see 4-8-3/1.17.2.

CONTENTS

SECTION 1	Diesel Engines	25
1	General	25
1.1	Application	25
1.3	Definitions	25
1.5	Increased Power Rating	25
1.7	Ambient Reference Conditions	26
1.9	Plans and Particulars to be Submitted	26
3	Materials	29
3.1	Material Specifications and Tests	29
3.3	Alternative Materials and Tests	29
5	Design	29
5.1	Bedplate/Crankcase	29
5.3	Crankcase Doors	29
5.5	Cylinders and Covers, Liners and Pistons	29
5.7	Securing of Nuts	30
5.9	Crankshafts	30
5.11	Shaft Couplings and Clutches	45
7	Engine Appurtenances	45
7.1	Explosion Relief Valves	45
7.2	Protection Against Crankcase Explosions	47
7.3	Governors and Overspeed Protection	49
7.5	Governors and Overspeed Protection for Engines Driving Generators	49
7.7	Materials, Fuel and Lube Oil Filters	51
7.9	Auxiliary Blowers	51
7.11	Fire Extinguishing System for Scavenge Manifold	51
7.13	Warning Notices	51
7.15	Jacket Drain and Overpressure Protection	51
7.17	Monitoring	51
7.19	Engine Turning Gear	52
9	Piping Systems for Diesel Engines	52
11	Installation of Diesel Engines	52
11.1	Seating Arrangements for Diesel Engines	52
11.3	Metal Chocks	52
11.5	Cast Resin Chocks	52
11.7	Resilient Mountings	52
11.9	Hot Surfaces	52

13	Testing, Inspection and Certification of Diesel Engines	53
13.1	Material and Nondestructive Tests	53
13.3	Hydrostatic Tests of Diesel Engine Components	53
13.5	Relief and Safety Valves	53
13.6	Manufacturer's Quality Control	53
13.7	Type Tests of Diesel Engines.....	56
13.9	Shop Tests of Internal Combustion, I.C. Engines.....	62
13.11	Type Tests of Mass-produced Diesel Engines	66
13.13	Certification of Diesel Engine	68
15	Shipboard Trials of Diesel Engines.....	68
15.1	Engines Driving Fixed Pitch Propellers or Impellers.....	68
15.3	Engines Driving Controllable Pitch Propellers	69
15.5	Engines Driving Propulsion Generators, Main Power Supply Generators and/or Emergency Generators	69
15.6	Propulsion Engines also Driving Power Take Off (PTO) Generator	69
15.7	Engines Driving Auxiliaries	69
15.9	Engines Burning Residual Fuel Oil or Other Special Fuel Oils	69
15.11	Torsional Vibration Barred Speed Range.....	69

TABLE 1	Required Material and Nondestructive Tests of Diesel Engine Parts.....	71
---------	---	----

TABLE 2	Test Pressures for Parts of Internal-combustion Engines	73
---------	---	----

FIGURE 1	Crank Throw for In Line Engine	31
FIGURE 2	Crank Throw for Vee Engine with 2 Adjacent Connecting-Rods	31
FIGURE 3	Reference Area of Crank Web Cross Section	32
FIGURE 4	Crankpin Section Through the Oil Bore	33
FIGURE 5	Crank Dimensions.....	38
FIGURE 6	Crank Throw of Semi-built Crankshaft.....	43
FIGURE 7	Limiting Curves for Loading 4-stroke Diesel Engines Step by Step from No-load to Rated Power as Function of the Brake Mean Effective Pressure	50
FIGURE 8	Type Test Power/Speed Diagram.....	62

SECTION 1 Appendix 1 – Approval of Diesel Engines..... 74

1	Scope	74
3	Definitions	74
5	Overview	74
5.1	Approval Process	74
5.3	Document Flow for Diesel Engines	75
5.5	Approval of Diesel Engine Components.....	76
5.7	Submission Format of Documentation	76
7	Type Approval Process.....	76
7.1	Documents for Information Table 1	76
7.3	Documents for Approval or Recalculation Table 2	76
7.5	Design Approval/Appraisal (DA).....	76

7.7	Type Approval Test.....	76
7.9	Type Approval Certificate	76
7.11	Design Modifications.....	76
7.13	Type Approval Certificate Renewals.....	76
7.15	Validity of Type Approval Certificate	77
7.17	Document Review and Approval	77
9	Certification Process	77
9.1	Document Development for Production	77
9.3	Documents to be Submitted for Inspection and Testing	77
9.5	Alternative Execution	78
9.7	Manufacturer Approval	78
9.9	Document Availability	78
9.11	Engine Assembly and Testing	78
ANNEX 1 –	Glossary	82
ANNEX 2 –	Representative Document Flow Diagrams	85
ANNEX 3 –	Internal Combustion Engine Approval Application Form and Data Sheet	87
ANNEX 4 –	Tabular Listing of Licensor's and Licensee's Drawing and Data.....	92
ANNEX 5 –	Sample Template for Confirmation of the Licensor's Acceptance of Licensee's Modifications	93
TABLE 1	Documentation to be Submitted for Information, as Applicable.....	79
TABLE 2	Documentation to be Submitted for Approval, as Applicable.....	80
TABLE 3	Documentation for the Inspection of Components and Systems	81
FIGURE 1	Type Approval Document Flow.....	85
FIGURE 2	Engine Certificate Document Flow.....	86
SECTION 1	Appendix 2 – Definition of Stress Concentration Factors in Crankshaft Fillets	94
SECTION 1	Appendix 3 –Stress Concentration Factors and Stress Distribution at the Edge of Oil Drillings.....	96
SECTION 1	Appendix 4 – Guidance for Spare Parts	98
1	General	98
3	Spare Parts for Main Propulsion Diesel Engines.....	98
5	Spare Parts for Auxiliary Diesel Engines	99

SECTION 1	Appendix 5 – Type Testing Procedure for Crankcase Explosion Relief Valves	101
1	Scope	101
3	Recognized Standards.....	101
5	Purpose.....	101
7	Test Facilities	101
9	Explosion Test Process	102
11	Valves to be Tested	103
13	Method	103
	13.1 General Requirements	103
	13.3 Stages of Testing	103
15	Assessment and Records.....	104
17	Design Series Qualification.....	105
	17.1 General.....	105
	17.3 Flame Arrester.....	105
	17.5 Valves of Larger Sizes than Have Been Satisfactorily Tested	105
	17.7 Valves of Smaller Sizes than Have Been Satisfactorily Tested ...	105
19	Reporting	106
21	Acceptance	106

SECTION 1	Appendix 6 – Type Testing Procedure for Crankcase Oil Mist Detection and Alarm Equipment.....	107
1	Scope	107
3	Recognized Environmental Test Standards	107
5	Purpose.....	107
7	Test Facilities	107
9	Equipment Testing	108
	9.1 For the Alarm/Monitoring Panel.....	108
	9.3 For the Detectors.....	108
11	Functional Tests.....	108
13	Detectors and Alarm Equipment to be Tested.....	109
15	Method	109
17	Assessment	110
19	Design Series Qualification.....	110
21	Reporting	110
23	Acceptance	111

SECTION 1	Appendix 7 – Alternative Method for Calculation of Stress Concentration Factors in the Web Fillet Radii of Crankshafts by Utilizing Finite Element Method	112
1	General	112
3	Model Requirements.....	112
	3.1 Element Mesh Recommendations.....	112
	3.3 Materials.....	113
	3.5 Element Mesh Quality Criteria.....	114

5	Load Cases	114
5.1	Torsion.....	114
5.3	Pure Bending (4 Point Bending)	115
5.5	Bending With Shear Force (3 Point Bending)	116
FIGURE 1	Oil Bore Proximity to Fillet.....	113
FIGURE 2	Boundary and Load Conditions for the Torsion Load Case	115
FIGURE 3	Boundary and Load Conditions for the Pure Bending Load Case	116
FIGURE 4	Boundary and Load Conditions for the 3-Point Bending Load Case of an Inline Engine.....	117
FIGURE 5	Load Applications for In-line and V-type Engines	118
SECTION 2	Turbochargers	119
1	General	119
1.1	Application	119
1.3	Definitions.....	119
1.5	Plans and Particulars to be Submitted.....	119
3	Materials.....	120
3.1	Material Specifications and Purchase Orders	120
3.3	Category A and B Turbochargers	120
3.5	Category C Turbochargers	120
3.7	Alternative Material Test Requirements.....	121
5	Design Requirements and Corresponding Type Testing	121
5.1	General.....	121
5.3	Containment	121
5.5	Disc-shaft Shrinkage Fit (applicable to turbochargers of category C)	122
5.7	Type Testing (applicable to category B and C turbochargers).....	122
7	Piping Systems for Turbochargers	122
8	Alarms and Monitoring	122
9	Installation of Turbochargers	123
9.1	Air Inlet	123
9.3	Hot Surfaces	123
9.5	Pipe and Duct Connections	123
11	Testing, Inspection and Certification of Turbochargers	123
11.1	Shop Inspection and Tests	123
11.3	Certification of Turbochargers	124
11.5	Engine and Shipboard Trials	125
13	Spare Parts	125
SECTION 3	Gas Turbines	126
1	General	126
1.1	Application	126
1.3	Definitions.....	126
1.5	Plans and Particulars to be Submitted.....	126

3	Materials.....	128
3.1	Material Specifications and Tests.....	128
3.3	Alternative Materials and Tests	128
5	Design.....	129
5.1	Rotors and Blades	129
5.3	Operation Above the Rated Speed and Power.....	129
5.5	Overhaul Interval	129
5.7	Type Test Data.....	129
5.9	Casing	129
7	Gas Turbine Appurtenances.....	130
7.1	Overspeed Protective Devices	130
7.3	Operating Governors for Propulsion Gas Turbines	130
7.5	Operating Governors for Turbines Driving Electric Generators	130
7.7	Safety Systems and Devices.....	131
7.9	Hand Trip Gear.....	132
7.11	Air-intake Filters and Anti-icing.....	132
7.13	Silencers.....	132
9	Piping and Electrical Systems for Gas Turbines	133
11	Installation of Gas Turbines	133
11.1	Pipe and Duct Connections	133
11.3	Intake and Exhaust.....	133
11.5	Hot Surfaces.....	133
13	Testing, Inspection and Certification of Gas Turbines.....	133
13.1	Shop Inspection and Tests	133
13.3	Certification of Gas Turbines	134
13.5	Shipboard Trials	135
15	Spare Parts	135

TABLE 1	List of Alarms and Shutdowns	132
---------	------------------------------------	-----

SECTION 3 Appendix 1 – Plans and Data for Gas Turbines..... 136

SECTION 4 Steam Turbines 138

1	General	138
1.1	Application.....	138
1.3	Definitions.....	138
1.5	Plans and Particulars to be Submitted	139
3	Materials.....	140
3.1	Material Specifications and Tests.....	140
3.3	Alternative Materials and Tests	140
5	Design.....	140
5.1	Casings	141
5.3	Rotor Shafts	141
5.5	Blades	142
5.7	Discs or Drums.....	142

7	Steam Turbine Appurtenances	144
7.1	Overspeed Protective Devices	144
7.3	Operating Governors for Propulsion Turbines	144
7.5	Operating Governors for Turbines Driving Electric Generators.....	145
7.7	Hand and Automatic Tripping	145
7.9	Shaft Turning Gear	146
7.11	Overpressure Protection.....	146
9	Piping Systems for Steam Turbines	146
11	Installation of Steam Turbines	146
11.1	Exhaust Steam to Turbine	146
11.3	Extraction of Steam	146
11.5	Pipe and Duct Connections	146
11.7	Hot Surfaces	146
13	Testing, Inspection and Certification of Steam Turbines	147
13.1	Shop Inspection and Tests	147
13.3	Certification of Steam Turbines	147
13.5	Shipboard Trials.....	148
SECTION 4	Appendix 1 – Guidance for Spare Parts	149
1	General	149
3	Spare Parts for Propulsion Steam Turbines	149
5	Spare Parts for Steam Turbines Driving Electric Generators	149

PART

4

CHAPTER 2 Prime Movers

SECTION 1 Diesel Engines

1 General

1.1 Application

Diesel 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.

Diesel engines having a rated power of less than 100 kW (135 hp) are not required to comply with the provisions 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.

Diesel 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. They are to comply with safety features, such as crankcase explosion relief valve, overspeed protection, etc., as provided in 4-2-1/7, as applicable. After installation, they are subject to a satisfactory performance test conducted in the presence of the Surveyor.

Piping systems serving diesel 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.

1.3 Definitions

For the purpose of this section, the following definitions apply:

1.3.1 Slow-, Medium-, High-speed Diesel Engines (2015)

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

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

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

1.3.2 Rated Power

The *Rated Power* is the maximum power output at which the engine is designed to run continuously at its rated speed between the normal maintenance intervals recommended by the manufacturer.

1.5 Increased Power Rating

The rated power of an engine, which has been type tested as specified in 4-2-1/13.7 or 4-2-1/13.11 and which has proven reliable in service, may be increased by not more than 10% of the type tested power rating without performing any new type test, subject to prior approval of relevant plans and particulars.

1.7 Ambient Reference Conditions

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)

1.9 Plans and Particulars to be Submitted

For a tabulated listing, see Appendix 4-2-A1.

1.9.1 Engine Construction

Engine transverse cross-section

Engine longitudinal section

Bedplate with welding details and procedures; frame/column with welding details and procedures; crankcase with welding details and procedures

Structural supporting and seating arrangements

Arrangement of foundation bolts (for main engines only)

Thrust bearing assembly

Thrust bearing bedplate

Tie rod

Cylinder cover, assembly or cylinder head

Cylinder jacket or engine block

Cylinder liner

Crankshaft, details

Crankshaft, assembly

Thrust shaft or intermediate shaft (if integral with engine)

Coupling bolts

Counterweights (if not integral with crankshaft)

Connecting rod

Connecting rod, assembly and details

Crosshead, assembly and details

Piston rod, assembly and details

Piston, assembly and details

Camshaft drive, assembly

Arrangement of crankcase explosion relief valve and breather arrangement (only for engines having a cylinder bore of 200 mm (8 in.) and above)

1.9.2 Engine Systems and Appurtenances (2001)

Starting air system
Fuel oil system
Lubricating oil system
Cooling water system
Governor arrangements
Schematic diagram of the engine control and safety system
Shielding and insulation of exhaust pipes, assembly
Shielding of high pressure fuel pipes, assembly as applicable
Turbochargers and superchargers, see 4-2-2/1.5
Couplings and clutches
Vibration damper assembly
Tuning wheel assembly, if fitted
Engine driven pump assembly
Scavenging pump and blower assemblies

1.9.3 Data

Type designation of engine and combustion cycle
Number of cylinders
Rated power, kW (PS, hp)
Rated engine speed, (rpm)
Sense of rotation (clockwise/counter-clockwise)
Firing order with the respective ignition intervals and, where necessary, V-angle, α_v
Cylinder diameter, mm (in.)
Stroke, mm (in.)
Maximum cylinder pressure $p_{\max}$, bar (kgf/mm², psi)
Mean effective pressure, bar (kgf/mm², psi)
Mean indicated pressure, bar (kgf/mm², psi)
Charge air pressure, bar (kgf/mm², psi), (before inlet valves or scavenge ports, whichever applies)
Nominal compression ratio
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/mm², 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 α_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

(2005) Operation and service manuals, including maintenance requirements for servicing and repair and details of any special tools and gauges that are to be used with their fittings/settings, together with any test requirements on completion of the maintenance (see also 4-6-2/9.6).

1.9.4 Materials

Crankshaft material:

- 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)
- Hardness at surface
- Hardness as a function of depth, mm (in.)
- Extension of surface hardening

Material specifications of other main parts

1.9.5 Calculations and Analyses (2001)

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

1.9.6 Submittals by Licensee

1.9.6(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 licensor'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 the licensor's plans, this list will not be required.

1.9.6(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, as appropriate. The licensor's statement of acceptance of the modifications is to be included in the submittal.

1.9.6(c) *Plans for surveyor.* A complete set of the licensor'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.

3 Materials

3.1 Material Specifications and Tests

Material specifications are to be in accordance with that in Part 2, Chapter 3 or other specifications approved under 4-2-1/3.3.1. Except as noted in 4-2-1/3.3, materials intended for engines required to be constructed under survey are to be tested and inspected in accordance with 4-2-1/Table 1. The material tests, where so indicated in the table, are to be witnessed by the Surveyor. Nondestructive tests in 4-2-1/Table 1 are 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 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

Hot-rolled steel bars up to 305 mm (12 in.) in diameter may be used when approved for any of the items indicated in 4-2-1/Table 1, subject to the conditions specified in Section 2-3-8

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

Material for engines having a rated power of 375 kW (500 hp) or less, including shafting, couplings, and coupling bolts will be accepted 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 will not require material testing.

3.3.4 Engines Certified Under Quality Assurance Approval

For diesel engines certified under quality assurance assessment as provided for in 4-2-1/13.13.2(b), material tests required by 4-2-1/3.1 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

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 4-2-1/11.1 for seating of diesel engines.

5.3 Crankcase Doors (2006)

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 4-2-1/7.1. 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 (2007)

5.9.1 General

5.9.1(a) Scope. 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.

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

5.9.1(c) Principles of calculation. 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 may be required.

Calculation of crankshaft strength consists of determining the nominal alternating bending (see 4-2-1/5.9.2) and nominal alternating torsional stresses (see 4-2-1/5.9.3) which, multiplied by the appropriate stress concentration factors (see 4-2-1/5.9.4), result in an equivalent alternating stress (uni-axial stress) (see 4-2-1/5.9.6). This equivalent alternating stress is then compared with the fatigue strength of the selected crankshaft material (see 4-2-1/5.9.7). This comparison will show whether or not the crankshaft concerned is dimensioned adequately (see 4-2-1/5.9.8).

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

5.9.2(a) 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/Figure 1 and 4-2-1/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/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/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 4-2-1/Figure 3). Mean stresses are neglected.

FIGURE 1
Crank Throw for In Line
Engine (2007)

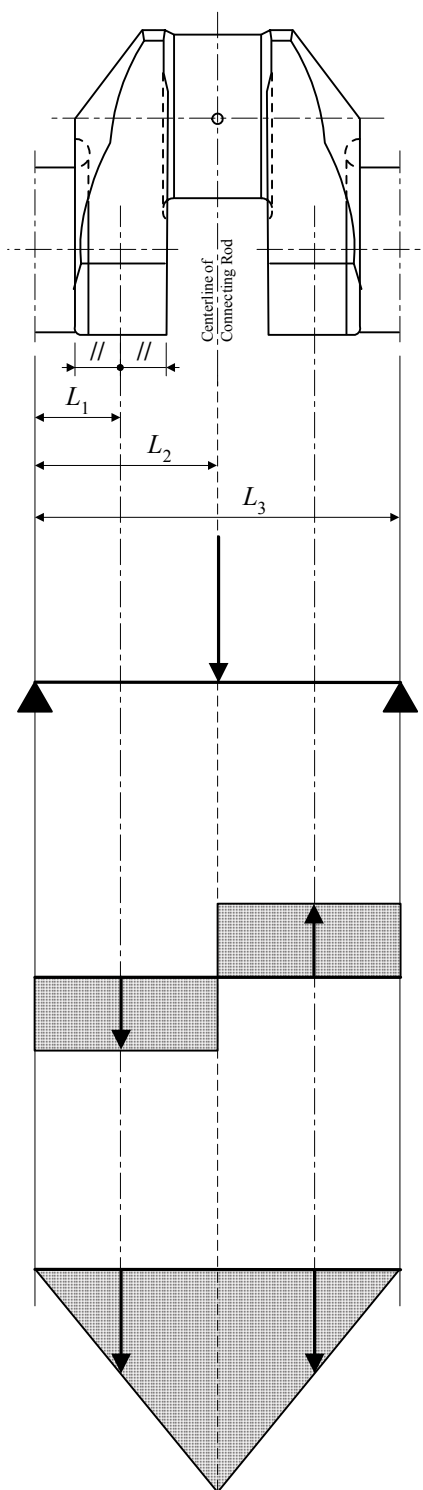
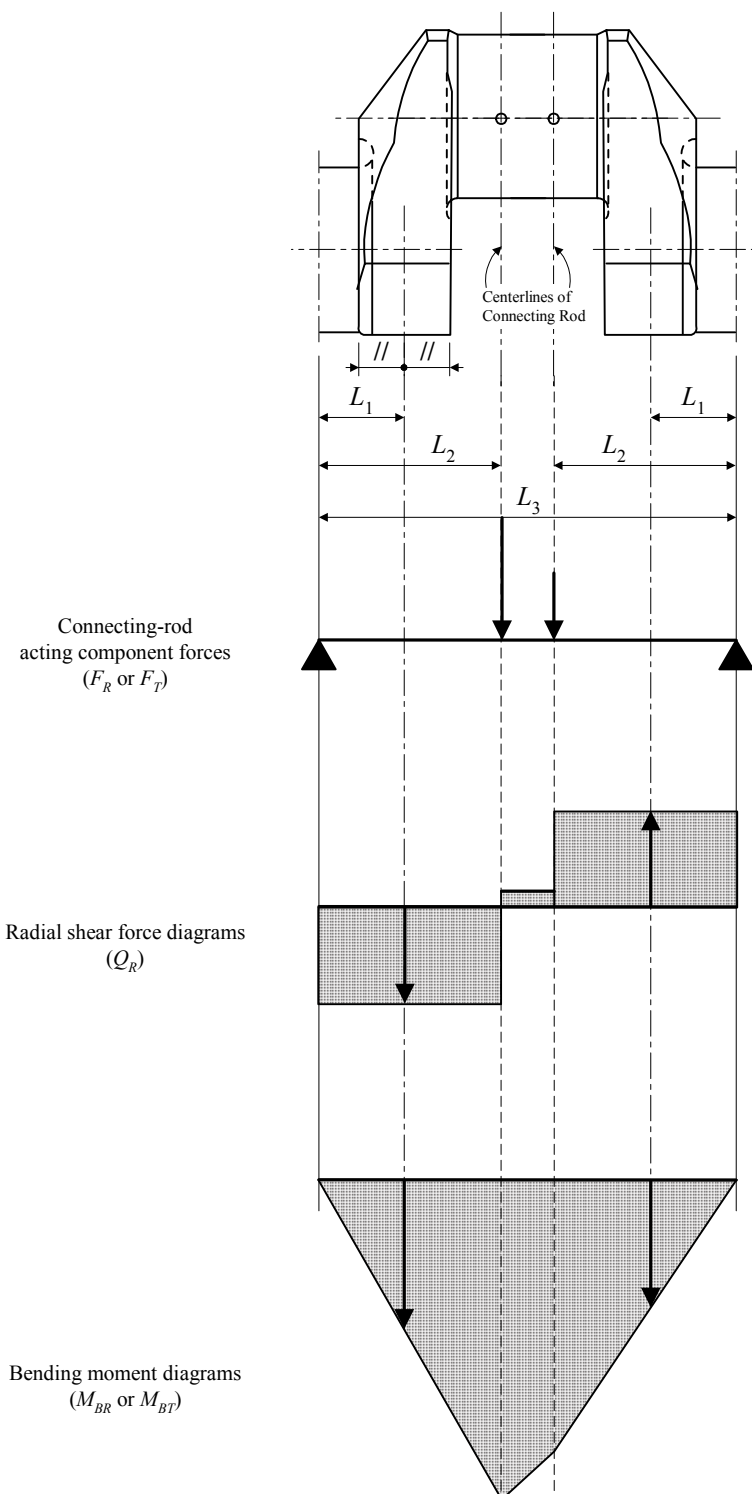
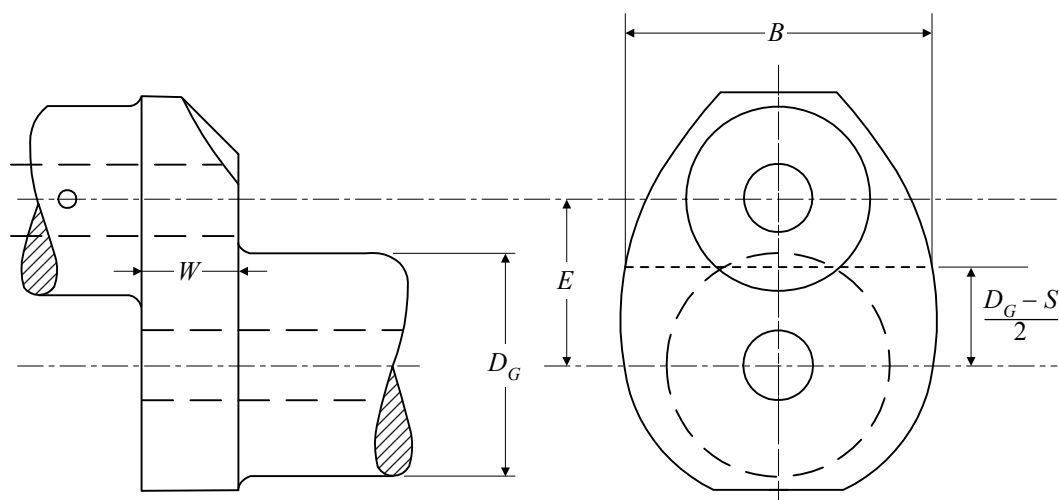


FIGURE 2
Crank Throw for Vee Engine with
2 Adjacent Connecting-Rods (2007)

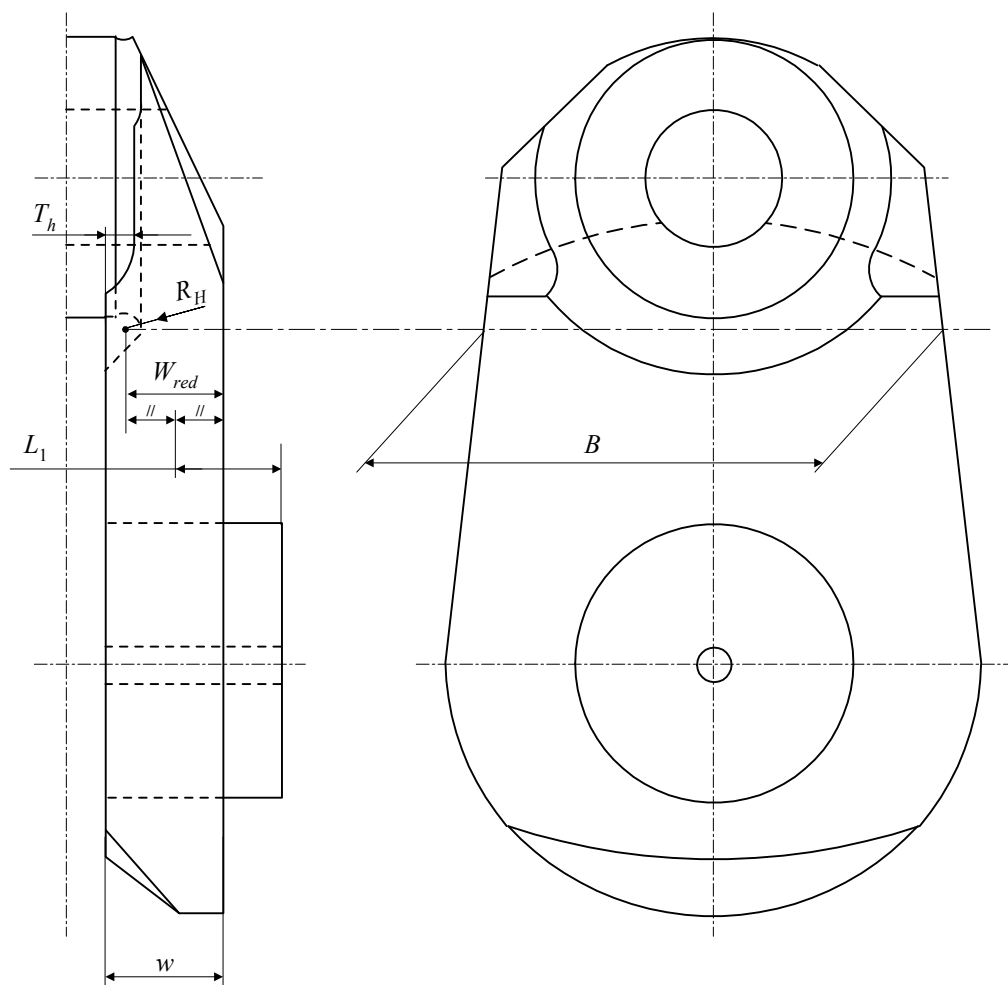


- L_1 = Distance between main journal centerline and crank web center
(see also 4-2-1/Figure 3 for crankshaft without overlap)
 L_2 = Distance between main journal centerline and connecting-rod center
 L_3 = Distance between two adjacent main journal centerlines

FIGURE 3
Reference Area of Crank Web Cross Section (2007)



Overlapped crankshaft



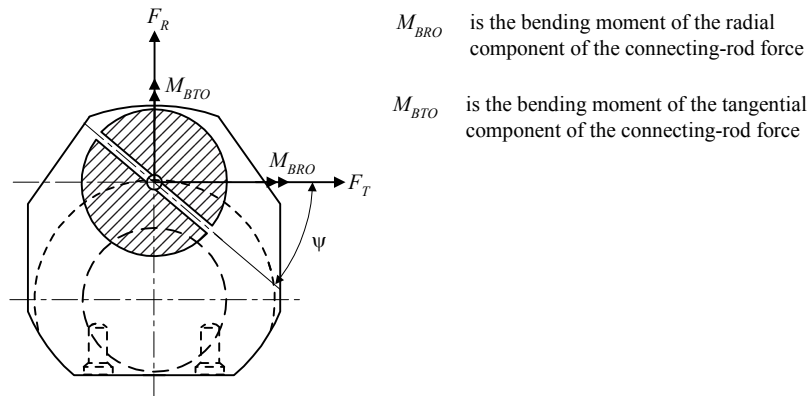
Crankshaft without overlap

- 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 (2007)



5.9.2(b) *Calculation of nominal alternating bending and compressive stresses in web.* The radial and tangential forces due to gas and inertia loads acting upon the crankpin at each connecting-rod position 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} , M_{BTO} and radial forces Q_{RF} as defined in 4-2-1/5.9.2(a)i) and 4-2-1/5.9.2(a)ii) 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:

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

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/mm²

M_{BRFN} = alternating bending moment related to the center of the web, in N-m
(see 4-2-1/Figure 1 and 4-2-1/Figure 2)

$$= \frac{1}{2} [M_{BFN \max} - M_{BFN \min}]$$

W_{eqw} = section modulus related to cross-section of web, in mm³

$$= \frac{B \cdot W^2}{6}$$

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/mm²

Q_{RFN} = alternating radial force related to the web, in N (see 4-2-1/Figure 1 and 4-2-1/Figure 2)

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

F = area related to cross-section of web, in mm²

$$= B \cdot W$$

- 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/mm²

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

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

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

ψ = angular position, in degrees (see 4-2-1/Figure 4)

$$W_e = \text{section modulus related to cross-section of axially bored crankpin, in mm}^3$$

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

5.9.2(c) *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

$$\sigma_{BH} = \text{alternating bending stress in crankpin fillet, in N/mm}^2$$

$$\alpha_B = \text{stress concentration factor for bending in crankpin fillet (see 4-2-1/5.9.4)}$$

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

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

where

$$\sigma_{BG} = \text{alternating bending stress in journal fillet, in N/mm}^2$$

$$\beta_B = \text{stress concentration factor for bending in journal fillet (see 4-2-1/5.9.4)}$$

$$\beta_Q = \text{stress concentration factor for compression due to radial force in journal fillet (determination as per 4-2-1/5.9.4)}$$

5.9.2(d) *Calculation of alternating bending stresses in outlet of crankpin oil bore.*

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

where

$$\sigma_{BO} = \text{alternating bending stress in outlet of crankpin oil bore, in N/mm}^2$$

$$\gamma_B = \text{stress concentration factor for bending in crankpin oil bore (determination as per 4-2-1/5.9.4)}$$

5.9.3 Calculation of Alternating Torsional Stresses

5.9.3(a) *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 appropriate 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 4-2-1/5.9.3(b). In either case supporting documentation is to be submitted for review.

5.9.3(b) *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 must 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 $\lambda \geq 0.8$ 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:

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

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

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

where

- τ_N = nominal alternating torsional stress referred to crankpin or journal, in N/mm²
- 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 mm³
- $M_{T \max}$ = 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.

5.9.3(c) *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/mm²
- α_T = stress concentration factor for torsion in crankpin fillet (determination as per 4-2-1/5.9.4)
- τ_N = nominal alternating torsional stress related to crankpin diameter, in N/mm²

- 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/mm²

β_T = stress concentration factor for torsion in journal fillet (determination as per 4-2-1/5.9.4)

τ_N = nominal alternating torsional stress related to journal diameter, in N/mm²

- 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/mm²

γ_T = stress concentration factor for torsion in outlet of crankpin oil bore (determination as per 4-2-1/5.9.4)

τ_N = nominal alternating torsional stress related to crankpin diameter, in N/mm²

5.9.4 Evaluation of Stress Concentration Factors

5.9.4(a) General (2012). The stress concentration factors are evaluated by means of the equations in 4-2-1/5.9.4(b), 4-2-1/5.9.4(c) and 4-2-1/5.9.4(d) 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 Appendix 4-2-1A7 may be undertaken. All crank dimensions necessary for the calculation of stress concentration factors are shown in 4-2-1/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/Appendix 2).

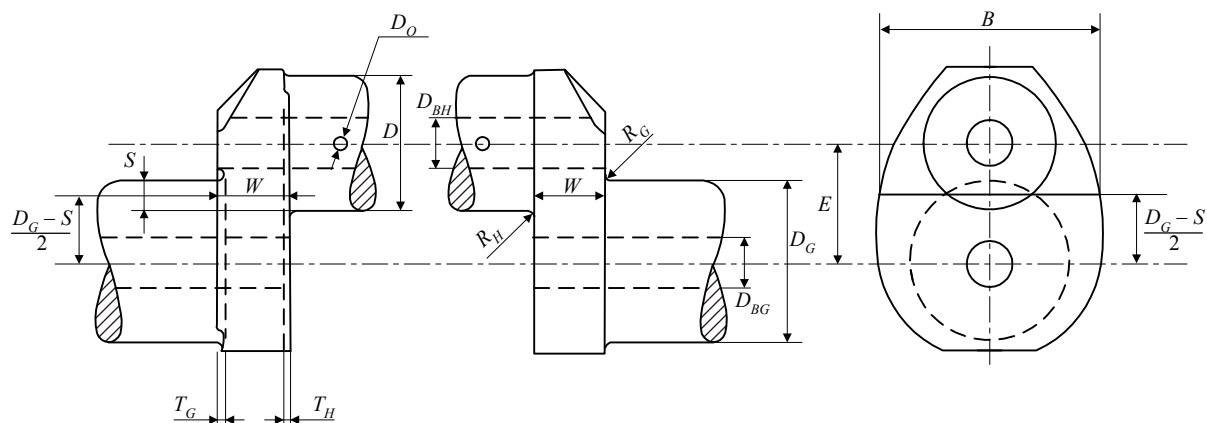
The stress concentration factor for compression (β_Q) in the journal fillet is defined as the ratio of the maximum equivalent stress (Von Mises), occurring in the fillet due to the radial force, to the nominal compressive stress related to the web cross-section.

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/Appendix 3).

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/Appendix 3).

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.

FIGURE 5
Crank Dimensions (2007)



• 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 must be considered as equal to:

$$W_{red} = W - (T_H - R_H) \quad (\text{see 4-2-1/Figure 3})$$

- Web width B must be taken in way of crankpin fillet radius center according to 4-2-1/Figure 3

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

<i>Crankpin fillet</i>	<i>Journal fillet</i>
$r = R_H/D$	$r = R_G/D$
$s = S/D$	
$w = W/D$	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:

$$\begin{aligned}
 s &\leq 0.5 \\
 0.2 &\leq w \leq 0.8 \\
 1.1 &\leq b \leq 2.2 \\
 0.03 &\leq r \leq 0.13 \\
 0 &\leq d_G \leq 0.8 \\
 0 &\leq d_H \leq 0.8 \\
 0 &\leq d_o \leq 0.2
 \end{aligned}$$

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 .

5.9.4(b) 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

$$\begin{aligned}
 f(s,w) &= -4.1883 + 29.2004 \cdot w - 77.5925 \cdot w^2 + 91.9454 \cdot w^3 - 40.0416 \cdot w^4 + (1-s) \cdot \\
 &\quad (9.5440 - 58.3480 \cdot w + 159.3415 \cdot w^2 - 192.5846 \cdot w^3 + 85.2916 \cdot w^4) + \\
 &\quad (1-s)^2 \cdot (-3.8399 + 25.0444 \cdot w - 70.5571 \cdot w^2 + 87.0328 \cdot w^3 - 39.1832 \cdot w^4) \\
 f(w) &= 2.1790 \cdot w^{0.7171} \\
 f(b) &= 0.6840 - 0.0077 \cdot b + 0.1473 \cdot b^2 \\
 f(r) &= 0.2081 \cdot r^{(-0.5231)} \\
 f(d_G) &= 0.9993 + 0.27 \cdot d_G - 1.0211 \cdot d_G^2 + 0.5306 \cdot d_G^3 \\
 f(d_H) &= 0.9978 + 0.3145 \cdot d_H - 1.5241 \cdot d_H^2 + 2.4147 \cdot d_H^3 \\
 f(recess) &= 1 + (t_H + t_G) \cdot (1.8 + 3.2 \cdot s)
 \end{aligned}$$

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

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

where

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

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

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

5.9.4(c) 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

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

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

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

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

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

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

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

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

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

where $f(r,s)$, $f(b)$ and $f(w)$ are to be determined in accordance with 4-2-1/5.9.4(b) (see calculation of α_T), however, the radius of the journal fillet is to be related to the journal diameter:

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