

SECTION 2 DIESEL ENGINES

1 General

1.1 Application

1.1.1 Diesel engines listed below are to be designed, constructed, installed, tested and certified in accordance with the requirements of this Section, under the supervision and to the satisfaction of the Society's Surveyors:

- a) main propulsion engines
- b) engines driving electric generators, including emergency generators
- c) engines driving other auxiliaries essential for safety and navigation and cargo pumps in tankers, when they develop a power of 110 kW and over.

All other engines are to be designed and constructed according to sound marine practice, with the equipment required in [2.3.4], and delivered with the relevant works' certificate (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]).

Engines intended for propulsion of lifeboats and compression ignition engines intended for propulsion of rescue boats are to comply with the relevant Rule requirements.

Additional requirements for control and safety systems for dual fuel engines are given in Ch 1, App 2.

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

1.2 Documentation flow for diesel engine

1.2.1 Document flow for obtaining a type approval certificate

- For the initial engine type, the engine designer prepares the documentation in accordance with requirements in Tab 1 and Tab 2 and forwards to the Society according to the agreed procedure for review.
In addition, the documents and drawing listed in Ch 1, App 2, Tab 1 are to be submitted for approval of DF engines
- Upon review and approval of the submitted documentation (evidence of approval), it is returned to the engine designer.
- The engine designer arranges for a Surveyor to attend an engine type test and upon satisfactory testing the Society issues a type approval certificate.

1.2.2 Document flow for engine certificate

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

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

- c) The engine builder/licensee develops a comparison list of the production documentation to the documentation listed in Tab 1 and Tab 2.

If there are differences in the technical content on the licensee's production drawings/documents compared to the corresponding licensor's drawings, the licensee must obtain agreement to such differences from the licensor.

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

- d) The engine builder/licensee submits the comparison list and the production documentation to the Society according to the agreed procedure for review/approval.
- e) The Society returns documentation to the engine builder/licensee with confirmation that the design has been approved. This documentation is intended to be used by the engine builder/licensee and their subcontractors and attending Surveyors. As the attending Surveyors may request the engine builder/licensee or their subcontractors to provide the actual documents indicated in the list, the documents are necessary to be prepared and available for the Surveyors.
- f) The attending Surveyors, at the engine builder/licensee/subcontractors, will issue product certificates as necessary for components manufactured upon satisfactory inspections and tests.
- g) The engine builder/licensee assembles the engine, tests the engine with a Surveyor present. An engine certificate is issued by the Surveyor upon satisfactory completion of assembly and tests.

1.2.3 Approval of diesel engine components

Components of engine designer's design which are covered by the type approval certificate of the relevant engine type are regarded as approved whether manufactured by the engine manufacturer or sub-supplied. For components of subcontractor's design, necessary approvals are to be obtained by the relevant suppliers (e.g. exhaust gas turbochargers, charge air coolers, etc.).

Table 1 : Document to be submitted for information, as applicable

No.	Item
1	Engine particulars (e.g. Data sheet with general engine information, Project Guide, Marine Installation Manual)
2	Engine cross section
3	Engine longitudinal section
4	Bedplate and crankcase of cast design
5	Thrust bearing assembly (1)
6	Frame/frame box/gearbox of cast design (2)
7	Tie rod
8	Connecting rod
9	Connecting rod, assembly (3)
10	Crosshead, assembly (3)
11	Piston rod, assembly (3)
12	Piston, assembly (3)
13	Cylinder jacket/ block of cast design (2)
14	Cylinder cover, assembly (3)
15	Cylinder liner
16	Counterweights (if not integral with crankshaft), including fastening
17	Camshaft drive, assembly (3)
18	Flywheel
19	Fuel oil injection pump
20	Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly
21	For electronically controlled engines, construction and arrangement of: <ul style="list-style-type: none">• Control valves• High-pressure pumps• Drive for high pressure pumps
22	
23	
24	Operation and service manuals (4)
25	FMEA (for engine control system) (5)
26	Production specifications for castings and welding (sequence)
27	Evidence of quality control system for engine design and in service maintenance
28	Quality requirements for engine production
29	Type approval certification for environmental tests, control components (6)
<p>(1) If integral with engine and not integrated in the bedplate.</p> <p>(2) Only for one cylinder or one cylinder configuration.</p> <p>(3) Including identification (e.g. drawing number) of components.</p> <p>(4) Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.</p> <p>(5) Where engines rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves, a failure mode and effects analysis (FMEA) is to be submitted to demonstrate that failure of the control system will not result in the operation of the engine being degraded beyond acceptable performance criteria for the engine. The FMEA reports required will not be explicitly approved by the Society.</p> <p>(6) Tests are to demonstrate the ability of the control, protection and safety equipment to function as intended under the specified testing conditions (see Ch 3, Sec 6, [2]).</p>	

Table 2 : Documentation to be submitted for approval, as applicable

No	Item
1	Bedplate and crankcase of welded design, with welding details and welding instructions (1) (2)
2	Thrust bearing bedplate of welded design, with welding details and welding instructions (1)
3	Bedplate/oil sump welding drawings (1)
4	Frame/framebox/gearbox of welded design, with welding details and instructions (1) (2)
5	Engine frames, welding drawings (1) (2)
6	Crankshaft, details, each cylinder No.
7	Crankshaft, assembly, each cylinder No.
8	Crankshaft calculations (for each cylinder configuration) according to the attached data sheet and Ch 1, App 1
9	Thrust shaft or intermediate shaft (if integral with engine)
10	Shaft coupling bolts
11	Material specifications of main parts with information on non-destructive material tests and pressure tests (3)
12	Schematic layout or other equivalent documents on the engine of: <ul style="list-style-type: none">Starting air systemFuel oil systemLubricating oil systemCooling water systemHydraulic systemHydraulic system (for valve lift)Engine control and safety system
13	
14	
15	
16	
17	
18	
19	Shielding of high pressure fuel pipes, assembly (4)
20	Construction of accumulators (for electronically controlled engine)
21	Construction of common accumulators (for electronically controlled engine)
22	Arrangement and details of the crankcase explosion relief valve (see [2.3]) (5)
23	Calculation results for crankcase explosion relief valves ([2.3])
24	Details of the type test program and the type test report) (6)
25	High pressure parts for fuel oil injection system (7)
26	Oil mist detection and/or alternative alarm arrangements (see [2.3])
27	Details of mechanical joints of piping systems (Ch 1, Sec 10, [2.4])
28	Documentation verifying compliance with inclination limits (see Ch 1, Sec 1, [2.4])
29	Documents as required in Ch 3, Sec 3, as applicable
(1) For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.	
(2) For each cylinder for which dimensions and details differ.	
(3) For comparison with Society requirements for material, NDT and pressure testing as applicable.	
(4) All engines.	
(5) Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m3 or more.	
(6) The type test report may be submitted shortly after the conclusion of the type test.	
(7) The documentation to contain specifications for pressures, pipe dimensions and materials.	

Table 3 : Documentation for the inspection of components and systems

No	Item
1	Engine particulars
2	Material specifications of main parts with information on non-destructive material tests and pressure tests (1)
3	Bedplate and crankcase of welded design, with welding details and welding instructions (2)
4	Thrust bearing bedplate of welded design, with welding details and welding instructions (2)
5	Frame/framebox/gearbox of welded design, with welding details and instructions (2)
6	Crankshaft, assembly and details
7	Thrust shaft or intermediate shaft (if integral with engine)
8	Shaft coupling bolts
9	Bolts and studs for main bearings
10	Bolts and studs for cylinder heads and exhaust valve (two stroke design)
11	Bolts and studs for connecting rods
12	Tie rods
	Schematic layout or other equivalent documents on the engine of: (3)
13	• Starting air system
14	• Fuel oil system
15	• Lubricating oil system
16	• Cooling water system
17	• Hydraulic system
18	• Hydraulic system (for valve lift)
19	• Engine control and safety system
20	Shielding of high pressure fuel pipes, assembly (4)
21	Construction of accumulators for hydraulic oil and fuel oil
22	High pressure parts for fuel oil injection system (5)
23	Arrangement and details of the crankcase explosion relief valve (see [2.3]) (6)
24	Oil mist detection and/or alternative alarm arrangements (see [2.3])
25	Cylinder head
26	Cylinder block, engine block
27	Cylinder liner
28	Counterweights (if not integral with crankshaft), including fastening
29	Connecting rod with cap
30	Crosshead
31	Piston rod
32	Piston, assembly (7)
33	Piston head
34	Camshaft drive, assembly (7)
35	Flywheel
36	Arrangement of foundation (for main engines only)
37	Fuel oil injection pump
38	Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly
39	Construction and arrangement of dampers
	For electronically controlled engines, assembly drawings or arrangements of:
40	• Control valves
41	• High-pressure pumps
42	• Drive for high pressure pumps
43	• Valve bodies, if applicable
44	Operation and service manuals (8)

No	Item
45	Test program resulting from FMEA (for engine control system) (9)
46	Production specifications for castings and welding (sequence)
47	Type approval certification for environmental tests, control components (10)
48	Quality requirements for engine production
(1)	For comparison with Society requirements for material, NDT and pressure testing as applicable.
(2)	For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.
(3)	Details of the system so far as supplied by the engine manufacturer such as: main dimensions, operating media and maximum working pressures.
(4)	All engines.
(5)	The documentation to contain specifications for pressures, pipe dimensions and materials.
(6)	Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m3 or more.
(7)	Including identification (e.g. drawing number) of components.
(8)	Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.
(9)	Required for engines that rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves.
(10)	Documents modified for a specific application are to be submitted to the Society for information or approval, as applicable. See [1.2.2], item b).

1.3 Definitions

1.3.1 Engine type

In general, the type of an engine is defined by the following characteristics:

- the cylinder diameter
- the piston stroke
- the method of injection (direct or indirect injection)
- the kind of fuel (liquid, gaseous or dual-fuel)
- the working cycle (4-stroke, 2-stroke)
- the gas exchange (naturally aspirated or supercharged)
- the maximum continuous power per cylinder at the corresponding speed and/or brake mean effective pressure corresponding to the above-mentioned maximum continuous power
- the method of pressure charging (pulsating system or constant pressure system)
- the charging air cooling system (with or without inter-cooler, number of stages, etc.)
- cylinder arrangement (in-line or V-type).

1.3.2 Engine power

The maximum continuous power is the maximum power at ambient reference conditions (see [1.3.3]) which the engine is capable of delivering continuously, at nominal maximum speed, in the period of time between two consecutive overhauls.

Power, speed and the period of time between two consecutive overhauls are to be stated by the Manufacturer and agreed by the Society.

The rated power is the maximum power at ambient reference conditions (see [1.3.3]) which the engine is capable of delivering as set after works trials (fuel stop power) at the maximum speed allowed by the governor.

The rated power for engines driving electric generators is the nominal power, taken at the net of overload, at ambient reference conditions (see [1.3.3]), which the engine is capable of delivering as set after the works trials (see [4.3]).

1.3.3 Ambient reference conditions

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

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

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

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

1.3.4 Same type of engines

Two diesel engines are considered to be of the same type when they do not substantially differ in design and construction characteristics, such as those listed in the engine type definition as per [1.3.1], it being taken for granted that the documentation concerning the essential engine components listed in Tab 1, Tab 2 and Tab 3, and associated materials employed has been submitted, examined and, where necessary, approved by the Society.

1.3.5 Substantive modifications or major modifications or major changes

Design modifications, which lead to alterations in the stress levels, operational behaviour, fatigue life or an effect on other components or characteristics of importance such as emissions.

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

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

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

2 Design and construction

2.1 Materials and welding

2.1.1 Crankshaft materials

In general, crankshafts are to be of forged steel having a tensile strength not less than 400 N/mm² and not greater than 1000 N/mm².

The use of forged steels of higher tensile strength is subject to special consideration by the Society in each case.

The Society, at its discretion and subject to special conditions (such as restrictions in ship navigation), may accept crankshafts made of cast carbon steel, cast alloyed steel of appropriate quality and manufactured by a suitable procedure having a tensile strength as follows:

- a) between 400 N/mm² and 560 N/mm² for cast carbon steel
- b) between 400 N/mm² and 700 N/mm² for cast alloyed steel.

The Society, at its discretion and subject to special conditions (such as restrictions in ship navigation), may also accept crankshafts made of cast iron for engines of a nominal power not exceeding 110 kW with a significant in-service behaviour either in marine or industry. The cast iron is to be of "SG" type (spheroidal graphite) of appropriate quality and manufactured by a suitable procedure.

2.1.2 Welded frames and foundations

Steels used in the fabrication of welded frames and bed-plates are to comply with the requirements of NR216 Materials and Welding.

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

2.2 Crankshaft

2.2.1 Check of the scantling

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

2.3 Crankcase

2.3.1 Strength

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 [2.3.4]. Crankcase doors are to be fastened sufficiently securely for them not be readily displaced by a crankcase explosion.

2.3.2 Ventilation and drainage

Ventilation of crankcase, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted.

Vent pipes, where provided, are to be as small as practicable. If provision is made for the forced extraction of gases from the crankcase (e.g. for detection of explosive mixtures), the vacuum in the crankcase is not to exceed:

2,5 10⁻⁴ MPa

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

2.3.3 Warning notice

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

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

2.3.4 Crankcase explosion relief valves

- a) Diesel engines of a cylinder diameter of 200 mm and above or a crankcase gross volume of 0,6 m³ and above are to be provided with crankcase explosion relief valves in accordance with the following requirements.
- b) Engines having a cylinder bore not exceeding 250 mm, are to have at least one valve near each end, but over eight crankthrows, an additional valve is to be fitted near the middle of the engine. Engines having a cylinder bore exceeding 250 mm, but not exceeding 300 mm, are to have at least one valve in way of each alternate crankthrow, with a minimum of two valves. Engines having a cylinder bore exceeding 300 mm are to have at least one valve in way of each main crankthrow.
- c) Additional relief valves are to be fitted on separate spaces of the crankcase, such as gear or chain cases for camshaft or similar drives, when the gross volume of such spaces is 0,6 m³ or above. Scavenge spaces in open connection to the cylinders are to be fitted with explosion relief valves.
- d) The free area of each relief valve is not to be less than 45 cm².
- e) The combined free area of the valves fitted on an engine is not to be less than 115 cm² per cubic metre of the crankcase gross volume. (See Note 1).
- f) Crankcase explosion relief valves are to be provided with lightweight spring-loaded valve discs or other quick-acting and self closing devices to relieve a crankcase of pressure in the event of an internal explosion and to prevent any inrush of air thereafter.
- g) The valve discs in crankcase explosion relief valves are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.
- h) Crankcase explosion relief valves are to be designed and constructed to open quickly and to be fully open at a pressure not greater than 0,02 MPa.
- i) Crankcase explosion relief valves are to be provided with a flame arrester that permits flow for crankcase pressure relief and prevents passage of flame following a crankcase explosion.
- j) Crankcase explosion relief valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine.

The purpose of type testing crankcase explosion valves is:

- to verify the effectiveness of the flame arrester
- to verify that the valve closes after an explosion
- to verify that the valve is gas/air tight after an explosion
- to establish the level of overpressure protection provided by the valve.

Where crankcase relief valves are provided with arrangements for shielding emissions from the valve following an explosion, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

Type testing procedure is to comply with Ch 1, App 4.

- k) Crankcase explosion relief valves are to be provided with a copy of the manufacturer's installation and maintenance manual that is pertinent to the size and type of valve being supplied for installation on a particular engine.

The manual is to contain the following information:

- description of valve with details of function and design limits
- copy of type test certification
- installation instructions
- maintenance in service instructions to include testing and renewal of any sealing arrangements
- actions required after a crankcase explosion.

- l) A copy of the installation and maintenance manual required in i) above is to be provided on board the unit.

- m) Valves are to be provided with suitable markings that include the following information:

- name and address of manufacturer
- designation and size
- month/year of manufacture
- approved installation orientation.

Note 1: The total volume of the stationary parts within the crankcase may be discounted in estimating the crankcase gross volume (rotating and reciprocating components are to be included in the gross volume).

2.3.5 Oil mist detection

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

- for alarm and slow down purposes for low speed diesel engines of 2250 kW and above or having cylinders of more than 300 mm bore
- for alarm and automatic shutoff purposes for medium and high speed diesel engines of 2250 kW and above or having cylinders of more than 300 mm bore

Oil mist detection arrangements are to be of a type approved and tested in accordance with Ch 3, App 1 and comply with b) to c) below. Engine bearing temperature monitors or equivalent devices used as safety devices have to be of a type approved by the Society for such purposes

Note 1: An equivalent device for high speed engines could be interpreted as measures applied to high speed engines where specific design features to preclude the risk of crankcase explosions are incorporated.

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

- Schematic layout of engine oil mist detection and alarm system showing location of engine crankcase sample points and piping or cable arrangements together with pipe dimensions to detector
- Evidence of study to justify the selected location of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry and the predicted crankcase atmosphere where oil mist can accumulate
- The manufacturer's maintenance and test manual
- Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist detection equipment

- c) A copy of the oil mist detection equipment maintenance and test manual required by item b) is to be provided on board ship

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

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

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

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

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

- i) Where oil mist detection equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with individual Society requirements for such systems

- j) Plans showing details and arrangements of oil mist detection and alarm arrangements are to be submitted for approval in accordance with Tab 2 under item 18

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

- l) Where sequential oil mist detection arrangements are provided the sampling frequency and time is to be as short as reasonably practicable

m) Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase details are to be submitted for consideration of individual Societies. The following information is to be included in the details to be submitted for consideration:

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

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

2.3.6 When materials other than steel are used for crankcase, requirements in Ch 1, Sec 1, [3.7.2] are to be referred to.

2.4 Scavenge manifolds

2.4.1 Fire extinguishing

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

2.4.2 Blowers

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

2.4.3 Relief valves

Scavenge spaces in open connection to the cylinders are to be fitted with explosion relief valves in accordance with [2.3.4].

2.5 Systems

2.5.1 General

In addition to the requirements of the present sub-article, those given in Ch 1, Sec 10 and in Ch 1, Sec 1, [3.7.2] are to be satisfied.

Flexible hoses in the fuel and lubricating oil system are to be limited to the minimum and are to be type approved.

Unless otherwise stated in Ch 1, Sec 10, propulsion engines are to be equipped with external connections for standby pumps for:

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

2.5.2 Fuel oil system

Relief valves discharging back to the suction of the pumps or other equivalent means are to be fitted on the delivery side of the pumps.

In fuel oil systems for propulsion machinery, filters are to be fitted and arranged so that an uninterrupted supply of filtered fuel oil is ensured during cleaning operations of the filter equipment, except when otherwise stated in Ch 1, Sec 10.

a) *All external high pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are to be protected with a shielded piping system capable of containing fuel from a high pressure line failure.*

A shielded pipe incorporates an outer pipe into which the high pressure fuel pipe is placed forming a permanent assembly.

The shielded piping system is to include a means for collection of leakages and arrangements are to be provided for an alarm to be given in the event of a fuel line failure.

If flexible hoses are used for shielding purposes, these are to be approved by the Society.

When in fuel oil return piping the pulsation of pressure with peak to peak values exceeds 2 MPa, shielding of this piping is also required as above.

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

2.5.3 Lubricating oil system

Efficient filters are to be fitted in the lubricating oil system when the oil is circulated under pressure.

In such lubricating oil systems for propulsion machinery, filters are to be arranged so that an uninterrupted supply of filtered lubricating oil is ensured during cleaning operations of the filter equipment, except when otherwise stated in Ch 1, Sec 10.

Relief valves discharging back to the suction of the pumps or other equivalent means are to be fitted on the delivery side of the pumps.

The relief valves may be omitted provided that the filters can withstand the maximum pressure that the pump may develop.

Where necessary, the lubricating oil is to be cooled by means of suitable coolers.

2.5.4 Charge air system

a) Requirements relevant to design, construction, arrangement, installation, tests and certification of exhaust gas turbochargers are given in Ch 1, Sec 14.

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

2.6 Starting air system

2.6.1 The requirements given in [3.1] apply.

2.7 Control and monitoring

2.7.1 General

In addition to those of this item, the general requirements given in Part C, Chapter 3 apply.

2.7.2 Alarm

The lubricating oil system of diesel engines with a power equal to or in excess of 37 kW is to be fitted with alarms to give audible and visual warning in the event of an appreciable reduction in pressure of the lubricating oil supply.

2.7.3 Governors of main and auxiliary engines

Each engine, except the auxiliary engines for driving electric generators for which [2.7.5] applies, is to be fitted with a speed governor so adjusted that the engine does not exceed the rated speed by more than 15%.

2.7.4 Overspeed protective devices of main and auxiliary engines

In addition to the speed governor, each:

- main propulsion engine having a rated power of 220 kW and above, which can be declutched or which drives a controllable pitch propeller, and
- auxiliary engine having a rated power of 220 kW and above, except those for driving electric generators, for which [2.7.6] applies,

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

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

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

2.7.5 Governors for auxiliary engines driving electric generators

- Prime movers for driving generators of the main and emergency sources of electrical power are to be fitted with a speed governor which will prevent transient frequency variations in the electrical network in excess of $\pm 10\%$ of the rated frequency with a recovery time to steady state conditions not exceeding 5 seconds, when the maximum electrical step load is switched on or off.

In the case when a step load equivalent to the rated output of a generator is switched off, a transient speed variation in excess of 10% of the rated speed may be acceptable, provided this does not cause the intervention of the overspeed device as required by [2.7.6].

- At all loads between no load and rated power, the permanent speed variation is not to be more than 5% of the rated speed.
- Prime movers are to be selected in such a way that they meet the load demand within the ship's mains and, when running at no load, can satisfy the requirement in

item a) above if suddenly loaded to 50% of the rated power of the generator, followed by the remaining 50% after an interval sufficient to restore speed to steady state. Steady state conditions (see Note 1) are to be achieved in not more than 5 s. (See Note 1)

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

- Application of the electrical load in more than 2 load steps can only be allowed if the conditions within the ship's mains permit the use of those auxiliary engines which can only be loaded in more than 2 load steps (see Fig 1 for guidance on 4-stroke diesel engines expected maximum possible sudden power increase) and provided that this is already allowed for in the designing stage.

This is to be verified in the form of system specifications to be approved and to be demonstrated at ship's trials. In this case, due consideration is to be given to the power required for the electrical equipment to be automatically switched on after blackout and to the sequence in which it is connected

This also applies to generators to be operated in parallel and where the power is to be transferred from one generator to another, in the event that any one generator is to be switched off.

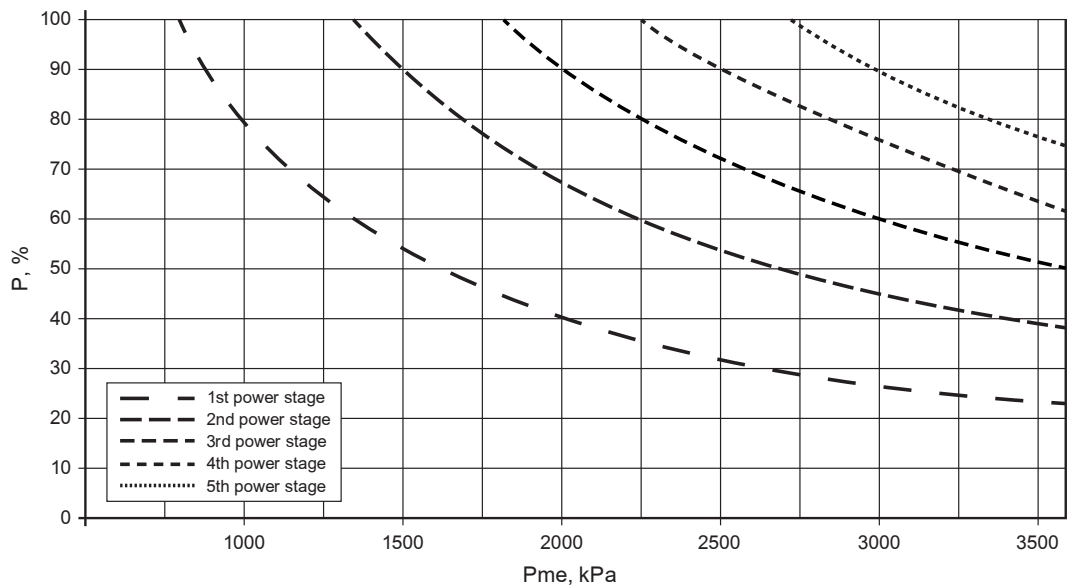
- Emergency generator sets must satisfy the governor conditions as per items a) and b) when:

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

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

For alternating current generating sets intended to operate in parallel, facilities are to be provided to adjust the governor sufficiently finely to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.

Figure 1 : Reference values for maximum possible sudden power increases P as a function of brake mean effective pressure, P_{me} , at declared power (four-stroke diesel engines)



P: power increase referred to declared power at site conditions; P_{me} : declared power mean effective pressure

2.7.6 **Overspeed protective devices of auxiliary engines driving electric generators**

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

This device is to automatically shut down the engine.

2.7.7 **Use of electronic governors**

a) Type approval

Electronic governors and their actuators are to be type approved by the Society.

b) Electronic governors for main propulsion engines

If an electronic governor is fitted to ensure continuous speed control or resumption of control after a fault, an additional separate governor is to be provided unless the engine has a manually operated fuel admission control system suitable for its control.

A fault in the governor system is not to lead to sudden major changes in propulsion power or direction of propeller rotation.

Alarms are to be fitted to indicate faults in the governor system.

The acceptance of electronic governors not in compliance with the above requirements will be considered by the Society on a case by case basis, when fitted on ships with two or more main propulsion engines.

c) Electronic governors forming part of a remote control system

When electronic speed governors of main internal combustion engines form part of a remote control system, they are to comply with the following conditions:

- If lack of power to the governor may cause major and sudden changes in the present speed and direc-

tion of thrust of the propeller, back up power supply is to be provided;

- Local control of the engines is always to be possible even in the case of failure in any part of the automatic or remote control systems. To this purpose, from the local control position it is to be possible to disconnect the remote signal, bearing in mind that the speed control according to [2.7.3] is not available unless an additional separate governor is provided for such local mode of control.

d) Electronic governors for auxiliary engines driving electric generators

In the event of a fault in the electronic governor system the fuel admission is to be set to “zero”.

Alarms are to be fitted to indicate faults in the governor system.

The acceptance of electronic governors fitted on engines driving emergency generators will be considered by the Society on a case by case basis.

2.7.8 **Summary tables**

Diesel engines installed on ships without automation notations are to be equipped with monitoring equipment as detailed in Tab 4 or Tab 5 for main propulsion, in Tab 6 for auxiliary services and in Tab 7 for emergency respectively.

For ships classed for restricted navigation, the acceptance of a reduction in the monitoring equipment required in Tab 4, Tab 5 and Tab 6 may be considered.

The alarms are to be visual and audible.

The indicators are to be fitted at a normally attended position (on the engine or at the local control station).

Table 4 : Monitoring of main propulsion cross-head (slow speed) diesel engines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indica- tion	Slow- down	Shut- down	Control	Stand by Start	Stop
Fuel oil pressure after filter (engine inlet)		local					
Fuel oil viscosity before injection pumps or fuel oil temperature before injection pumps (for engine running on heavy fuel)		local					
Leakage from high pressure pipes where required	H						
Lubricating oil to main bearing and thrust bearing pressure	L	local					
	LL			X			
Lubricating oil to cross-head bearing pressure when separate	L	local					
	LL			X			
Lubricating oil to camshaft pressure when separate	L	local					
	LL			X			
Turbocharger lubricating oil inlet pressure		local					
Lubricating oil inlet temperature		local					
Thrust bearing pads or bearing outlet temperature	H	local					
Main, crank, cross-head bearing, oil outlet temp	H						
Oil mist concentration in crankcase (or engine bearing temperature monitors or equivalent devices) (5)	H		X				
Cylinder fresh cooling water system inlet pressure	L	local (3)					
Cylinder fresh cooling water outlet temperature or, when common cooling space without individual stop valves, the common cylinder water outlet temperature		local					
Piston coolant inlet pressure on each cylinder (1)	L	local					
Piston coolant outlet temperature on each cylinder (1)		local					
Piston coolant outlet flow on each cylinder (1) (2)	L						
Speed of turbocharger		local					
Scavenging air receiver pressure		local					
Scavenging air box temperature (detection of fire in receiver)		local					
Exhaust gas temperature		local (4)					
Engine speed / direction of speed (when reversible)		local					
	H			X			
Fault in the electronic governor system	X						
(1) Not required, if the coolant is oil taken from the main cooling system of the engine (2) Where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted (3) For engines of 220 KW and above (4) Indication is required after each cylinder, for engines of 500 kW/cylinder and above (5) For engine of 2250 KW and above or having cylinders of more than 300 mm bore							

Table 5 : Monitoring of main propulsion trunk-piston (medium or high speed) engines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil pressure after filter (engine inlet)		local					
Fuel oil viscosity before injection pumps or fuel oil temperature before injection pumps (for engine running on heavy fuel)		local					
Leakage from high pressure pipes where required	H						
Lubricating oil to main bearing and thrust bearing pressure	L	local					
	LL			X			
Lubricating oil filter differential pressure	H	local					
Turbocharger lubricating oil inlet pressure (1)		local					
Lubricating oil inlet temperature		local					
Oil mist concentration in crankcase (or engine bearing temperature monitors or equivalent devices) (3)	H			X			
Cylinder fresh cooling water outlet temperature or, when common cooling space without individual stop valves, the common cylinder water outlet temperature		local					
Scavenging air receiver pressure		local					
Scavenging air box temperature (detection of fire in receiver)		local					
Exhaust gas temperature		local (2)					
Engine speed / direction of speed (when reversible)		local					
	H			X			
Fault in the electronic governor system	X						
(1) If without integrated self-contained oil lubrication system (2) Indication is required after each cylinder, for engines of 500 kW/cylinder and above (3) For engine of 2250 KW and above or having cylinders of more than 300 mm bore							

Table 6 : Monitoring of trunk-piston diesel engines used for auxiliary services

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil viscosity or temperature before injection (for engine running on heavy fuel)		local					
Fuel oil pressure		local					
Fuel oil leakage from high pressure pipes	H						
Lubricating oil pressure	L	local		X			
Oil mist concentration in crankcase (or engine bearing temperature monitors or equivalent devices) (1)	H			X			
Pressure or flow of cooling water, if not connected to main system	L	local					
Temperature of cooling water or cooling air		local					
Engine speed		local					
	H			X			
Fault in the electronic governor system	X						
(1) For engine of 2250 KW and above or having cylinders of more than 300 mm bore							

Table 7 : Monitoring of emergency diesel engines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil leakage from high pressure pipes	H	local					
Lubricating oil temperature (1)	H	local					
Lubricating oil pressure	L	local					
Oil mist concentration in cranckcase (2)	H	local					
Pressure or flow of cooling water (1)	L	local					
Temperature of cooling water or cooling air		local					
Engine speed		local					
	H			X (1)			
(1) Not applicable to emergency generator of less than 220 kW (2) For engines having a power of more than 2250kW or a cylinder bore of more than 300 mm Note 1: The safety and alarm systems are to be designed to ‘fail safe’. The characteristics of the ‘fail safe’ operation are to be evaluated on the basis not only of the system and its associated machinery, but also the complete installation, as well as the ship. Note 2: Regardless of the engine output, if shutdowns additional to those above specified except for the overspeed shutdown, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation. Note 3: The alarm system is to function in accordance with AUT notation, with additional requirements that grouped alarms are to be arranged on the bridge. Note 4: In addition to the fuel oil control from outside the space, a local means of engine shutdown is to be provided. Note 5: The local indications are to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.							

3 Arrangement and installation

3.1 Starting arrangements

3.1.1 Mechanical air starting

- a) Air starting the main and auxiliary engines is to be arranged in compliance with Ch 1, Sec 10, [17.3.1].
- b) The total capacity of air compressors and air receivers is to be in compliance with Ch 1, Sec 10, [17.3.2] and Ch 1, Sec 10, [17.3.3].
- c) The main starting air arrangements for main propulsion or auxiliary diesel engines are to be adequately protected against the effects of backfiring and internal explosion in the starting air pipes. To this end, the following safety devices are to be fitted:
 - An isolating non-return valve, or equivalent, at the starting air supply connection to each engine.
 - A bursting disc or flame arrester:
 - in way of the starting valve of each cylinder, for direct reversing engines having a main starting air manifold
 - at least at the supply inlet to the starting air manifold, for non-reversing engines.The bursting disc or flame arrester above may be omitted for engines having a bore not exceeding 230 mm.

Other protective devices will be specially considered by the Society.

The requirements of this item c) do not apply to engines started by pneumatic motors.

- d) Compressed air receivers are to comply with the requirements of Ch 1, Sec 3. Compressed air piping and associated air compressors are to comply with the requirements of Ch 1, Sec 10.

3.1.2 Electrical starting

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

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

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

The combined capacity of batteries is to be sufficient to provide within 30 min, without recharging, the number of starts required in [3.1.1] b) in the event of air starting.
- b) Electrical starting arrangements for auxiliary engines are to have two separate storage batteries or may be supplied by two separate circuits from main engine storage batteries when these are provided. In the case of a single auxiliary engine, one battery is acceptable. The combined capacity of the batteries is to be sufficient for at least three starts for each engine.

- c) The starting batteries are only to be used for starting and for the engine's alarm and monitoring. Provision is to be made to maintain the stored energy at all times.
- d) Each charging device is to have at least sufficient rating for recharging the required capacity of batteries within 6 hours.

3.1.3 Special requirements for starting arrangements for emergency generating sets

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

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

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

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

- *electrical and hydraulic starting systems shall be maintained from the emergency switchboard*
- *compressed air starting systems shall be provided in accordance with Ch 1, Sec 10, [17.3.4].*

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

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

3.2 Turning gear

3.2.1 Each engine is to be provided with hand-operated turning gear; where deemed necessary, the turning gear is to be both hand and mechanically-operated.

The turning gear engagement is to inhibit starting operations.

3.3 Trays

3.3.1 Trays fitted with means of drainage are to be provided in way of the lower part of the crankcase and, in general, in way of the parts of the engine, where oil is likely to spill in order to collect the fuel oil or lubricating oil dripping from the engine.

3.4 Exhaust gas system

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

4 Type tests, material tests, workshop inspection and testing, certification

4.1 Type testing

4.1.1 Objectives

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

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

4.1.2 Validity

- a) Type testing is required for every new engine type intended for installation onboard ships subject to classification.
- b) A type test carried out for a particular type of engine at any place of manufacture will be accepted for all engines of the same type built by licensees or the licensor, subject to each place of manufacture being found to be acceptable to the Society.
- c) A type of engine is defined by:
 - bore and stroke
 - injection method (direct or indirect)
 - valve and injection operation (by cams or electronically controlled)
 - kind of fuel (liquid, dual-fuel, gaseous)
 - working cycle (4-stroke, 2-stroke)
 - turbo-charging system (pulsating or constant pressure)
 - the charging air cooling system (e.g. with or without intercooler)
 - cylinder arrangement (in-line or V) (see Note 1)
 - cylinder power, speed and cylinder pressures (see Note 2)

Note 1: One type test will be considered adequate to cover a range of different numbers of cylinders. However, a type test of an in-line engine may not always cover the V-version. Subject to the individual Societies' discretion, separate type tests may be required for the V-version. On the other hand, a type test of a V-engine covers the in-line engines, unless the bmep is higher.

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

Note 2: The engine is type approved up to the tested ratings and pressures (100% corresponding to MCR).

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

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

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

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

d) De-rated engine

If an engine has been design approved, and internal testing per Stage A (see [4.1.4]) is documented to a rating higher than the one type tested, the Type Approval may be extended to the increased power/bmep/rpm upon submission of an Extended Delivery Test Report at:

- Test at over speed (only if nominal speed has increased)
- Rated power, i.e. 100% output at 100% torque and 100% speed corresponding to load point 1 (see Fig 2), 2 measurements with one running hour in between
- Maximum permissible torque (normally 110%) at 100% speed corresponding to load point 3 (see Fig 2) or maximum permissible power (normally 110%) and speed according to nominal propeller curve corresponding to load point 3a (see Fig 2), 0,5 hour
- 100% power at maximum permissible speed corresponding to load point 2 (see Fig 2), 0,5 hour.

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

4.1.3 Safety precautions

- a) Before any test run is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer/shipyard and is to be operational, and its correct functioning is to be verified.
- b) This applies especially to crankcase explosive conditions protection, but also over-speed protection and any other shut down function.

- c) The inspection for jacketing of high-pressure fuel oil lines and proper screening of pipe connections (as required in [4.1.7], item i) is also to be carried out before the test runs.

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

4.1.4 Test programme

- a) The type testing is divided into 3 stages:

- Stage A - internal tests.

This includes some of the testing made during the engine development, function testing, and collection of measured parameters and records of testing hours. The results of testing required by the Society or stipulated by the designer are to be presented to the Society before starting stage B.

- Stage B - witnessed tests.

This is the testing made in the presence of the Surveyor.

- Stage C - component inspection.

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

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

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

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

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

- e) High speed engines for marine use are normally to be subjected to an endurance test of 100 hours at full load. Omission or simplification of the type test may be considered for the type approval of engines with long service experience from non-marine fields or for the extension of type approval of engines of a well-known type, in excess of the limits given in [4.1.2].

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

4.1.5 Measurements and recordings

- a) During all testing the ambient conditions (air temperature, air pressure and humidity) are to be recorded.
- b) As a minimum, the following engine data are to be measured and recorded:
 - Engine r.p.m.
 - Torque
 - Maximum combustion pressure for each cylinder (see Note 1)
 - Mean indicated pressure for each cylinder (see Note 1)
 - Charging air pressure and temperature
 - Exhaust gas temperature
 - Fuel rack position or similar parameter related to engine load
 - Turbocharger speed
 - All engine parameters that are required for control and monitoring for the intended use (propulsion, auxiliary, emergency).

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

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

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

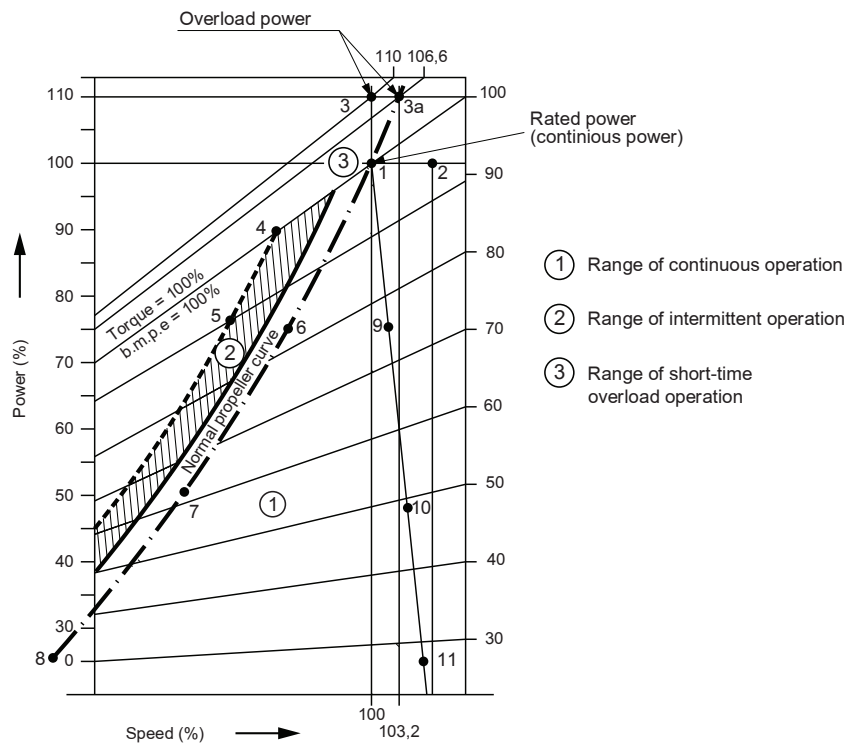
4.1.6 Stage A - internal tests

- a) During the internal tests, the engine is to be operated at the load points important for the engine designer and the pertaining operating values are to be recorded. The load conditions to be tested are also to include the testing specified in the applicable type approval programme.
- b) At least the following conditions are to be tested:
 - Normal case:
The load points 25%, 50%, 75%, 100% and 110% of the maximum rated power for continuous operation, to be made along the normal (theoretical) propeller curve and at constant speed for propulsion engines (if applicable mode of operation i.e. driving controllable pitch propellers), and at constant speed for engines intended for generator sets including a test at no load and rated speed.
 - The limit points of the permissible operating range. These limit points are to be defined by the engine manufacturer.
 - For high speed engines, the 100 hr full load test and the low cycle fatigue test apply as required in connection with the design assessment.
 - Specific tests of parts of the engine, required by the Society or stipulated by the designer.

4.1.7 Stage B - witnessed tests

- a) The tests listed below are to be carried out in the presence of a Surveyor. The achieved results are to be recorded and signed by the attending Surveyor after the type test is completed.
- b) The over-speed test is to be carried out and is to demonstrate that the engine is not damaged by an actual engine overspeed within the overspeed shutdown system set-point. This test may be carried out at the manufacturer's choice either with or without load during the speed overshoot.
- c) The engine is to be operated according to the power and speed diagram (see Fig 2). The data to be measured and recorded when testing the engine at the various load points have to include all engine parameters listed in [4.1.5]. The operating time per load point depends on the engine size (achievement of steady state condition) and on the time for collection of the operating values. Normally, an operating time of 0,5 hour can be assumed per load point, however sufficient time should be allowed for visual inspection by the Surveyor.
- d) The load points (see Fig 2) are:
 - Rated power (MCR), i.e. 100% output at 100% torque and 100% speed corresponding to load point 1, normally for 2 hours with data collection with an interval of 1 hour. If operation of the engine at limits as defined by its specified alarm system (e.g. at alarm levels of lub oil pressure and inlet temperature) is required, the test should be made here
 - 100% power at maximum permissible speed corresponding to load point 2
 - Minimum permissible speed at 100% torque, corresponding to load point 4
 - Minimum permissible speed at 90% torque corresponding to load point 5 (Applicable to propulsion engines only).
 - Part loads e.g. 75%, 50% and 25% of rated power and speed according to nominal propeller curve (i.e. 90.8%, 79.3% and 62.9% speed) corresponding to points 6, 7 and 8 or at constant rated speed setting corresponding to points 9, 10 and 11, depending on the intended application of the engine
 - Crosshead engines not restricted for use with C.P. propellers are to be tested with no load at the associated maximum permissible engine speed.
- e) During all these load points, engine parameters are to be within the specified and approved values.
- f) Operation with damaged turbocharger:
For 2-stroke propulsion engines, the achievable continuous output is to be determined in the case of turbocharger damage.
Engines intended for single propulsion with a fixed pitch propeller are to be able to run continuously at a speed (r.p.m.) of 40% of full speed along the theoretical propeller curve when one turbocharger is out of operation. (The test can be performed by either by-passing the turbocharger, fixing the turbocharger rotor shaft or removing the rotor).

Figure 2 : Load points



- g) Functional tests:
- Verification of the lowest specified propulsion engine speed according to the nominal propeller curve as specified by the engine designer (even though it works on a water-brake). During this operation, no alarm shall occur.
 - Starting tests, for non-reversible engines and/or starting and reversing tests, for reversible engines, for the purpose of determining the minimum air pressure and the consumption for a start.
 - Governor tests: tests for compliance with [2.7] are to be carried out.
- h) Integration test:
- For electronically controlled diesel engines, integration tests are to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes. The scope of these tests is to be agreed with the Society for selected cases based on the FMEA required in Tab 1.
- i) Fire protection measures:
- Screening of pipe connections in piping containing flammable liquids and insulation of hot surfaces:
- The engine is to be inspected for jacketing of high-pressure fuel oil lines, including the system for the detection of leakage, and proper screening of pipe connections in piping containing flammable liquids.
 - Proper insulation of hot surfaces is to be verified while running the engine at 100% load, alternatively at the overload approved for intermittent use. Readings of surface temperatures are to be done by use of Infrared Thermoscanning Equipment. Equivalent measurement equipment may be used when so approved by the Society. Readings obtained are to be randomly verified by use of contact thermometers.

4.1.8 Stage C - Opening up for Inspections

- a) The crankshaft deflections are to be measured in the specified (by designer) condition (except for engines where no specification exists).
- b) High speed engines for marine use are normally to be stripped down for a complete inspection after the type test.
- c) For all the other engines, after the test run the components of one cylinder for in-line engines and two cylinders for V-engines are to be presented for inspection as follows (engines with long service experience from non-marine fields can have a reduced extent of opening):
- piston removed and dismantled
 - crosshead bearing dismantled
 - guide planes
 - connecting rod bearings (big and small end) dismantled (special attention to serrations and fretting on contact surfaces with the bearing backsides)
 - main bearing dismantled
 - cylinder liner in the installed condition
 - cylinder head, valves disassembled
 - cam drive gear or chain, camshaft and crankcase with opened covers. (The engine must be turnable by turning gear for this inspection.)
- d) For V-engines, the cylinder units are to be selected from both cylinder banks and different crank throws.
- e) If deemed necessary by the surveyor, further dismantling of the engine may be required.

4.1.9 If an electronically controlled diesel engine has been type tested as a conventional engine the Society may waive tests required by this article provided the results of the individual tests would be similar.

Table 8 : Summary of required documentation for engine components

Item No.	Part (4) (5) (6) (7) (8)	Material properties (1)	Non-destructive examination (2)	Hydraulic testing (3)	Dimensional inspection, including surface condition	Visual inspection (Surveyor)	Applicable to engines:	Component certificate
1	Welded bedplate	W(C+M)	W(UT+CD)			fit-up + post-welding	All	SC
2	Bearing transverse girders GS	W(C+M)	W(UT+CD)			X	All	SC
3	Welded frame box	W(C+M)	W(UT+CD)			fit-up + post-welding	All	SC
4	Cylinder block GJL			W (10)			> 400 kW/cyl	
5	Cylinder block GJS			W (10)			> 400 kW/cyl	
6	Welded cylinder frames	W(C+M)	W(UT+CD)			fit-up + post-welding	CH	SC
7	Engine block GJL			W (10)			> 400 kW/cyl	
8	Engine block GJS	W(M)		W (10)			> 400 kW/cyl	
9	Cylinder liner	W(C+M)		W (10)			D > 300mm	
10	Cylinder head GJL			W			D > 300mm	
11	Cylinder head GJS			W			D > 300mm	
12	Cylinder head GS	W(C+M)	W(UT+CD)	W		X	D > 300mm	SC
13	Forged cylinder head	W(C+M)	W(UT+CD)	W		X	D > 300mm	SC
14	Piston crown GS	W(C+M)	W(UT+CD)			X	D > 400mm	SC
15	Forged piston crown	W(C+M)	W(UT+CD)			X	D > 400mm	SC
16	Crankshaft: made in one piece	SC(C+M)	W(UT+CD)		W	Random, of fillets and oil bores	All	SC
17	Semi-built Crankshaft (Crankthrow, forged main journal and journals with flange)	SC(C+M)	W(UT+CD)		W	Random, of fillets and shrink fittings	All	SC
18	Exhaust gas valve cage			W			CH	
19	Piston Rod, if applicable	SC(C+M)	W(UT+CD)			Random	D > 400mm CH	SC
20	Cross head	SC(C+M)	W(UT+CD)			Random	CH	SC
21	Connecting rod with cap	SC(C+M)	W(UT+CD)		W	Random, of all surfaces, in particular those shot peened	All	SC
22	Coupling bolts for crankshaft	SC(C+M)	W(UT+CD)		W	Random, of interference fit	All	SC
23	Bolts and studs for main bearings	W(C+M)	W(UT+CD)				D > 300mm	
24	Bolts and studs for cylinder heads	W(C+M)	W(UT+CD)				D > 300mm	
25	Bolts and studs for connecting rods	W(C+M)	W(UT+CD)		TR of thread making		D > 300mm	
26	Tie rod	W(C+M)	W(UT+CD)		TR of thread making	Random	CH	SC

Item No.	Part (4) (5) (6) (7) (8)	Material properties (1)	Non-destructive examination (2)	Hydraulic testing (3)	Dimensional inspection, including surface condition	Visual inspection (Surveyor)	Applicable to engines:	Component certificate
27	High pressure fuel injection pump body	W(C+M)		W			D > 300mm	
		W(C+M)		TR			D ≤ 300mm	
28	High pressure fuel injection valves (only for those not autofretted)			W			D > 300mm	
				TR			D ≤ 300mm	
29	High pressure fuel injection pipes including common fuel rail	W(C+M)		W for those that are not autofretted			D > 300mm	
		W(C+M)		TR for those that are not autofretted			D ≤ 300mm	
30	High pressure common servo oil system	W(C+M)		W			D > 300mm	
		W(C+M)		TR			D ≤ 300mm	
31	Cooler, both sides (9)	W(C+M)		W			D > 300mm	
32	Accumulator	W(C+M)		W			All engines with accumulators with a capacity of > 0,5 l	
33	Piping, pumps, actuators, etc. for hydraulic drive of valves, if applicable	W(C+M)		W			> 800 kW/cyl	
34	Engine driven pumps (oil, water, fuel, bilge) other than pumps referred to in item 27 and 33			W			> 800 kW/cyl	
35	Bearings for main, crosshead, and crankpin	TR(C)	TR (UT for full contact between base material and bearing metal)		W		> 800 kW/cyl	

Note 1: Symbols used in this Table are listed in [4.2.1].

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

(2) Non-destructive examination means e.g. ultrasonic testing, crack detection by MPI or DP.

(3) Hydraulic testing is applied on the water/oil side of the component. Items are to be tested by hydraulic pressure at the pressure equal to 1,5 times the maximum working pressure. High pressure parts of the fuel injection system are to be tested by hydraulic pressure at the pressure equal to 1,5 maximum working pressure or maximum working pressure plus 300 bar, whichever is the less. Where design or testing features may require modification of these test requirements, special consideration may be given.

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

(5) For turbochargers, see Ch 1, Sec 14.

(6) Crankcase safety valves are to be type tested in accordance with Ch 1, App 4 and documented according to [2.3.4].

(7) Oil mist detection systems are to be type tested in accordance with Ch 3, App 1 and documented according to [2.3.5]

(8) For Speed governor and overspeed protective devices, see [2.7].

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

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

4.2 Material and non-destructive tests for engine components

4.2.1 List of components

Engine components are to be tested in accordance with Tab 8 and with the requirements of NR216 Materials and Welding.

Symbols used on Tab 8 are defined as below:

C	: Chemical composition
CD	: Crack detection by MPI (magnetic particul inspection) or DP (dye penetration inspection)
CH	: Crosshead engines
D	: Cylinder bore diameter (mm)
GJL	: Gray cast iron
GJS	: Spheroidal graphite cast iron
GS	: Cast steel
M	: Mechanical properties
SC	: Society certificate
TR	: Test report
UT	: Ultrasonic testing
W	: Work certificate
X	: Visual examination of accessible surfaces by the Surveyor

For components and materials not listed in Tab 8, consideration shall be given by the Society upon full details being submitted and reviewed.

4.3 Factory Acceptance Test

4.3.1 Safety precautions

- Before any test run is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer / shipyard and is to be operational.
- This applies especially to crankcase explosive conditions protection, but also to over-speed protection and any other shut down function.
- The overspeed protective device is to be set to a value, which is not higher than the overspeed value that was demonstrated during the type test for that engine. This set point shall be verified by the surveyor.

4.3.2 General

- Before any official testing, the engines shall be run-in as prescribed by the engine manufacturer.
- Adequate test bed facilities for loads as required in [4.3.3] shall be provided. All fluids used for testing purposes such as fuel, lubrication oil and cooling water are to be suitable for the purpose intended, e.g. they are to be clean, preheated if necessary and cause no harm to engine parts. This applies to all fluids used temporarily or repeatedly for testing purposes only.

- Engines are to be inspected for:
 - Jacketing of high-pressure fuel oil lines including the system used for the detection of leakage.
 - Screening of pipe connections in piping containing flammable liquids.
 - Insulation of hot surfaces by taking random temperature readings that are to be compared with corresponding readings obtained during the type test. This shall be done while running at the rated power of engine. Use of contact thermometers may be accepted at the discretion of the attending Surveyor. If the insulation is modified subsequently to the Type Approval Test, the Society may request temperature measurements as required by [4.1.7], item g).
- These inspections are normally to be made during the works trials by the manufacturer and the attending surveyor, but at the discretion of the Society parts of these inspections may be postponed to the shipboard testing.

4.3.3 Works trials (Factory Acceptance Test)

a) Objectives

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

b) Records

- The following environmental test conditions are to be recorded:
 - Ambient air temperature
 - Ambient air pressure
 - Atmospheric humidity
- For each required load point, the following parameters are normally to be recorded:
 - Power and speed
 - Fuel index (or equivalent reading)
 - Maximum combustion pressures (only when the cylinder heads installed are designed for such measurement)
 - Exhaust gas temperature before turbine and from each cylinder (to the extent that monitoring is required in Ch 1, Sec 14 and [2.7])
 - Charge air temperature
 - Charge air pressure
 - Turbocharger speed (to the extent that monitoring is required in Ch 1, Sec 14)
- Calibration records for the instrumentation are, upon request, to be presented to the attending Surveyor.
- For all stages at which the engine is to be tested, the pertaining operational values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer. This also includes crankshaft deflections if considered necessary by the engine designer.

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

c) Test loads

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

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

- 2) Propulsion engines driving propeller or impeller only:

- 100% power (MCR) at corresponding speed n_0 : at least 60 min.
- 110% power at engine speed $1,032n_0$: Records to be taken after 15 minutes or after steady conditions have been reached, whichever is shorter.

Note 2: 110% test load is only required once for each different engine/turbocharger configuration.

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

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

- 3) Engines driving generators for electric propulsion:

- 100% power (MCR) at corresponding speed n_0 : at least 60 min.
- 110% power at engine speed n_0 : 15 min. - after having reached steady conditions.
- Governor tests for compliance with [2.7] are to be carried out.
- 75%, 50% and 25% power and idle, the sequence to be selected by the engine manufacturer.

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

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

- 4) Engines driving generators for auxiliary purposes:

Tests to be performed as in item c) 3).

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

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

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

- 6) Engines driving auxiliaries:

- 100% power (MCR) at corresponding speed n_0 : at least 30 min.
- 110% power at engine speed n_0 : 15 min. - after having reached steady conditions.
- Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
- For variable speed engines, 75%, 50% and 25% power in accordance with the nominal power consumption curve, the sequence to be selected by the engine manufacturer.

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

- d) Turbocharger matching with engine

- 1) Compressor chart

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

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

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

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

2) Surge margin verification

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

- For 4-stroke engines:

The following shall be performed without indication of surging:

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

- For 2-stroke engines:

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

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

This test shall be performed at two different engine loads:

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

e) Integration tests

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

f) Component inspections

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

4.4 Certification**4.4.1 Type approval certificate**

- a) For each type of engine that is required to be approved, a type approval certificate is to be obtained by the engine designer. The process details for obtaining a type approval certificate are given below (see also [1.2]). This process consists of the engine designer obtaining from the Society:

- drawing and specification approval
- conformity of production
- approval of type testing programme
- type testing of engines
- review of the obtained type testing results
- evaluation of the manufacturing arrangements
- issue of a type approval certificate.

The manufacturing facility of the engine presented for the type approval test is to be assessed in accordance with NR320.

b) Type approval certificate renewal

A renewal of type approval certificates will be granted upon:

- The submission of modified documents or new documents with substantial modifications replacing former documents compared to the previous submission(s), or alternatively,
- A declaration that no substantial modifications have been applied since the last issuance of the type approval certificate.

c) Validity of type approval certificate

The limit of the duration facility of the type approval certificate shall comply with requirements of NR 320. The maximum period of validity of a type approval certificate is 5 years.

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

4.4.2 Engine certificate

- a) Each diesel engine manufactured for a shipboard application is to have an engine certificate. This process consists of the engine builder/licensee obtaining design approval of the engine application specific documents, submitting a comparison list of the production drawings to the previously approved engine design drawings referenced in [4.4.1] forwarding the relevant production drawings and comparison list for the use of the Surveyors at the manufacturing plant and shipyard if necessary, engine testing and upon satisfactorily meeting the Rule requirements, the issuance of an engine certificate.

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

- b) Society’s requirements for production facilities comprising manufacturing facilities and processes, machining tools, quality assurance, testing facilities, etc. shall be assessed according to NR320 requirements.

4.4.3 Certification of engine components

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

- b) Society Certificate (SC)

This is a document issued by the Society stating:

- conformity with Rule requirements
- that the tests and inspections have been carried out on the finished certified component itself, or on samples taken from earlier stages in the production of the component, when applicable
- that the inspection and tests were performed in the presence of the Surveyor or in accordance with an Alternative Survey Scheme according to NR320.

- c) Work’s Certificate (W)

This is a document signed by the manufacturer stating:

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

A Work’s Certificate may be considered equivalent to a Society Certificate and endorsed by the Society under the following cases:

- the test was witnessed by the Society Surveyor; or
- an Alternative Survey Scheme according to NR320 is in place between the Society and the manufacturer or material supplier; or
- the Work’s certificate is supported by tests carried out by an accredited third party that is accepted by the Society and independent from the manufacturer and/or material supplier.

- d) Test Report (TR)

This is a document signed by the manufacturer stating:

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

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

- f) The Surveyor is to review the TR and W for compliance with the agreed or approved specifications. SC means that the Surveyor also witnesses the testing, batch or individual, unless an Alternative Survey Scheme, according to NR320, provides other arrangements.

- g) The manufacturer is not exempted from responsibility for any relevant tests and inspections of those parts for which documentation is not explicitly requested by the Society.

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