RULES FOR CLASSIFICATION

Ships

Edition January 2016

Part 4 Systems and components

Chapter 3 Rotating machinery - drivers
FOREWORD

DNV GL rules for classification contain procedural and technical requirements related to obtaining and retaining a class certificate. The rules represent all requirements adopted by the Society as basis for classification.

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Any comments may be sent by e-mail to rules@dnvgl.com

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CHANGES – CURRENT

This document supersedes the October 2015 edition.
Changes in this document are highlighted in red colour. However, if the changes involve a whole chapter, section or sub-section, normally only the title will be in red colour.

Main changes January 2016, entering into force 1 July 2016

• Sec.1 Reciprocating internal combustion engines
  The section has been updated to align with the following revised and new IACS URs:
  — M44 - Documents for the approval of diesel engines
  — M51 - Factory Acceptance Test and Shipboard Trials of I.C. Engines
  — M71 - Type Testing of I.C. Engines
  — M72 - Certification of Engine Components
  — M73 - Turbochargers

Editorial corrections

In addition to the above stated changes, editorial corrections may have been made.
## CONTENTS

Changes – current.................................................................................................................. 3

Section 1 Reciprocating internal combustion engines......................................................... 8

1 General.......................................................................................................................... 8
   1.1 Application........................................................................................................ 8
   1.2 Documentation of the engine.......................................................................... 10
   1.3 Drawing particulars....................................................................................... 14
   1.4 Documentation of arrangement.................................................................... 15
   1.5 Documentation of vibration......................................................................... 15

2 Design.......................................................................................................................... 15
   2.1 General........................................................................................................... 15
   2.2 Approved materials.................................................................................... 16
   2.3 Safety valves and crankcase ventilation.................................................... 18
   2.4 Turning appliances and interlocking device............................................ 19
   2.5 Crankshaft calculation............................................................................... 19
   2.6 Fire protection and general requirements to piping systems fitted on the engine........................................ 21
   2.7 Hydraulic oil system.................................................................................. 22
   2.8 Fuel oil system.............................................................................................. 22
   2.9 Fuel gas system............................................................................................ 23
   2.10 Charge air system, blowers and cooler.................................................... 23
   2.11 Starting equipment.................................................................................... 24
   2.12 Lubrication oil system.................................................................................. 24
   2.13 Cooling system............................................................................................. 25
   2.14 Type approval testing.................................................................................. 25
   2.15 Type testing data collection........................................................................ 25
   2.16 Type testing program................................................................................... 26

3 Testing and Inspection................................................................................................. 30
   3.1 Recognition of engine manufacturer’s workshops................................... 30
   3.2 Manufacturing inspections........................................................................... 30
   3.3 Testing of materials and components....................................................... 31
   3.4 Inspection during assembly......................................................................... 35

4 Workshop testing.......................................................................................................... 36
   4.1 Application..................................................................................................... 36
   4.2 General engine tests.................................................................................... 36
   4.3 Testing of propulsion engines...................................................................... 37
4.4 Auxiliary driving engines and engines driving electrical generators........ 39
4.5 Survey after testing.................................................................................. 39

5 Control and Monitoring........................................................................... 39
  5.1 General................................................................................................. 39
  5.2 Speed governing.................................................................................. 40
  5.3 Overspeed protection........................................................................... 41
  5.4 Propulsion engines.............................................................................. 41
  5.5 Auxiliary engines................................................................................ 45
  5.6 Emergency engines............................................................................ 48
  5.7 Oil mist detection/monitoring and alarm system (Oil mist detector)..... 50

6 Arrangement............................................................................................ 51
  6.1 Engine Alignment/Seating................................................................. 51
  6.2 Accessibility of engines..................................................................... 51
  6.3 Earthing.............................................................................................. 51
  6.4 Starting with compressed air............................................................. 51
  6.5 Electrical starting equipment.............................................................. 51
  6.6 Exhaust pipes..................................................................................... 52
  6.7 Lubrication and fuel oil systems......................................................... 52
  6.8 Crankcase ventilation pipes............................................................... 52

7 Vibration.................................................................................................. 52
  7.1 Torsional and axial vibration.............................................................. 52

8 Installation Inspections........................................................................... 52
  8.1 Engine Seating.................................................................................... 53
  8.2 Engine alignment............................................................................... 53

9 Shipboard Testing..................................................................................... 53
  9.1 Shipboard testing (dock and sea trials).............................................. 53
  9.2 General engine tests.......................................................................... 53
  9.3 Testing of propulsion engines.............................................................. 54
  9.4 Testing of engines driving auxiliaries and electrical generators........ 55
  9.5 Engine vibration............................................................................... 55
  9.6 Opening up after testing.................................................................... 55

10 Gas only and dual fuel engines........................................................... 55
  10.1 General............................................................................................. 55
  10.2 Design............................................................................................... 55
  10.3 Testing and inspection...................................................................... 60
  10.4 Workshop testing............................................................................... 60
  10.5 Control and monitoring................................................................. 60
  10.6 Arrangement.................................................................................... 63
  10.7 Vibration.......................................................................................... 63
10.8 Installations inspections................................................................. 63
10.9 Shipboard testing........................................................................... 63
10.10 Retrofit....................................................................................... 63

11 Auxiliary equipment and components........................................... 64
11.1 Turbochargers............................................................................... 64
11.2 Torsional vibration dampers.......................................................... 71
11.3 Axial vibration dampers................................................................. 72
11.4 Explosion relief valves................................................................... 72

Section 2 Gas Turbines........................................................................ 74
1 General............................................................................................ 74
1.1 Application..................................................................................... 74
1.2 Definitions..................................................................................... 74
1.3 Certification................................................................................... 75
1.4 Documentation requirements - Manufacturer................................. 76
1.5 Documentation requirements – Builder.......................................... 79

2 Design and Construction................................................................. 81
2.1 General.......................................................................................... 81
2.2 Component design requirements – manufacturer............................ 83
2.3 Systems Design requirements - package provider / builder............. 84
2.4 Enclosure, Fire Safety.................................................................... 88

3 Control and Monitoring................................................................. 89
3.1 Gas Turbine Control....................................................................... 90
3.2 Monitoring and instrumentation system......................................... 92
3.3 Auxiliary system controls............................................................... 92
3.4 Control stations............................................................................. 92

4 Arrangement.................................................................................... 93
4.1 Alignment and reaction forces......................................................... 93
4.2 Mounting in general...................................................................... 93
4.3 Rigid mounting............................................................................. 94
4.4 Resilient mounting....................................................................... 94

5 System vibration.............................................................................. 95
5.1 General.......................................................................................... 95
5.2 Documentation of vibration analysis.............................................. 95
5.3 gas turbine vibration................................................................... 96

6 Tests and trials............................................................................... 96
6.1 Tests, General............................................................................... 96
6.2 Testing of material and components.............................................. 98
6.3 Tests on components (manufacturer’s works)............................... 99
6.4 Type approval test (manufacturer’s works).........................................................99
6.5 Type testing program.......................................................................................... 101
6.6 Inspection of condition of parts (Borescope / tear down)............................ 103
6.7 Certification testing (FAT, manufacturer’s works)........................................ 104
6.8 Certification test program.................................................................................. 104
6.9 Inspection of condition of parts (Borescope).................................................. 106
6.10 Shipboard trials................................................................................................ 106

Section 3 Steam Turbines......................................................................................... 108

1 General..................................................................................................................... 108
1.1 Application............................................................................................................ 108
1.2 Certification requirements.................................................................................. 108
1.3 Documentation requirements - Manufacturer................................................. 108
1.4 Documentation requirements - Builder.............................................................. 109

2 Design..................................................................................................................... 109
2.1 General............................................................................................................... 109
2.2 Component design requirements...................................................................... 110

3 Inspection and testing........................................................................................... 110
3.1 General............................................................................................................... 110

4 Workshop testing.................................................................................................. 111
4.1 General turbine tests.......................................................................................... 111

5 Control and monitoring......................................................................................... 112
5.1 General............................................................................................................... 112
5.2 Speed governing.................................................................................................. 112
5.3 Safety functions and devices............................................................................... 113
5.4 Monitoring............................................................................................................ 113

6 Arrangement........................................................................................................... 115
6.1 General arrangement........................................................................................... 115
6.2 Arrangement of propulsion machinery.............................................................. 116

7 Vibrations................................................................................................................ 116
7.1 Torsional vibrations............................................................................................. 116

8 Installation inspections.......................................................................................... 117
8.1 General............................................................................................................... 117

9 Shipboard testing.................................................................................................... 117
9.1 General............................................................................................................... 117
9.2 Auxiliary turbines............................................................................................... 117
9.3 Propulsion turbines............................................................................................. 117

Changes – historic..................................................................................................... 118
SECTION 1  RECIPROCATING INTERNAL COMBUSTION ENGINES

1 General

1.1 Application

1.1.1 The requirements in this section apply to reciprocating internal combustion engines used for main functions listed in Pt.1 Ch.1 Sec.1 Table 2. For other engines, see [1.1.6]. The engines are subject to approval, installation survey and shipboard testing.

1.1.2 "Reciprocating internal combustion engine" in this section is referred to as "engine".

1.1.3 For the purpose of these requirements, engines are:
— diesel engines, fuelled with liquid fuel oil
— dual-fuel engines, fuelled with liquid fuel oil and/or with gaseous fuel
— gas-only engines, fuelled with gaseous fuel only and ignited by either a spark or micropilot of liquid fuel oil

1.1.4 Depending on engine speed, engines are divided into:
— Low-Speed Engines means engines having a rated speed of less than 300 rpm
— Medium-Speed Engines means engines having a rated speed of 300 rpm and above, but less than 1400 rpm
— High-Speed Engines means engines having a rated speed of 1400 rpm or above

1.1.5 Definition of engine type
The type specification of an engine is defined by the following data:
— manufacturer's type designation
— cylinder bore
— stroke
— method of injection (direct, indirect)
— valve and injection operation (by cams or electronically controlled)
— fuels which can be used (liquid, dual-fuel, gaseous)
— working cycle (4-stroke, 2-stroke)
— method of gas exchange (naturally aspirated or supercharged)
— rated power per cylinder at rated speed as well as mean effective pressure, see [2.1.8]
— method of pressure charging (pulsating pressure system or constant-pressure charging system)
— charge air cooling system (with or without intercooler, number of stages)
— cylinder arrangement (in-line, vee).

1.1.6 For diesel engines with power less than 300 kW and engines not used for main functions, the requirements in this section are limited to:
— insulation of hot surfaces, see [2.6]
— jacketing of high-pressure fuel oil lines and screening of pipe connections in piping containing flammable liquids, see [2.6] and [2.8]
— requirements for starting equipment if applicable, see [2.11.3] and [2.11.4]
— requirements for type testing as given in [2.14.2]
— requirements for workshop testing as given in [4.1.6]
— requirements for control and monitoring according to [5.6], but shut down due to low lubricating oil pressure according to Table 9 to be provided. Shut down not required for emergency fire-extinguishing sets.
— requirements for shipboard testing as given in [9]
For dual-fuel and gas-only engines additional requirements in [10] applies.

1.1.7 Engines driving generators in electric propulsion systems shall be equipped with sensors and monitored as propulsion engines (Table 9) and with safety actions according to Table 10.

1.1.8 Type Testing
Engines shall be Type Tested according to requirements stated in this section.
For more information regarding the Society's Type Approval scheme, see DNVGL-CG-0338.

1.1.9 For diesel engines intended for other purposes than those listed in [1.1.1], only the requirements given by IMO, referred to as the two first bullets in [1.1.6] have to be fulfilled.

1.1.10 In case of engines intended for vessels approved for unmanned machinery installations (Class Notation E0), Pt.6 Ch.2 Sec.2 applies in addition to the requirements in this section.

1.1.11 For all engine installations intended for running on crude oil or gas, additional requirements are given in Pt.6 Ch.2 Sec.5 and Pt.6 Ch.2 Sec.6.

1.1.12 Regarding the use of marine fuels with a sulphur content not exceeding 0.1% m/m and minimum viscosity of 2 cSt the engine manufacturer’s recommendations with respect to e.g. fuel change-over process, lubricity, viscosity and compatibility shall be described in the operation manual.


1.1.14 Certification requirements
Engines shall be delivered with a product certificate according to Table 1.

Table 1 Certification required

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard*</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel Engine</td>
<td>PC</td>
<td>Manufacturer</td>
<td>P&lt;300Kw</td>
<td></td>
</tr>
<tr>
<td>Diesel Engine</td>
<td>PC</td>
<td>Society</td>
<td>P&gt;300Kw</td>
<td></td>
</tr>
<tr>
<td>Gas fuelled Engine</td>
<td>PC</td>
<td>Society</td>
<td>All</td>
<td></td>
</tr>
</tbody>
</table>

*Unless otherwise specified the certification standard is the Society's Rules

For general certification requirements see Pt.1 Ch.3 Sec.4.
For a definition of the certification types see Pt.1 Ch.3 Sec.5.

1.1.15 Engines manufactured under license
For engines manufactured under licence, the licensee shall submit the following documents for approval:
— comparison of all the drawings and documents as per Table 2 - Table 5, where applicable, indicating the relevant drawings used by the licensee and the licensor
— all drawings of modified components, as per Table 2 - Table 5 together with the licensor’s declaration of consent to the modifications
— a complete set of approved drawings or list of approved drawing shall be put at the disposal of the local inspection office of the Society as a basis for the performance of tests and inspections. This shall include the drawings marked "P" in the Info column in Table 2.

1.1.16 Engines manufactured under Manufacturing Survey Arrangement
Trunk engines which will be manufactured in mass or in series, can be produced according to agreed Manufacturing Survey Arrangement (MSA) after recognition of the manufacturer. More information can be found in DNV GL Class guideline DNVGL-CG-C-0483.

1.1.16.1 Document requirements for Engines manufactured under MSA
Engine types that shall be produced according to a MSA, must be documented with DNVGL data sheet ENG921 in addition to the requirements in these rules.

1.2 Documentation of the engine

1.2.1 General
Drawings, data, specifications, calculations and other information shall be submitted as applicable according to Table 2, Table 3 and Table 4, except for items covered by a valid type approval. Documentation listed in Table 2 - Table 4 marked with a "P" in the info field, are additional documentation required to be submitted if production applies for the facility.

1.2.2 Design modifications
Following initial approval of an engine type by the Society, only those documents listed in Table 2 to Table 4 which embodies design modifications shall be resubmitted for approval.

1.2.3 Approval of engine components
The manufacturers shall request approval from the Society for exhaust gas turbochargers, torsional vibration dampers, crankcase relief valves etc, see [11] for more information. For oil mist detectors see [5.7].

Table 2 Documentation of engine fuelled by liquid fuel oil

<table>
<thead>
<tr>
<th>No.</th>
<th>Additional description</th>
<th>Documentation type</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Engine particulars, Society forms ENG 901, ENG 911 and ENG 921</td>
<td>Z110 – Data sheet</td>
<td>FI(TA)</td>
</tr>
<tr>
<td>02</td>
<td>Engine cross section</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>FI(TA)</td>
</tr>
<tr>
<td>03</td>
<td>Engine longitudinal section</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>FI(TA)</td>
</tr>
<tr>
<td>04</td>
<td>Bedplate and crankcase/engine block - cast</td>
<td>C020 - Assembly or arrangement drawing</td>
<td>FI(TA)</td>
</tr>
<tr>
<td></td>
<td>- welded design, with welding details and welding instructions 1)</td>
<td>C030 - Detailed drawing</td>
<td>AP(TA)</td>
</tr>
<tr>
<td>05</td>
<td>Thrust bearing assembly²)</td>
<td>C030 - Detailed drawing</td>
<td>FI(TA)</td>
</tr>
<tr>
<td>06</td>
<td>Thrust bearing bedplate - cast</td>
<td>C020 - Assembly or arrangement drawing</td>
<td>FI(TA)</td>
</tr>
<tr>
<td></td>
<td>- welded design, with welding details and welding instructions²)</td>
<td>C030 - Detailed drawing</td>
<td>AP(TA)</td>
</tr>
<tr>
<td>No.</td>
<td>Additional description</td>
<td>Documentation type</td>
<td>Info</td>
</tr>
<tr>
<td>-----</td>
<td>------------------------</td>
<td>--------------------</td>
<td>------</td>
</tr>
</tbody>
</table>
| 07  | Frame/framebox/cylinder jacket/ block/gearbox  
- cast  
- welded design, with welding details and instructions | C020 - Assembly or arrangement drawing  
C030 – Detailed drawing | FI (TA)  
Ap (TA) |
| 08  | Tie rod | C030 – Detailed drawing | FI (TA) |
| 09  | Cylinder cover/ head , assembly  
Cylinder cover/head | C020 – Assembly or arrangement drawing  
C030 – Detailed drawing | FI (TA)  
Ap (P) |
| 10  | Cylinder liner | C030 – Detailed drawing | FI (TA) |
| 11  | Crankshaft details, each cylinder number  
- data sheet for calculation of crankshaft stress | C030 – Detailed drawing  
Z110 - Datasheet | Ap (TA)  
F (TA) |
| 12  | Crankshaft assembly for each number of cylinders  | C020 – Assembly or arrangement drawing | Ap (TA) |
| 13  | Thrust shaft or intermediate shaft, if integrated in the engine | C030 – Detailed drawing | Ap (TA) |
| 14  | Shaft coupling bolts  | C030 – Detailed drawing | Ap (TA) |
| 15  | Counter weight (if not integral with crankshaft)  
- including fastening  
| C030 – Detailed drawing  
C020 – Assembly or arrangement drawing | FI (TA)  
F (TA) |
| 16  | Connecting rod  
| C030 – Detailed drawing | FI (TA) |
| 17  | Connecting rod, assembly  
- Crosshead  
| C020 – Assembly or arrangement drawing  
C030 – Detailed drawing | FI (TA)  
Ap (P) |
| 18  | Crossheads, assembly  
- Crosshead | C020 – Assembly or arrangement drawing  
C030 – Detailed drawing | FI (TA)  
Ap (P) |
| 19  | Piston rod assembly  
- Piston rod | C020 – Assembly or arrangement drawing  
C030 – Detailed drawing | FI (TA)  
Ap (P) |
| 20  | Piston, assembly  
- piston crown/head | C020 – Assembly or arrangement drawing  
C030 – Detailed drawing | FI (TA)  
Ap (P) |
| 21  | Camshaft arrangement and high pressure pump drive,  
assembly  
| C020 – Assembly or arrangement drawing | FI (TA) |
| 22  | Material data for engine main parts with information on non-destructive material tests and pressure tests  
| M010 - Material specification, metals | Ap (TA) |
| 23  | Arrangement of foundation (for main engines only)  | C020 – Assembly or arrangement drawing | FI (TA) |
| 24  | Schematic layout or other equivalent documents of the starting air system  
[1.3.2],[2.11] | S010 – Piping diagram (PD) | Ap (TA) |
| 25  | Schematic layout or other equivalent documents of the fuel oil system  
[1.3.2],[2.8] | S010 – Piping diagram (PD) | Ap (TA) |
| 26  | Schematic layout or other equivalent documents of the Lubrication oil system  
[1.3.2],[2.12] | S010 – Piping diagram (PD) | Ap (TA) |
| 27  | Schematic layout or other equivalent documents of the Cooling water system  
[1.3.2],[2.13] | S010 – Piping diagram (PD) | Ap (TA) |
<table>
<thead>
<tr>
<th>No.</th>
<th>Additional description</th>
<th>Documentation type</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>Schematic diagram of engine control and safety system, including list of set points of required alarms and shutdowns [5]</td>
<td>I200 - Control and monitoring system documentation</td>
<td>ApTA</td>
</tr>
<tr>
<td>29</td>
<td>Schematic diagram of engine electronic components, systems and FMEA, including list of set points of required alarms and shutdowns [5]</td>
<td>I200 - Control and monitoring system documentation</td>
<td>ApTA</td>
</tr>
<tr>
<td>30</td>
<td>Shielding and insulation of the exhaust system [2.6.1]</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>FTA</td>
</tr>
<tr>
<td>31</td>
<td>Shielding of high pressure parts containing flammable liquids, assembly [2.8.7]</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>ApTA</td>
</tr>
<tr>
<td>32</td>
<td>Crankcase explosion relief valves, arrangement and details [1.3.1], [2.3]</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>ApTA</td>
</tr>
<tr>
<td>34</td>
<td>Schematic layout or other equivalent documents of hydraulic system on the engine [1.3.8], [2.7]</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>ApTA</td>
</tr>
<tr>
<td>36</td>
<td>High pressure parts for fuel oil injection system [11]</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>FTA</td>
</tr>
<tr>
<td></td>
<td>- High-pressure pumps</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>ApTA</td>
</tr>
<tr>
<td></td>
<td>- Control valves</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>ApTA</td>
</tr>
<tr>
<td></td>
<td>- bodies</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>ApTA</td>
</tr>
<tr>
<td></td>
<td>- accumulators for hydraulic oil and fuel oil</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>ApTA</td>
</tr>
<tr>
<td></td>
<td>- piping with connections</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>ApTA</td>
</tr>
<tr>
<td>37</td>
<td>Arrangement of oil mist detection and/or alternative alarm arrangements, monitoring and alarm system [5.7]</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>ApTA</td>
</tr>
<tr>
<td>38</td>
<td>Schematic layout or other equivalent documents of Exhaust and charge air system [1.3.2], [2.10]</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>ApTA</td>
</tr>
<tr>
<td>39</td>
<td>Documentation of vibration, mass elastic data and excitation values [1.5], Ch.2 Sec.2</td>
<td>C040 – Design analysis</td>
<td>FTA</td>
</tr>
<tr>
<td>40</td>
<td>Flywheel</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>FTA</td>
</tr>
<tr>
<td>41</td>
<td>Construction and arrangement of torsional vibration dampers</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>FTA</td>
</tr>
<tr>
<td>42</td>
<td>Bolt and studs</td>
<td>C030 - Detailed drawing</td>
<td>ApTA</td>
</tr>
<tr>
<td></td>
<td>- for main bearings</td>
<td>C030 - Detailed drawing</td>
<td>ApTA</td>
</tr>
<tr>
<td></td>
<td>- for cylinder heads and exhaust valve (two stroke design)</td>
<td>C030 - Detailed drawing</td>
<td>ApTA</td>
</tr>
<tr>
<td></td>
<td>- for connecting rods</td>
<td>C030 - Detailed drawing</td>
<td>ApTA</td>
</tr>
</tbody>
</table>

Table 3 Additional documentation for gas fuelled engines, see [10].

<table>
<thead>
<tr>
<th>No.</th>
<th>Additional description</th>
<th>Documentation type</th>
<th>Info</th>
</tr>
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<tbody>
<tr>
<td>43</td>
<td>Functional description of gas fuelled engine</td>
<td>Z060 – Functional description</td>
<td>FTA</td>
</tr>
</tbody>
</table>
### Table 4 Additional documentation for auxiliary equipment and components

<table>
<thead>
<tr>
<th>No.</th>
<th>Additional description</th>
<th>Documentation type</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>44</td>
<td>Engine safety concept, including system FMEA with regard to gas as fuel</td>
<td>Z071 - Failure mode and effect analysis (FMEA)</td>
<td>FI(TA)</td>
</tr>
</tbody>
</table>
| 45  | Fuel gas system including double wall piping and ventilation system \[8\][10.2.9]  
- Schematic layout of fuel gas system \[7\]  
- Schematic layout of ventilation system \[7\]  
- Fuel gas system  
- Fuel gas piping and flange design |  
S010 – Piping diagram (PD)  
S010 - Piping diagram (PD)  
C020 – Assembly or arrangement drawing  
C030 – Detailed drawing | AP(TA)  
AP(TA)  
FI(TA)  
AP(TA) |
| 46  | Charge air system[10.2.6]:  
- Documentation of sufficient strength if relief valve is not installed arrangement  
- Relief valve arrangement if installed |  
Z265 – Calculation report  
C020 – Assembly or arrangement drawing | AP(TA)  
AP(TA) |
| 47  | Engine exhaust gas system:  
- Documentation of sufficient strength if relief valve is not installed arrangement [10.2.6]  
- Relief valve arrangement if installed [10.2.6] |  
Z265 – Calculation report  
S010 - Piping diagram (PD) | AP(TA)  
AP(TA) |
| 48  | Testing procedure for gas detection system [10.4] | Z252 - Test procedure at manufacturer | FI(TA) |
| 49  | Testing procedure for gas tightness [10.4] | Z252 - Test procedure at manufacturer | FI(TA) |

### Additional documentation for auxiliary equipment and components

<table>
<thead>
<tr>
<th>Object</th>
<th>Additional description</th>
<th>Documentation type</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbocharger</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
 - 13) [11.1] | I200 - Control and monitoring system documentation | AP |
| Torsional vibration damper |  
 - [11.2] | I200 - Control and monitoring system documentation | AP |
| Axial vibration damper |  
 - [11.3] | I200 - Control and monitoring system documentation | FI(TA) |
| Engine |  
- Alarm and monitoring, see [5] | I200 - Control and monitoring system documentation | AP |
| - Safety System, see [5] | I200 - Control and monitoring system documentation | AP |
| - Speed control / governor / combustion, see [5] | I200 - Control and monitoring system documentation | AP |
| - Gas Valve Unit (GVU), see Pt.6 Ch.2 Sec.5 | I200 - Control and monitoring system documentation | AP |
Table 5 Remarks to Table 2 - 4

<table>
<thead>
<tr>
<th>TA</th>
<th>Covered by Type approval</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP</td>
<td>For approval</td>
</tr>
<tr>
<td>FI</td>
<td>for information</td>
</tr>
<tr>
<td>P</td>
<td>Required if engine production applies</td>
</tr>
</tbody>
</table>

1) the welding procedure specification shall include details of pre and post weld heat treatment, welding consumables and fit-up conditions
2) If integrated with engine and not in the bedplate
3) Only for one cylinder
4) Applies to engines with cylinder diameter > 150 mm
5) Only necessary if sufficient details are not shown on the transverse cross section and longitudinal section
6) For comparison with the Society requirements for material, NDT and pressure testing as applicable
7) Integrated in engine design and the auxiliary system
8) If engines incorporate electronic control systems a failure mode and effect analysis (FMEA) shall be submitted to demonstrate that failure of an electronic control system shall not result in any significant reduction of engine performance
9) Only for engines with bore ≥200 mm, or a crankcase volume ≥ 0.6 m³
10) Operation and service manuals shall contain maintenance requirements (servicing and repair) including details of any special tools and gauges that shall be used with their fitting/settings together with any test requirements on completion of maintenance
11) The documentation has to contain specifications of pressures, pipe dimensions and materials
12) only for engines with bore > 300 mm, or a total engine break power of 2250 kW
13) Shall be type approved, either as a separate component or as an integral part of the diesel engine. Not applicable to turbochargers serving cylinder groups with combined power less than or equal to 1000 kW

1.2.4 For general requirements for documentation, including definition of the info codes, see Pt.1 Ch.3 Sec.2

1.2.5 For a full definition of the documentation types, see Pt.1 Ch.3 Sec.3.

1.2.6 For details about NDT specification, see Ch.2 Sec.1 [3.1.2]

1.3 Drawing particulars

1.3.1 Crankcase relief valve arrangement
The documentation of crankcase relief valve arrangement shall indicate
— make and type of valves
— the number of valves
— their position
— the free area of the relief valves
— the crankcase volume.

1.3.2 Starting and charge air, Fuel-, lubrication-, hydraulic- and cooling water systems
The schematic drawing of the charge air, fuel oil, lubrication oil, cooling water and hydraulic oil systems only need to show design pressures and required pumps/blowers, valves, filters and sensors. For starting air system the safety devices shall be shown, if applicable.

1.3.3 Turbochargers
Turbochargers are usually type approved separately, but may also be approved as part of the engine. Same document requirements apply. See [11.1] for requirements regarding documentation, design and testing.
1.3.4 Electronic components and systems
Electronic components and systems which are necessary for the control of engines shall be approved according to [5] and Ch.9.

1.3.5 Electronic engine management system is a collective term for electronic systems governing fuel oil injection, exhaust valve operation, operation of high pressure fuel oil injection pumps etc.  The documentation required per Table 2 and Table 3 shall provide a principal description of the system(s) as well as reference to valid type approval certificates for the associated software and hardware.  In case of a failure of an electronic control system, the equipment shall enter a safe state defined and proven by a structured analysis (e.g. FMEA), which has to be provided by the Electronic engine management system’s manufacturer. This analysis shall include all possible failure modes and effects.

1.4 Documentation of arrangement
The following plans and particulars shall be in accordance with the engine designer/manufacturer’s specifications and be submitted by the builder for approval:

1) Foundation/Seating arrangement, see Ch.2 Sec.1 [6].
2) Top stay arrangement, if applicable, including reaction forces. See Ch.2 Sec.1 [6].

1.5 Documentation of vibration
Mass elastic data and table of excitations shall be included in the documentation as information, either as an appendix to the datasheet, a separate document or as an example of a torsional vibration calculation. Also see Ch.2 Sec.2.

2 Design

2.1 General

2.1.1 Rated power
Engines shall be designed such that their rated power when running at rated speed can be delivered as a continuous power. This shall be done in accordance with the specifications of the engine manufacturer at ambient conditions as defined in Ch.1 Sec.3 [2.2]. Engines shall be capable of operating continuously within power range ① in Figure 1 and intermittently in power range ②. The extent of the power ranges shall be specified by the engine manufacturer.

2.1.2 Maximum continuous power shall be understood as the standard service power which an engine is capable of delivering continuously, provided that the maintenance is carried out as stated by the engine manufacturer.

2.1.3 The maximum continuous power shall be specified in such a way that an overload power of 110% of the rated power can be demonstrated at the corresponding speed for an uninterrupted period of 1 hour. Deviations from the overload power value require the agreement of the Society.

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

2.1.5 For main engines, a power diagram, Figure 1 shall be prepared showing the power ranges within which the engine is able to operate continuously and for short periods under service conditions.
2.1.6 Power increase within 5 %
If the combustion pressure, mean effective pressure and/or rpm of a type tested and operationally proven engine is increased by less than 5 %, a new type test is not required. Approval of the power increase includes review of the relevant drawings.

2.1.7 Power increase within 10 %
If the combustion pressure, mean effective pressure and/or rpm of a type tested and operationally proven engine is increased by less than 10 %, a new type test may not be required provided that evidence of successful service experience in similar applications or internal testing are submitted. Approval of the power increase includes review of the relevant drawings.

2.1.8 Power increase above 10 %
If the rated power (continuous power) of a type tested and operationally proven engine is increased by more than 10%, a new type test is required. Approval of the power increase includes review of the relevant drawings.

2.1.9 De-rated engine used to document higher power within 10 %
If an engine has been design approved, and internal testing per Stage A is documented to a rating higher than the one type tested, the Type Approval may be extended to the increased power/mep/rpm upon submission of an Extended Delivery Test Report including:
- Test at over speed (only if nominal speed has increased)
- Rated power, i.e. 100% output at 100% torque and 100% speed corresponding to load point 1., 2 measurements with one running hour in between
- Maximum permissible torque (normally 110%) at 100% speed corresponding to load point 3 or maximum permissible power (normally 110%) and speed according to nominal propeller curve corresponding to load point 3a., ½ hour
- 100% power at maximum permissible speed corresponding to load point 2, ½ hour

Figure 1 Example of a power diagram
2.2 Approved materials

2.2.1 The mechanical characteristics of materials used for the components of engines shall conform to Pt.2 Ch.2.

The materials approved for the various components are shown in Table 6 together with the minimum required characteristics.

Table 6 Approved materials

<table>
<thead>
<tr>
<th>Approved materials</th>
<th>Society’s rules*</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forged steel $R_m \geq 360$ N/mm$^2$</td>
<td>Pt.2 Ch.2 Sec.6 [4]</td>
<td>Crankshafts</td>
</tr>
<tr>
<td></td>
<td>Pt.2 Ch.2 Sec.6 [3]</td>
<td>Connecting rods, Pistons rods, Crossheads, Pistons and piston crowns, Cylinder covers/heads, Camshaft drive wheels</td>
</tr>
<tr>
<td>Rolled or forged steel rounds $R_m \geq 360$ N/mm$^2$</td>
<td>Pt.2 Ch.2 Sec.6 [3]</td>
<td>Tie rods, Bolts and studs</td>
</tr>
<tr>
<td>Special grade cast steel $R_m \geq 440$ N/mm$^2$ and special grade forged steel $R_m \geq 440$ N/mm$^2$</td>
<td>Pt.2 Ch.2 Sec.6 [8.3.1]</td>
<td>Throws and webs of built-up crankshafts</td>
</tr>
<tr>
<td>Cast steel</td>
<td>Pt.2 Ch.2 Sec.8 [3]</td>
<td>Bearing transverse girders (viewable)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pistons and piston crowns, Cylinder covers/heads, Camshaft drive wheels</td>
</tr>
<tr>
<td>Nodular cast iron, preferably ferritic grades $R_m \geq 350$ N/mm$^2$</td>
<td>Pt.2 Ch.2 Sec.9 [2]</td>
<td>Engine blocks, Bedplates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cylinder blocks, Pistons and piston crowns, Cylinder covers/heads, Flywheels, Valve bodies</td>
</tr>
<tr>
<td>Lamellar cast iron $R_m \geq 200$ N/mm$^2$</td>
<td>Pt.2 Ch.2 Sec.9 [3]</td>
<td>Engine blocks, Bedplates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cylinder blocks, Cylinder liners, Cylinder covers/heads</td>
</tr>
</tbody>
</table>
2.2.2 Materials with properties deviating from the requirements specified may be used only with the Society’s explicit permission. The Society requires proof of the suitability of such materials.

2.3 Safety valves and crankcase ventilation

2.3.1 Crankcase safety relief valves
Crankcase safety relief valves to safeguard against overpressure in the crankcase shall be fitted to all engines with a cylinder bore of ≥ 200 mm or a crankcase volume of ≥ 0.6 m³.
All separated spaces within the crankcase, e.g. gear or chain casings for camshafts or similar drives, shall be equipped with additional safety devices if the volume of these spaces exceeds 0.6 m³.

Table 7 Crankcase safety relief valves

<table>
<thead>
<tr>
<th>Cylinder diameter D (mm)/Crankcase volume V (m³)</th>
<th>Number of crank-throws</th>
<th>Number of safety relief valves</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 ≤ D ≤ 250 or V &gt; 0.6</td>
<td>≤ 8</td>
<td>One at each end of the engine</td>
</tr>
<tr>
<td>200 ≤ D ≤ 250</td>
<td>&gt; 8</td>
<td>As above plus one near the middle of the engine</td>
</tr>
<tr>
<td>250 &lt; D ≤ 300</td>
<td></td>
<td>One in way of each alternate crank-throw, minimum 2</td>
</tr>
<tr>
<td>D &gt; 300</td>
<td></td>
<td>One in way of each crank-throw</td>
</tr>
</tbody>
</table>

2.3.2 Relief valves
Crankcase safety relief valves shall be approved according to [11.4].

2.3.3 The free area of each crankcase safety relief valve shall not be less than 45 cm². The combined free area of the valves fitted on an engine shall not be less than 115 cm²/m³ of the crankcase gross volume.

Guidance note 1:
Each one of the crankcase safety relief valves required to be fitted, may be replaced by not more than two crankcase safety relief valves of smaller area, provided that the free area of each valve is not less than 45 cm².

Guidance note 2:
The total volume of stationary parts within the crankcase may be discounted in estimating the crankcase gross volume (rotating and reciprocating components should be included in the gross volume).

Guidance note 3:
A space communicating with the crankcase via a total free cross-sectional area of > 115 cm²/m³ of volume need not be considered as a separate space.
2.3.4 Safety devices shall be provided with a manufacturer’s installation and maintenance manual that is pertinent to the size and type of device as well as on the installation on the engine. A copy of this manual shall be kept on board of the ship.

2.3.5 Crankcase airing and venting
The airing of crankcases and any arrangement which could produce air intake within the crankcase is not allowed.
Where crankcase venting systems are provided, their clear opening shall be dimensioned as small as practically possible.
Where provision has been made for forced extracting of lubrication oil mist, e.g. for monitoring the oil mist concentration, the vacuum in the crankcase shall not exceed 2.5 mbar.
In case of two-stroke engines the lubrication oil mist from the crankcase shall not be admitted into the scavenge manifolds respectively the air intake pipes of the engine.

2.3.6 Warning notice
A signboard shall be fitted either on the control stand or, preferably, on a crankcase door on each side of the engine. It shall specify that the crankcase doors or sight holes, in case of detected oil mist, shall not be opened before a reasonable time has passed. The time shall be sufficient to permit adequate cooling after stopping the engine.

2.3.7 Crankcase doors and sight holes
Crankcase doors and their fittings shall be so dimensioned as not to suffer permanent deformation due to the overpressure occurring during the time needed for the safety equipment to respond.

2.3.8 Crankcase doors and hinged inspection ports shall be equipped with appropriate latches to effectively prevent unintended closing.

2.4 Turning appliances and interlocking device

2.4.1 Engines shall be equipped with suitable and adequately dimensioned turning appliances.

2.4.2 The turning appliances shall be of the self-locking type.

2.4.3 An automatic interlocking device shall be provided to ensure that the engines cannot start up while the turning gear is engaged.

2.5 Crankshaft calculation

2.5.1 Design methods
Crankshafts shall be designed to withstand the stresses occurring when the engine runs at rated power and speed. Calculations shall be based on the Class Guideline DNVGL-CG-0037.
Other methods of calculation may be used provided that they do not result in dimensions smaller than those obtained by applying the aforementioned Class Guideline.

2.5.2 Maximum nominal altering torsional stress
The maker of the engine shall apply for approval of a maximal additional (vibratory) shear stress, which is referred to the crank with the highest load due to mean torque and bending forces.
This approved additional shear stress may be applied for first evaluation of the calculated vibratory stresses in the crankshaft via the torsional vibration model. Common values are between 30 and 70 N/mm² for medium and high speed engines and between 25 and 40 N/mm² for two stroke engines, but special confirmation of the value considered for judgement by the Society is necessary. For further details, see Ch.2 Sec.2.
2.5.3 When the approved limit for the vibratory stresses for the crankshaft of the engine as defined under [2.5.2] is exceeded, special considerations may be applied to define a higher limit for the special investigated case. For this detailed system calculations (combined axial / torsional model) and application of the actual calculated data within the model in accordance to the Class Guideline DNVGL-CG-0037, as quoted under [2.5.1] are necessary. Such special considerations, especially the application of combined axial and torsional vibration calculations, may only be considered for direct coupled two stroke engine plants. For such evaluations the acceptability factor in accordance to [2.5.2] shall in no case be less than 1.15 over the whole speed range.

2.5.4 Class Guideline DNVGL-CG-0037 also contains requirements for safety versus slippage of semi-built crankshafts. (Fully built crankshafts shall be considered on basis of equivalence with these requirements.) The required minimum safety factor against slippage is 2.0. This is valid for the highest peak torque in the crankshaft and also taking the shrink fitting procedure into account. The maximum shrinkage amount is limited by the permissible amount of plastification of the web and journal materials.

2.5.5 Split crankshafts
Only fitted bolts shall be used for assembling split crankshafts.

2.5.6 Power-end flange couplings
The bolts used to connect power-end flange couplings shall be designed as fitted bolts in accordance with Ch.4 Sec.1 [1.2.3].
If the use of fitted bolts is not feasible, the Society may agree to the use of an equivalent frictional resistance transmission. In these cases the corresponding calculations shall be submitted for approval.

2.5.7 Impact torqued due to operation in ice
For direct coupled propulsion engines (i.e. no elastic coupling) in ships with class notation Ice, the crankshaft and the crankshaft bolts shall be designed for the ice impact torques. The procedure for calculation of the applicable impact torque is given in the Rules for Classification of Ships Pt.5 Ch.1. The applicable impact torque is additional to the engine vibration torque and is of special importance for the safety against slippage.

2.5.8 Torsional vibration, critical speeds
See Ch.2 Sec.2 [2].

2.5.9 Torsional vibration dampers
For torsional vibration dampers the following requirements apply, see [11.2]:
— sub-contracted dampers of standard design (including design concept) shall be type approved.
— dampers of tailor made (unique) design may be case by case approved.
— dampers produced by the engine manufacturer shall be type approved either as a separate product or as a part of the engine.
2.6 Fire protection and general requirements to piping systems fitted on the engine

2.6.1 Maximum surface temperature
All exposed surfaces shall be kept below the maximum permissible temperature of 220°C. Surfaces that reach higher temperatures shall be insulated with material having non oil-absorbing surface, or equivalently protected so that flammable fluids spray reaching the surface cannot be ignited.

Guidance note:
Insulation by use of detachable lagging wrapped around hot exhaust manifold is an example of means where inadequate workmanship (during e.g. maintenance work onboard by crew) should expose hot spots. Water cooled exhaust manifold is on the other hand typically a mean of insulating, which may not be affected by workmanship, all depending on the design, (e.g. areas in way of flanged connections where the water is not sufficiently cooling the metal).

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

2.6.2 Screening
All pipe connections in piping containing flammable liquids with pressure above 1.8 bar shall be screened or otherwise suitably protected to prevent as far as practicable oil spray or oil leakage onto potentially hot surfaces.
Potentially hot surfaces are those surfaces which when left uninsulated may reach a temperature of >220°C and for which workmanship affects the efficiency of the insulation.
Any means applied to protect pipe connections as required per [2.6.2] should not deteriorate when dismantled and re-assembled (during e.g. maintenance work). Proper re-assembly shall be possible without the need of spare parts.

2.6.3 Flexible hoses and compensators
Use of flexible hoses and compensators in fuel oil, fuel gas, lubrication oil and hydraulic oil systems is only permitted where necessary in order to allow for relative movements.
Flexible hoses with couplings and compensators shall be type approved, see Ch.6.
2.7 Hydraulic oil system

2.7.1 [2.6] applies.

2.7.2 Double piping or shielding including both end connections is required for hydraulic systems on engines.

2.8 Fuel oil system

2.8.1 [2.6] applies.

2.8.2 General
Only pipe connections with metal sealing surfaces or equivalent pipe connections of approved design may be used for fuel injection lines.

2.8.3 Feed and return lines shall be designed in such a way that no unacceptable pressure surges occur in the fuel supply system. Where necessary, the engines shall be fitted with surge dampers approved by the Society.

2.8.4 All components of the fuel system shall be designed to withstand the maximum peak pressures which may occur in the system.

2.8.5 If fuel oil reservoirs or dampers with a limited life cycle are fitted in the fuel oil system the life cycle together with overhaul instructions shall be specified by the engine manufacturer in the operation and maintenance manuals.

2.8.6 Oil fuel lines shall not be located immediately above or near units which have high temperature, steam pipelines, exhaust manifolds, silencers or other equipment required to be insulated. The number of joints in such piping systems shall be kept to a minimum.

2.8.7 Shielding
All external high pressure fuel injection lines between injection pumps and injection valves shall be shielded by jacket pipes in such a way that any leaking fuel is:

— safely collected
— drained away unpressurized and
— alarm upon leakage.

The high pressure fuel pipe and the outer jacket pipe shall be of permanent assembly.

2.8.8 Fuel leak drainage
Appropriate design measures shall be introduced to ensure that leaking fuel is drained efficiently and cannot enter into the engine lubrication oil system.

2.8.9 Heating, thermal insulation, re-circulation
Fuel lines, including fuel injection lines, to engines which are operated with preheated fuel shall be insulated against heat losses and, when necessary, provided with heating.

Means of fuel re-circulation shall be provided.

2.8.10 Filters
Fuel oil filters mounted directly on the engine shall not be located above rotating parts or in the immediate proximity of hot components.

2.8.11 Where the arrangement stated in [2.8.10] is not feasible, the rotating parts and the hot components shall be shielded.
2.8.12 Filters shall be so arranged that fluid residues can be collected by adequate means, e.g. an oil pan. The same applies to lubrication oil filters if oil can escape when the filter is opened.

2.8.13 Change-over filters with two or more chambers shall be equipped with means enabling a safe pressure release before opening and a proper venting before re-starting of any chamber. Shut-off devices shall be used. It shall be clearly visible, which chamber is in and which is out of operation.

2.8.14 Oil filters fitted in parallel for the purpose of enabling cleaning without disturbing supply of filtered oil to engines (e.g. duplex filters) shall be provided with arrangements that shall minimize the possibility of a filter under pressure being opened by mistake. Filters/ filter chambers shall be provided with suitable means for:
— venting when put into operation
— depressurizing before being opened.

Valves or cocks with drain pipes led to a safe location shall be used for this purpose.

2.9 Fuel gas system

2.9.1 [10.2.9] applies.

2.10 Charge air system, blowers and cooler

2.10.1 General
Means shall be provided for regulating the temperature of the charge air within the temperature range specified by the engine manufacturer.

2.10.2 The charge air lines of engines with charge air coolers shall be provided with sufficient means of drainage.

2.10.3 Safety devices in scavenging air ducts
In 2-stroke engines, charge air spaces in open connection to the cylinders shall be fitted with:
— safety valves which shall open quickly in case of an overpressure
— a connection to an approved fire-extinguishing system that is entirely separate from the fire-extinguishing system of the engine room.

2.10.4 Exhaust gas turbochargers
The documentation, construction and testing of exhaust gas turbochargers are covered by [11.1].

2.10.5 Exhaust gas turbochargers shall exhibit no critical speed ranges over the entire operating range of the engine.

2.10.6 The lubrication oil supply shall be ensured during start-up and run-down of the exhaust gas turbochargers.

2.10.7 Even at low engine speeds, main engines shall be supplied with charge air in a manner that ensures reliable operation.

2.10.8 Emergency operation of single propulsion engines shall be possible in the event of a turbocharger failure.

2.10.9 Auxiliary blowers
All single propulsion 2-stroke engines shall be fitted with at least two auxiliary blowers where necessary.
2.10.10 For single propulsion 2-stroke engines with only one turbocharger, intended for driving a fixed pitch propeller, the auxiliary blowers shall have a capacity sufficient to operate the engine continuously at an engine speed of approximately 40% of the rated speed along the theoretical propeller curve.

2.10.11 The engine speed at which the auxiliary blowers are started and stopped shall be selected taking into account the necessity of passing quickly through a barred speed range, see Ch.2 Sec.2 [3.1].

2.11 Starting equipment

2.11.1 General
For requirements related to starting arrangement, see Pt.4 Ch.6 for starting air piping systems and Ch.8 for electrical starting arrangement.

2.11.2 Starting equipment for emergency generating sets
Requirements for starting arrangements for emergency generating sets are given in Ch.8 Sec.2.

2.11.3 Start-up of emergency fire-extinguisher sets
[2.11.4] applies.
Engines driving emergency fire pumps shall be so designed that they can be started by hand at a temperature of 0°C.
If the engine can be started only at higher temperatures, or where there is a possibility that lower temperatures may occur, heating equipment shall be fitted to ensure reliable starting.

2.11.4 If manual start-up using a hand crank is not possible, the emergency fire-pump shall be fitted with a starting device approved by the Society which enables at least 6 starts to be performed within 30 minutes, two of these being carried out within the first 10 minutes.

2.11.5 Safety devices in the starting air system
In order to protect the starting air system against explosion arising from improper functioning of the starting valve, the following devices shall be fitted:
— an isolation 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 manifold
— at the supply inlet to the starting air manifold for non-reversing engines.
The bursting discs or flame arresters may be omitted for engines having a bore not exceeding 230 mm.

2.12 Lubrication oil system
[2.6] applies. For requirements related to lubrication oil arrangement, see [6.7].

2.12.1 Engine sumps serving as oil reservoirs shall be so equipped that the oil level can be monitored, and if necessary, topped up during operation. Means shall be provided for completely draining the oil sump.

2.12.2 Main lubrication oil pumps driven by the engine shall be designed to maintain the supply of lubrication oil over the entire operating range.

2.12.3 Lubrication oil systems for cylinder lubrication which are necessary for the operation of the engine and which are equipped with electronic dosing units shall be approved by the Society.

2.12.4 Filters
Lubrication oil filters mounted directly on the engine shall not be located above rotating parts or in the immediate proximity of hot components.
2.13 Cooling system

2.13.1 [2.6] applies as found relevant.

2.13.2 General
Main cooling water pumps driven by the engine shall be designed to maintain the supply of cooling water over the entire operating range.

2.14 Type approval testing

2.14.1 General
Upon finalisation of every new type of engine, one engine shall be presented for type testing. The type testing shall preferably be made with the type of fuel oil for which the engine is intended. However, for engines intended for running on heavy fuel oil, the verification of the engine’s suitability for this type of fuel may be postponed to the sea trial.

2.14.2 Type testing of engines with less power than 300Kw
Engines with rated power less than 300 kW shall be subjected to the following type tests:
— verification of compliance with requirements for jacketing of high-pressure fuel oil lines and screening of pipe connections in piping containing flammable liquids, see [2.16.4.5].
— verification of compliance with requirements for insulation of hot surfaces, see [2.16.4.5].
— if driving an emergency generator, testing the safety system to the extent as integrated in the engine design (e.g. overspeed trip device), however limited to the requirements for such systems as given in [5.6].

2.15 Type testing data collection

2.15.1 All relevant equipment for the safety of personnel shall be operational during the type testing.

2.15.2 Ambient conditions
The following particulars shall be recorded:
— ambient air temperature
— ambient air pressure
— atmospheric humidity
— external cooling water temperature
— fuel and lubrication oil characteristics.

2.15.3 Engine data shall be measured and recorded according to the specification of the engine designer and approved by the Society.
2.16 Type testing program

2.16.1 Preconditions for type approval testing
Preconditions for test engines subjected to type approval testing are:
— the engine conforms to the specific requirements for the series and has been suitably optimized for the intended duty
— the Society is informed of major inspections and measurements carried out by the manufacturer during work tests necessary for a reliable and continuous operation
— the Society has issued approved drawings based on the documents to be submitted in accordance with Table 2 to Table 4.

2.16.2 Scope of type approval testing
The type approval test is subdivided into three stages, namely:
— Stage A - Internal tests
Functional tests and collection of operating values including test hours during the internal tests. The result shall be made available to the Society during the type test.
— Stage B - Type test
This test shall be performed in the presence of the surveyor.
— Stage C - Component inspection
Upon completion of the tests, major components shall be presented to the Society for inspection. The operating hours of the engine components that are presented for inspection after type testing in accordance with [2.16.2] shall be stated.

2.16.3 Stage A - Internal tests
Functional tests and the collection of operating data shall be performed during the internal tests. The engine shall be operated at the load points selected by the engine manufacturer and the pertaining operating values shall be recorded. The load points shall be selected according to the range of application of the engine.

2.16.3.1 Normal operating conditions
This includes the load points 25%, 50%, 75%, 100% and 110% of the rated power
a) along the nominal (theoretical) propeller curve and/or at constant speed for propulsion engines
b) at rated speed with constant governor setting for generator drive.
   The limit points of the permissible operating range as defined by the engine manufacturer shall be tested.

2.16.3.2
High speed engines shall be tested for at least 100 hours at full load. High speed propulsion engines shall carry out a low cycle fatigue test of at least 500 cycles, idle-full load-idle, using the steepest load ramp that may apply.

2.16.4 Stage B - Type test
During the type test all the tests listed below under [2.16.4.1] to [2.16.4.5] shall be carried out in the presence of the surveyor. The results of individual tests shall be recorded and signed by the surveyor. Deviations from this program, if any, require the Society's agreement.

2.16.4.1 Type testing data collection
All relevant equipment for safety of personnel shall be operational during the type testing. The following particulars shall be recorded:
— ambient air temperature
— ambient air pressure
— atmospheric humidity
— external cooling water temperature
— fuel and lubrication oil characteristics.

As a minimum the following engine data shall be measured and recorded 2):

— engine r/min
— torque
— maximum combustion pressure for each cylinder
— mean indicated pressure for each cylinder
— lubrication oil pressure and temperature. The measurements shall cover all readings as required per Table 9 to Table 11 (reference is made to footnote 3), whichever is applicable
— lubrication oil pressure and temperature at turbocharger inlet/ outlet as applicable, see Table 9
— cooling water pressure and temperatures
— exhaust gas temperature before and after turbine and, where required, from each cylinder. To be measured also if installed due to manufacturers minimum sensor delivery
— exhaust gas pressure before turbine 1)
— r/min of turbocharger (applicable when the turbocharger is served by a group of cylinders > 1 000 kW)
— charging air pressure
— charging air temperature before and after cooler
— jacket cooling temperature
— piston cooling temperature (in case of separate cooling medium).

Guidance note:

1) The data need not necessarily be taken from the engine that is presented for type test - stage B. Data recorded from development engines used during type test - stage A can be accepted. The combustion data shall be recorded from a representative number of cylinder units, e.g. 1/3 of all cylinders. These data shall be presented to the attending surveyor in connection with type test - stage B, and included in the final type test report.

2) Exemptions to the listed parameters may be accepted pending limitations due to accessibility of the measuring points for the specific engine design and engine size.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

2.16.4.2 Test of safety systems
Prior to start of running the load points, the following safety precautions shall be tested:

— Test of the safety system, over speed, oil mist detection and low lubricating oil pressure
— Leakage test of double walled high pressure injection fuel oil lines, with alarm indication
— Demonstration of proper screening of pipe connections
— Test of mechanical starting interlocking device

2.16.4.3 Load points
Load points at which the engine shall be operated shall conform to the power/speed diagram in Figure 2.

The data to be measured and recorded when testing the engine at various load points shall include all the parameters necessary for an assessment.

The operating time per load point depends on the engine size and on the time for collection of the operating values. The measurements shall in every case only be performed after achievement of steady-state condition.

An operating time of 0.5 hour may be assumed per load point.

At 100% output (rated power) in accordance with [2.16.3.1] an operating time of 2 hours is required. At least two sets of readings shall be taken at an interval of 1 hour in each case.

1) Rated power (continuous power)
The rated power is defined as 100% output at 100% torque and 100% speed (rated speed) corresponding to load point 1.

2) 100% power
   The operation point 100% output at maximum allowable speed corresponding to load point 2 has to be performed.

3) Maximum permissible torque
   The maximum permissible torque results at 110% output at 100% speed corresponding to load point 3 or at maximum permissible power (110% at a speed according to the nominal propeller curve corresponding to load point 3a.

4) Minimum permissible speed for intermittent operation
   The minimum permissible speed for intermittent operation has to be adjusted:
   — at 100% torque corresponding to load point 4
   — at 90% torque corresponding to load point 5

5) Part-load operation
   For part-load operation the operation points 75%, 50%, 25% of the rated power at speeds according to the nominal propeller curve at load points 6, 7 and 8 and proceeding from the nominal speed at constant governor setting have to be adjusted corresponding to load points 9, 10 and 11.

---

**Figure 2 Power/speed diagram**

1. range of continuous operation
2. range of intermittent operation
3. range of short-time overload operation
2.16.4.4 Emergency operation in case of damaged turbocharger
Engines intended for single propulsion shall demonstrate the achievable output in case of turbocharger failure:
— engines with one turbocharger, when rotor is blocked or removed
— engines with two or more turbochargers, when the damaged turbocharger is shut off.
Engines intended for fixed pitch propeller application shall be able to run continuously at a speed \((r/min)\) of approximately 40% of full engine speed along theoretical propeller curve when one turbocharger is out of operation.

**Guidance note:**
The engine manufacturer should state whether the achievable output is continuous. If there is a time limit, the permissible operating time should be indicated.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

2.16.4.5 Functional tests
Functional tests shall be carried out as follows:
— ascertainment of lowest engine speed according to the nominal propeller curve
— starting tests for non-reversible engines and/or starting and reversing tests for reversible engines
— governor test
— test of the safety system particularly for overspeed, oil mist and failure of the lubrication oil system, etc.
— test of electronic components and systems according to the test program approved by the Society
— for electronically controlled engines integration tests to demonstrate that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes. The scope of these tests shall be proposed by the manufacturer/licensor based on the FMEA required in Table 3, and agreed by the Society.
— The functioning of water drain from the charge air system shall be demonstrated, during engine operation

2.16.4.6 Fire protection measures
Verification of compliance shall be demonstrated for jacketing of high-pressure fuel oil lines, screening of pipe connections in piping containing flammable liquids, including alarm upon leakage of fuel oil and insulation of hot surfaces.
Insulation of hot surfaces shall be verified while running the engine at rated power.
Measurements of surface temperatures shall be done by use of infrared thermoscanning equipment or by an equivalent measurement technique when approved by the Society. Results shall be verified by use of contact thermometers.

2.16.5 Stage C - Component inspection
The crankshaft deflections shall be measured in the specified (by designer) condition (except for small engines where no specification exists).
Immediately after the test run the components of one cylinder for in-line engines and two cylinders for in-V engines shall be presented for inspection as follows:
— piston, removed and dismantled
— crosshead bearing, dismantled
— crank bearing and main bearing, removed
— cylinder liner in the installed condition
— cylinder cover/ head, valves disassembled
— camshaft, camshaft drive and crankcase with opened covers
For V-engines, the cylinder units shall be selected from different cylinder banks and different crank throws.
If deemed necessary by the surveyor, further dismantling of the engine may be required.
2.16.6 Type approval test report
The results of the type approval test shall be compiled in a report which shall be submitted to the Society.

2.16.7 Type approval certificate
After successful performance evaluation of the test and of the required documents, the Society shall issue a Type Approval Certificate. The Type Approval Certificate is valid for a period of 5 years. Validity may be renewed on application by the engine designer.

3 Testing and Inspection

3.1 Recognition of engine manufacturer’s workshops

3.1.1 Every workshop where engines are assembled and tested has to be recognised by the Society when:
— the workshop is newly set up,
— a new production line is started,
— a new engine type is introduced, or
— a new production process is implemented.

3.1.2 Requirements for recognition of engine manufacturer’s workshops:
The manufacturer’s works shall be audited by the Society. Manufacturer’s works shall have suitable production and testing facilities, competent staff and a quality management system, which ensures a uniform production quality of the products according to the specification.

3.1.3 Manufacturing plants shall be equipped in such a way that all materials and components can be machined and manufactured to a specified standard. Production facilities and assembly lines, including machining units, welding processes, special tools, special devices, assembly and testing rigs as well as lifting and transportation devices shall be suitable for the type and size of engine, its components, and the intended purpose. Materials and components shall be manufactured in compliance with all production and quality instructions specified by the manufacturer.

3.1.4 Suitable test bed facilities for load tests shall be provided, also for dynamic response testing, if required. All liquids used for testing purposes such as fuel oil, lubrication oil and cooling water shall be suitable for the intended purpose, e.g. they shall be clean, preheated if necessary and cause no harm to engine parts.

3.1.5 Trained personnel shall be available for production of parts, assembly, testing and partly dismantling for shipping, if applicable.

3.1.6 Storage, reassembly and testing processes for engines at shipyards shall be such that the risk of damage to the engine or its parts is minimized.

3.1.7 Engine manufacturer’s workshops shall have a Quality Management System recognized by the Society.

3.2 Manufacturing inspections

3.2.1 The manufacturing of engines required to be provided with the Society Certification is subject to supervision by the Society. The scope of supervision can be agreed upon, see DNVGL-CG-0483.
3.3 Testing of materials and components

3.3.1 For individually produced engines, the parts listed in Table 8 shall be subjected to material tests, NDT tests and pressure tests as listed in Table 8.

3.3.2 Material tests
Material tests shall be performed in accordance with Table 8.

3.3.3 Non-destructive tests
For individually manufactured engines, non-destructive material tests shall be performed in accordance with Table 8.

3.3.4 Magnetic particle or dye penetrant tests shall be performed in accordance with Table 8 at those locations where experience shows that defects are likely to occur.

3.3.5 Ultrasonic tests shall be carried out by the manufacturer in accordance with Table 8 and the corresponding manufacturer’s test reports shall be submitted to the Society.

3.3.6 Welded seams of important engine components may be required to be subject to approved methods of testing.

3.3.7 When possible defects is revealed by any of the tests above in any engine component, additional non-destructive testing by approved methods may be required in addition to the tests mentioned above.

3.3.8 Results from the testing and inspection as required in [3.3] shall be evaluated against the acceptance criteria found in applicable NDT specifications as listed in Table 2. Where the corresponding NDT specification is not listed in Table 2, test and inspection results shall fulfil the revision of the designer’s specification valid at date of testing.

3.3.9 Welded crankshafts
Crankshafts welded together from forged or cast parts are subject to the Society’s approval. Both the manufacturer and the welding process shall be approved. The materials and the welds shall be tested.

3.3.10 Pressure tests
The individual components of internal combustion engines are subject to pressure tests at the pressures specified in Table 8. The Society Test Report shall be issued for the results of the pressure tests.

3.3.11 Items shall be tested by hydraulic pressure. Where design or testing features require modification of these test requirements, such test requirements shall be agreed.

3.3.12 Ancillaries not covered by Table 8 such as pumps, electric motors, coolers, piping, filters, valves, etc. that are delivered as integral parts of the fuel oil, lubrication, hydraulic and pneumatic operation and cooling systems on the engine, shall be checked as found relevant by the engine manufacturer.

Table 8 Certification, Testing and inspection requirements for engines its components and systems

<table>
<thead>
<tr>
<th>Object</th>
<th>Additional description</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard</th>
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<tbody>
<tr>
<td>Applicable for All Engine sizes</td>
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<td></td>
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<td>Component</td>
<td>Certification</td>
<td>Control</td>
<td>Manufacturer</td>
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<td>----------------------------------</td>
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<tr>
<td>Alarm and monitoring system</td>
<td>See [5]</td>
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<td>Society</td>
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<td>Safety system</td>
<td>see [5]</td>
<td>PC</td>
<td>Society</td>
<td></td>
</tr>
<tr>
<td>Speed control/governor, electrical</td>
<td>See [5]</td>
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<td>Society</td>
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<tr>
<td>Gas Valve unit (GVU), control system</td>
<td>See Pt.6 Ch.2 Sec.5</td>
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<td>Society</td>
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<td>Welded bedplate</td>
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<td>Society</td>
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<tr>
<td></td>
<td>C+M</td>
<td>MC</td>
<td>Manufacturer</td>
<td></td>
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<td></td>
<td>UT+CD</td>
<td>NDT Report</td>
<td>Manufacturer</td>
<td></td>
</tr>
<tr>
<td>Bearing transverse girders GS</td>
<td>Component certificate</td>
<td>PC</td>
<td>Society</td>
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<td>C+M</td>
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<td></td>
<td>UT+CD</td>
<td>NDT Report</td>
<td>Manufacturer</td>
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<td>Welded frame box</td>
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<td>UT+CD</td>
<td>NDT Report</td>
<td>Manufacturer</td>
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<td>Crankshaft: made in one piece</td>
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<td>Society</td>
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<td>PC</td>
<td>Manufacturer</td>
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<td>UT+CD</td>
<td>NDT Report</td>
<td>Manufacturer</td>
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<td></td>
<td>Dimensional control</td>
<td>PC</td>
<td>Manufacturer</td>
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<td>Forged main journal and journals with flange</td>
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<td></td>
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<td>PC</td>
<td>Manufacturer</td>
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</tr>
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<td>Connecting rod with cap</td>
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<td>Society</td>
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<td>C+M</td>
<td>MC</td>
<td>Society</td>
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<td>NDT Report</td>
<td>Manufacturer</td>
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<td>Society</td>
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<tr>
<td></td>
<td>C+M</td>
<td>MC</td>
<td>Society</td>
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</table>

#### Part 4 Chapter 3 Section 1

<table>
<thead>
<tr>
<th>Component Type</th>
<th>System Details</th>
<th>Testing Details</th>
<th>Company Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accumulator of common rail fuel or servo oil system</td>
<td>All engines with accumulators with a capacity of &gt;0.5 l</td>
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<tr>
<td>High pressure fuel injection pump body</td>
<td>Pressure testing</td>
<td>D&gt;300mm</td>
<td>PC</td>
</tr>
<tr>
<td></td>
<td>Pressure testing</td>
<td>D≤300mm</td>
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</tr>
<tr>
<td>High pressure fuel injection valves (only for not auto-fretted)</td>
<td>Pressure testing</td>
<td>D&gt;300mm</td>
<td>PC</td>
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<tr>
<td></td>
<td>Pressure testing</td>
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#### Additional requirements for engines with Cylinder bore D > 300 mm

<table>
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<th>System Details</th>
<th>Testing Details</th>
<th>Company Details</th>
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<tbody>
<tr>
<td>Cylinder liner</td>
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<td>MC</td>
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<tr>
<td></td>
<td>Pressure testing</td>
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<td>PC</td>
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<tr>
<td>Cylinder head GJL &amp; GJS</td>
<td>Component certificate</td>
<td></td>
<td>PC</td>
</tr>
<tr>
<td></td>
<td>C+M</td>
<td></td>
<td>MC</td>
</tr>
<tr>
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<td>UT+CD</td>
<td>NDT Report</td>
<td>Manufacturer</td>
</tr>
<tr>
<td></td>
<td>Pressure testing</td>
<td></td>
<td>PC</td>
</tr>
<tr>
<td>Forged cylinder head</td>
<td>Component certificate</td>
<td></td>
<td>PC</td>
</tr>
<tr>
<td></td>
<td>C+M</td>
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</tr>
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<td>UT+CD</td>
<td>NDT Report</td>
<td>Manufacturer</td>
</tr>
<tr>
<td></td>
<td>Pressure testing</td>
<td></td>
<td>PC</td>
</tr>
<tr>
<td>Bolts and studs for main bearings</td>
<td>C+M</td>
<td></td>
<td>MC</td>
</tr>
<tr>
<td></td>
<td>UT+CD</td>
<td>NDT Report</td>
<td>Manufacturer</td>
</tr>
<tr>
<td></td>
<td>Bolts and studs for cylinder heads</td>
<td>C+M</td>
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</tr>
<tr>
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<td>NDT Report</td>
<td>Manufacturer</td>
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<td>Bolts and studs for connecting rods</td>
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<td>NDT Report</td>
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<td>Thread making</td>
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<td>TR Report</td>
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<td></td>
<td>High pressure fuel injection pipes including common fuel rail</td>
<td>Pressure testing, for those that are not auto-fretted</td>
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</tr>
<tr>
<td>Component</td>
<td>Certification</td>
<td>Method</td>
<td>Responsible Party</td>
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<tr>
<td>----------------------------------------------</td>
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<td>PC</td>
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<tr>
<td>Cooler, both sides</td>
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<td></td>
<td>Pressure testing</td>
<td>PC</td>
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### Additional requirements for engines with Cylinder bore D > 400 mm

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<th>Component</th>
<th>Certification</th>
<th>Method</th>
<th>Responsible Party</th>
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<tbody>
<tr>
<td>Piston crown GS</td>
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<td>PC</td>
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<td>C+M</td>
<td>MC</td>
<td>Manufacturer</td>
</tr>
<tr>
<td></td>
<td>UT+CD</td>
<td>NDT Report</td>
<td>Manufacturer</td>
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<tr>
<td>Forged piston crown</td>
<td>Component certificate</td>
<td>PC</td>
<td>Society</td>
</tr>
<tr>
<td>Piston rod, if applicable</td>
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<td>MC</td>
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</tr>
<tr>
<td></td>
<td>UT+CD</td>
<td>NDT Report</td>
<td>Manufacturer</td>
</tr>
<tr>
<td></td>
<td>Component certificate</td>
<td>PC</td>
<td>Society</td>
</tr>
<tr>
<td></td>
<td>C+M</td>
<td>MC</td>
<td>Manufacturer</td>
</tr>
<tr>
<td></td>
<td>UT+CD, CD again after final machining (grinding)</td>
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<td>Manufacturer</td>
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### Additional requirements for engines with Cylinder power P > 400 kW/cyl

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<th>Method</th>
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<tbody>
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<td>Engine block GJL</td>
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<tr>
<td>Engine block GJS</td>
<td>M</td>
<td>MC</td>
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### Additional requirements for engines with Cylinder power P > 800 kW/cyl

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<th>Certification</th>
<th>Method</th>
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</thead>
<tbody>
<tr>
<td>Piping, pumps, actuators, etc. for hydraulic drive of valves, if applicable</td>
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<td>MC</td>
<td>Manufacturer</td>
</tr>
<tr>
<td></td>
<td>Pressure testing</td>
<td>PC</td>
<td>Manufacturer</td>
</tr>
<tr>
<td>Engine driven pumps (oil, water, fuel, bilge)</td>
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<td>PC</td>
<td>Manufacturer</td>
</tr>
<tr>
<td>Bearings for main, crosshead, and crankpin</td>
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<td>TR</td>
<td>Society</td>
</tr>
<tr>
<td></td>
<td>UT (for full contact between basic material and bearing metal)</td>
<td>TR</td>
<td>Manufacturer</td>
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### Additional requirements for Cross head engines:

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<th>Method</th>
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<tbody>
<tr>
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<td>Welded cylinder frames</td>
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### Rotating machinery - drivers

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<th>Test Method</th>
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<td>Exhaust gas valve cage</td>
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<td>C+M</td>
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<td>Manufacturer</td>
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<td>UT+CD (CD again after final machining (grinding and polishing))</td>
<td>NDT Report</td>
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<td>Tie rod</td>
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<tr>
<td></td>
<td>C+M</td>
<td>MC</td>
<td>Manufacturer</td>
</tr>
<tr>
<td></td>
<td>UT+CD</td>
<td>NDT Report</td>
<td>Manufacturer</td>
</tr>
<tr>
<td></td>
<td>Thread making</td>
<td>TR Report</td>
<td>Manufacturer</td>
</tr>
</tbody>
</table>

**M+C =** 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).  
**NDT =** Non-destructive examination means e.g. ultrasonic testing, crack detection by MPI or DP.  
Pressure 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.

1) Charge air coolers need only be tested on the water side

3.3.13 For general certification requirements, see Pt.1 Ch.3 Sec.4.

3.3.14 For a definition of the certification types, see Pt.1 Ch.3 Sec.5.

3.4 Inspection during assembly

3.4.1 For crosshead engines the report on alignment of the bedplate, the crankshaft deflection, the guides and pistons shall be reviewed by the surveyor. The crankshaft deflections shall be reported at the different manufacturing steps.
4 Workshop testing

4.1 Application

4.1.1 Engines shall be subjected to trials on the test bed at the manufacturer's works and under the Society's supervision. The scope of these trials shall be as specified below. Exceptions to this require the agreement of the Society.

4.1.2 All relevant equipment for safety of personnel shall be operational during the workshop testing.

4.1.3 Scope of works trials
During the trials the operating values corresponding to each load point shall be measured and recorded by the engine manufacturer. All the results shall be compiled in a test report to be issued by the engine manufacturer.
In each case all measurements conducted at the various load points shall be carried out under steady operating conditions.
The readings for 100% power (rated power at rated speed) shall be taken twice at an interval of at least 30 minutes.

4.1.4 After running on the test bed, the fuel delivery system of main engines shall be so adjusted that after installation on board overload power cannot be delivered. The limitation of the fuel delivery system shall be secured permanently.

4.1.5 Subject to the prescribed conditions, engines driving electrical generators shall be capable of overload operation (110% rated power) in order to utilize 100% of rated load in parallel operation.

4.1.6 Workshop testing of engines less than 300 kW
For engines with rated power less than 300 kW, scope of workshop tests is identical with that of type testing, see [2.14.2].

4.2 General engine tests

4.2.1 Ambient condition
The following external shall be recorded:
— ambient air temperature
— ambient air pressure
— atmospheric humidity
— external cooling water temperature.

4.2.2 Engine performance
Engine data shall be measured and recorded according to the specification of the engine manufacturer and approved by the Society.

Guidance note:
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. An operating time of 0.5 to 1 hour should be assumed per load point.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

4.2.3 Integration tests
For electronically controlled engines integration tests shall be conducted to demonstrate that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes.
The scope of these tests shall be proposed by the manufacturer/licensor based on the FMEA required in Table 2 and Table 3 and agreed by the Society.

4.2.4 Demonstration of fire protection measures
The following fire protection measures shall be demonstrated:
— jacketing of high-pressure fuel oil lines, including system for detection of leakage, see [2.8.6],
— screening of pipe connections in piping containing flammable liquids, see [2.6.2].
— insulation of hot surfaces shall be randomly verified with the readings obtained during type test, see [2.6.1] while running the engine at 100% load, alternatively at the overload approved for intermittent use. Use of conventional contact thermometers may be accepted at discretion of the attending surveyor. However, if there have been made revisions to the insulation interface additional enhanced measurements to those conducted during type test may be required.

4.3 Testing of propulsion engines
4.3.1 Propulsion engines for direct propeller drive
The load tests shall be performed according to a) - c), functional tests according to d) - h).

a) 100% power (rated power)
   at 100% engine speed (rated engine speed)
   for at least 60 minutes after reaching the steady state condition
b) 110% power
   at 103% rated engine speed
   for 30 minutes after reaching the steady-state condition
   After the test bed trials the output shall be limited to the maximum continuous power (100% power) so that the engine cannot be overloaded in service.
c) 90%, 75%, 50% and 25% power depending on application as follows:
   The propeller curve based on the propeller law
   This applies if the engine is driving a fixed pitch propeller, water jet or controllable pitch propeller with variable r/min and pitch limited to nominal value.
   Or:
   The modified propeller curve
   This applies if the engine is driving a controllable pitch propeller that:
   — is intended to use a higher pitch than the nominal when running at reduced r/min In this case, the load point with lowest r/min at 100% of maximum continuous rated torque shall be added
   — has a combinator pitch control using reduced pitch at lower speeds. In this case the pitch limitations have to be stated on a signboard for the purpose of manual operation.
   Or:
   At constant speed
   This applies if the engine is driving a controllable pitch propeller with constant speed or a generator for propulsion.

d) test of starting and reversing manoeuvres
e) test of governor and independent overspeed protection device
f) test of engine shutdown devices
g) test of oil mist detection or alternative system, if available
h) test of mechanical starting interlocking device
Guidance note:
The 90% power given in C), may be replaced by the project specific Normal Continues Rating (NCR).
---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

4.3.2 Main engines for electrical propeller drive
The load tests shall be performed according to a) - c), functional tests according to d) - h)

a) 100% power (rated power):
   for at least 60 minutes after reaching the steady state condition

b) 110% power:
   for 30 minutes after reaching the steady-state condition
   After the test bed trials the output of engines driving generators shall be so adjusted that overload
   (110%) power can be supplied in service after installation on board in such a way that the governing
   characteristics and the requirements of the generator protection devices can be fulfilled at all times.

c) 75%, 50% and 25% power and idle run

d) start-up tests

e) test of governor and independent overspeed protection device

f) test of engine shutdown devices

g) test of oil mist detection or alternative system, if available

h) test of mechanical starting interlocking device

4.3.3 Testing of surge margins
Propulsion engines with a turbocharger which is served by cylinder groups with combined power in excess
of 2 500 kW shall be tested with regard to surge margins. The below mentioned tests may be waived if
successfully tested earlier on an identical configuration of engine and turbocharger

For 4-stroke engines, the following test shall be performed without indication of surging:
— at rated power, the speed shall be reduced with constant torque (fuel index) down to 90% power
— with 50% power at 80% speed (propeller characteristic for fixed pitch), the speed shall be reduced to
  72% while keeping constant torque (fuel index).

For 2-stroke engines, the surge margin shall be demonstrated by at least one of the following methods:

1) Engine working line established at the workshop testing of engine (w/turbocharger) shall be plotted into
the compressor map of the turbocharger. There shall be at least 15% surge margin in the full load range,
i.e. working flow shall be 15% above the theoretical flow at surge limit (at constant pressure).

2) Sufficient surge margin shall be demonstrated by sudden fuel cut-off to at least one cylinder. For
applications with more than one turbocharger, cut the fuel supply to the cylinder closest upstream to
each turbocharger.
   This test shall be performed at two different engine loads:
   — The maximum power permitted for one cylinder misfiring.
   — The engine load corresponding to a charge air pressure of about 0.6 bar (but without auxiliary
     blowers running).

3) Sufficient surge margin shall be demonstrated by an abrupt (< 2 sec) reduction in power from MCR to
50% of MCR.
Acceptance criteria for alternative 2) and 3):
— no continuous surging is accepted, and the turbocharger shall stabilise itself at the new load within 20
seconds.
4.4 Auxiliary driving engines and engines driving electrical generators

4.4.1 The scope of tests shall be performed according to [4.3.2].

4.4.2 In case of engines driving electrical generators the rated electrical power as specified by the manufacturer shall be verified as minimum power.

4.5 Survey after testing

4.5.1 All inspection covers shall be opened and the condition after trial shall be surveyed by the Society representative.

4.5.2 The crankshaft deflections shall be measured and checked according to the manufacturer’s specification. The condition of the crankshaft at the time of deflection measurements (hot or cold) shall be noted on the record.

4.5.3 Component inspection
The extent of random checks of components to be presented for inspection after the workshop test, shall be agreed with the Society representative.

Guidance note:
Typical components for inspection after the engine’s workshop test :
— camshaft drive train
— cams and cam rollers
— one piston to be removed for inspection of the unit.
— one crosshead with bearing and guide, if applicable
— one crankpin bearing
— one cylinder head with valves disassembled
— one main bearing
If deemed necessary by the surveyor, further dismantling of the engine may be required.

5 Control and Monitoring

5.1 General

5.1.1 The requirements in this sub-section are in addition to those given in Ch.9. For requirements related to design of the control and monitoring system in terms of:
— automatic control
— remote control
— safety system
— when, where and how to present alarms
— what kind of indication to be presented where
— system operation and maintenance
— power distribution
see Ch.9 Sec.3.
In case of engines intended for vessels approved for unmanned machinery installations (Class Notation E0), Pt. 6 Ch. 2 Sec. 2 and in case of gas fuelled ship installations, Pt. 6 Ch. 2 Sec. 5 applies in addition to these requirements.

5.1.2 Electronic components and systems
Electronic components and systems shall be approved and certified according to [1] and [3]. For electronic components and systems which are necessary for the control of internal combustion engines the requirements in Sec. 1 applies.

5.1.3 In the case of engine installations up to a total output of 600 kW, simplifications can be agreed with the Society.

Guidance note:
Control and monitoring according to Table 11, is acceptable, but shut down due to low lube oil pressure according to Table 9 to be provided.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

5.2 Speed governing

5.2.1 Main and auxiliary engines
Each engine not used to drive an electrical generator shall be equipped with a speed governor or regulator adjusted such that the engine speed cannot exceed the rated speed by more than 15%.

5.2.2 Engines driving electrical generators
For engine requirements to load response and speed variations in steady state and in transient operations, see Ch. 2 Sec. 5.

5.2.3 Use of electrical/electronic governors

5.2.3.1 The governor and the associated actuator shall, for controlling the respective engine, be suitable for the operating conditions laid down in the rules and for the requirements specified by the engine manufacturer.

The regulating conditions required for each individual application as described in [5.2.1] and [5.2.2] shall be satisfied by the governor system.

For requirements to power supply arrangement, see Ch. 9.

Speed sensor cabling shall be mechanically well protected.

Alarms to warn of faults in the governor system shall be arranged.

Governors for engines, other than those driving electrical generators, which keep the last position upon power failure, are regarded as fulfilling the redundancy type R0. Power supply to have redundancy type R0.

5.2.3.2 Requirements applying to main engines
For single engine plants it has to be ensured that in case of a failure of the electrical/ electronic governor or electronic engine management system the control of the engine can be taken over by another control device, withing the time required by redundancy type described in Ch. 1 Sec. 3. Electronic governors shall have their power supply independent of other consumers and the governor including its power supplies shall be arranged with redundancy type R0.

To ensure continuous speed control or immediate resumption of control after a fault at least one of the following requirements shall be satisfied:

a) the governor system has an independent back-up system or

b) there is a redundant governor assembly for manual change-over with a separately protected power supply or

c) the engine has a manually operated fuel admission control system suitable for manoeuvring.
5.2.3.3 Requirements applying to auxiliary engines driving electrical generators
Each auxiliary engine shall be equipped with its own governor system.
In the event of a fault of components or functions which are essential for the speed control in the governor
system, the speed demand output shall be set to "0" (i.e. the fuel admission in the injection pump shall be
set to "0"). Alarms to warn of faults in the governor system shall be arranged.

5.3 Overspeed protection
5.3.1 In addition to the normal governor, each engine with a rated power of 220 kW or over shall be fitted
with an independent overspeed protection device so adjusted that the engine speed cannot exceed the rated
speed by more than 20% except for diesel engines driving generators where protection device shall prevent
the engine speed from exceeding the rated speed by more than 15%.

5.3.2 For engines operating in areas defined as gas hazardous zones or spaces (see applicable class
notation), an additional device that automatically shuts the air inlet in case of overspeed is required. This
device shall activate at the same speed level as the overspeed protective device required in [5.3.1]. For
engines with turbochargers that can suffer overspeed due to a sudden shut of air intake, the shutting device
shall be between the turbocharger and the engine.

Guidance note:
Relating to [5.3.1]:
An independent overspeed protection device means a system all of whose component parts, including the drive, function independently
of the normal governor.

5.4 Propulsion engines
5.4.1 The propulsion engines shall as a minimum be fitted with instrumentation and alarms according to
Table 9 if not otherwise approved.

5.4.2 Local control station
For local operation without remote control of the propulsion plant a local control station shall be installed
from which the plant can be operated and monitored.

5.4.3 Indicators according to Table 9 shall be clearly visible at the local main engine control station.

5.4.4 Temperature indicators shall be provided at the local control station or directly on the engine.

5.4.5 Barred speed ranges shall be marked in red on the tachometers.

Table 9 Control and monitoring of propulsion engines

<table>
<thead>
<tr>
<th>System</th>
<th>Item</th>
<th>Valid for engine type 1)</th>
<th>Gr 1 Indication alarm load reduction</th>
<th>Gr 2 Automatic start of stand-by pump with alarm 2)</th>
<th>Gr 3 Shut down with alarm</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Fuel oil system</td>
<td>Leakage from jacketed high pressure pipes</td>
<td>C, T</td>
<td>A</td>
<td></td>
<td></td>
<td>Level monitoring of leakage tank or equivalent</td>
</tr>
<tr>
<td>System</td>
<td>Item</td>
<td>Valid for engine type</td>
<td>Gr 1 Indication alarm load reduction</td>
<td>Gr 2 Automatic start of stand-by pump with alarm</td>
<td>Gr 3 Shut down with alarm</td>
<td>Comments</td>
</tr>
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<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Fuel oil pressure at engine inlet</td>
<td>IL, IR, LA</td>
<td></td>
<td></td>
<td></td>
<td>Fuel oil viscosity is accepted as alternative</td>
</tr>
<tr>
<td></td>
<td>Fuel oil temperature at engine inlet</td>
<td>IL, IR, A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0 Lubricating oil system</td>
<td>Lubrication oil to all bearings, inlet pressure</td>
<td>C, T</td>
<td>IR, IL, LA, AS</td>
<td></td>
<td>SH^5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lubrication oil to all bearings, inlet temperature</td>
<td></td>
<td>IR, IL, HA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lubrication oil to dampers, inlet pressure</td>
<td></td>
<td>IR, IL, LA</td>
<td></td>
<td></td>
<td>If installed</td>
</tr>
<tr>
<td>3.0 Turbocharger system</td>
<td>Turbocharger lubrication oil inlet pressure</td>
<td>C, T</td>
<td>IR, IL, LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Turbocharger lubrication oil outlet temperature</td>
<td></td>
<td>IR, HA</td>
<td></td>
<td></td>
<td>Applicable only when the T/C is served by group of cylinders &gt; 1 000 kW</td>
</tr>
<tr>
<td></td>
<td>Speed of turbocharger</td>
<td></td>
<td>IR, HA</td>
<td></td>
<td></td>
<td>If not forced system, oil temperature near bearings</td>
</tr>
<tr>
<td>4.0 Piston cooling system</td>
<td>Piston coolant inlet pressure (common)</td>
<td>C</td>
<td>IR or IL, LA, LR</td>
<td>AS</td>
<td></td>
<td>Load reduction and automatic start of stand-by pump is not required if the coolant is oil taken from the main lubrication oil system of the engine</td>
</tr>
<tr>
<td></td>
<td>Piston coolant outlet flow each cylinder</td>
<td></td>
<td>IL, IR, HA, LR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System</td>
<td>Item</td>
<td>Valid for engine type</td>
<td>Gr 1 Indication</td>
<td>Gr 2 Automatic start of stand-by pump with alarm</td>
<td>Gr 3 Shut down with alarm</td>
<td>Comments</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Alarm</td>
<td>Load reduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0 Cylinder cooling medium</td>
<td>Cylinder cooling inlet pressure or flow</td>
<td>C, T</td>
<td>IR, IL, LA</td>
<td>AS</td>
<td>Monitoring of expansion tank level, with alarm at low level, is an acceptable alternative for engines with cylinder power &lt; 130 kW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cylinder cooling water temperature at engine outlet</td>
<td>C, T</td>
<td>IR, IL, HA</td>
<td></td>
<td>Temperature to be monitored for each cylinder if individual stop valves are fitted for the cylinder jackets, otherwise main outlet. Sensor location so as to enable alarm in event of closed valve</td>
<td></td>
</tr>
<tr>
<td>6.0 Starting and control air systems</td>
<td>Control air pressure (if arranged)</td>
<td>C, T</td>
<td>IR or IL, LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Starting air pressure</td>
<td>C, T</td>
<td>IR or IL, LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.1 Pneumatic return of exhaust valve</td>
<td>Exhaust gas valve air spring pressure</td>
<td>C</td>
<td>IR or IL, LA</td>
<td></td>
<td>Pressure readings shall be taken at the supply line locally on the engine</td>
<td></td>
</tr>
<tr>
<td>7.0 Charge air system</td>
<td>Charge air pressure</td>
<td>C, T</td>
<td>IL or IR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Charge air temperature, under each piston (fire detection)</td>
<td>C</td>
<td>LR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Charge air temperature at charge air cooler outlet</td>
<td>C, T</td>
<td>IL or IR, HA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.0 Exhaust gas system</td>
<td>Exhaust gas temp after each cylinder (^7)</td>
<td>C, T</td>
<td>HA</td>
<td>IR, LR</td>
<td>LR is only required when the T/C is served by group of cylinders &gt; 2 500 kW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exhaust gas temp before T/C (^9)</td>
<td>C, T</td>
<td>IR, HA, LR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System</td>
<td>Item</td>
<td>Valid for engine type</td>
<td>Gr 1 Indication alarm load reduction</td>
<td>Gr 2 Automatic start of stand-by pump with alarm</td>
<td>Gr 3 Shut down with alarm</td>
<td>Comments</td>
</tr>
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<td>-------------------------------------</td>
<td>----------------------------------------------------------------------</td>
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<td>--------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>9.0 Hydraulic oil system</td>
<td>Leakage from jacketed high pressure pipes for hydraulic operation of valves</td>
<td>C, T</td>
<td>A</td>
<td></td>
<td></td>
<td>Level monitoring of leakage tank or equivalent</td>
</tr>
<tr>
<td>10.0/11.0 Engine speed/direction of rotation</td>
<td>Engine speed/direction of rotation</td>
<td>C, T</td>
<td>IL, IR</td>
<td></td>
<td>SH</td>
<td>Applicable if ≥ 220 kW, see [5.3] SH shall be activated automatically</td>
</tr>
<tr>
<td>10.0/11.0 Engine speed/direction of rotation</td>
<td>Over speed protection</td>
<td>C, T</td>
<td>IL, IR</td>
<td></td>
<td>SH</td>
<td>Applicable if ≥ 220 kW, see [5.3] SH shall be activated automatically</td>
</tr>
<tr>
<td>12.0 Chain tension</td>
<td>Position feeler &quot;sensor&quot;</td>
<td>C</td>
<td>IL</td>
<td></td>
<td></td>
<td>Where applicable</td>
</tr>
<tr>
<td>13.0 Crankcase explosive condition</td>
<td>Oil mist detection</td>
<td>C</td>
<td>LR</td>
<td></td>
<td></td>
<td>Shall be activated automatically</td>
</tr>
<tr>
<td></td>
<td>Other systems than oil mist detection</td>
<td>T</td>
<td>HA</td>
<td>SH&lt;sup&gt;12)&lt;/sup&gt;</td>
<td>SH&lt;sup&gt;12)&lt;/sup&gt;</td>
<td>Either LR or SH Shall be activated automatically</td>
</tr>
<tr>
<td>14. Misfire&lt;sup&gt;15)&lt;/sup&gt;</td>
<td>Detection of misfire</td>
<td>C, T</td>
<td>A, LR</td>
<td></td>
<td></td>
<td>Chosen LR depends on permissible misfire</td>
</tr>
</tbody>
</table>

Gr 1 = Sensor(s) for indication, alarm, load reduction (common sensor permitted but with different set points and alarm shall be activated before any load reduction)

Gr 2 = Sensor for automatic start of standby pump

Gr 3 = Sensor for shut down

IL = Local indication (presentation of values), in vicinity of the monitored engine component or system

IR = Remote indication (presentation of values), in engine control room or another centralized control station such as the local platform/manoeuvring console

A = Alarm activated for logical value

LA = Alarm for low value

HA = Alarm for high value

AS = Automatic start of standby pump with corresponding alarm

LR = Load reduction, either manual or automatic, with corresponding alarm, either slow down (r/min reduction) or alternative means of load reduction (e.g. pitch reduction), whichever is relevant.

SH = Shut down with corresponding alarm. May be manually (request for shut down) or automatically executed if not explicitly stated above.

For definitions of Load reduction (LR) and Shut down (SH), see Ch.1 of the Rules for Classification of Ships.
### Rotating machinery - drivers

<table>
<thead>
<tr>
<th>System</th>
<th>Item</th>
<th>Valid for engine type</th>
<th>Gr 1 Indication</th>
<th>Gr 2 Automatic start of stand-by pump with alarm</th>
<th>Gr 3 Shut down with alarm</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>alarm load reduction</td>
<td>start with alarm</td>
<td>stand-by pump</td>
<td></td>
</tr>
<tr>
<td>1)</td>
<td></td>
<td>C = Crosshead engine, T = Trunk engine.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2)</td>
<td></td>
<td>To be provided when stand-by pump is required, see Ch.1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3)</td>
<td></td>
<td>For engines running on heavy fuel oil only.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4)</td>
<td></td>
<td>Pressure to be monitored for all inlets to main bearings, crosshead bearings, camshaft bearings and turbocharger where pressure may differ due to presence of pumps, throttles, rotor seals or pressure reduction valves</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5)</td>
<td></td>
<td>Only for engine output ≥220 kW</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>6)</td>
<td></td>
<td>Where outlet temperature from each bearing cannot be monitored due to the engine/turbocharger design alternative arrangements may be accepted. Continuous monitoring of inlet pressure and inlet temperature in combination with specific intervals for bearing inspection in accordance with the turbocharger manufacturer’s instructions may be accepted as an alternative.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>7)</td>
<td></td>
<td>Applicable when cylinder power &gt; 500 kW.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8)</td>
<td></td>
<td>Alarm with request for load reduction to be given in case of excessive average exhaust gas temperature. This applies when there is no separate sensor before T/C, and the T/C is served by a group of cylinders &gt; 1 000 kW. The alarm level shall be set with due considerations to safe operation of T/C.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9)</td>
<td></td>
<td>Applicable only when the T/C is served by a group of cylinders &gt; 1 000 kW and if no individual exhaust gas temperature for each cylinder.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10)</td>
<td></td>
<td>When driving in barred speed range in excess of approved maximum duration set by torsional vibration level in the shafting (where deemed necessary, limitations in duration shall be given in connection approval of torsional vibration analysis). This safety device shall only be required when so stated in connection with approval of torsional vibration analysis.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11)</td>
<td></td>
<td>Applicable to engines of 2 250 kW and above, or with cylinder diameter &gt; 300 mm.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12)</td>
<td></td>
<td>One Crankcase explosive condition monitoring device having two independent outputs for detecting alarm and shut-down is acceptable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13)</td>
<td></td>
<td>Oil mist detectors shall be type tested in accordance with IACS UR M67.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14)</td>
<td></td>
<td>Alternative methods of monitoring may be approved by the Society, see [5.7.10]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15)</td>
<td></td>
<td>If required by torsional vibration calculations, diesel engines with cylinder output of 130kW and above shall have means to detect misfire.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16)</td>
<td></td>
<td>On turbocharging systems where turbochargers are activated sequentially, speed monitoring is not required for the turbocharger(s) being activated last in the sequence provided all turbochargers share the same intake air filter and they are not fitted with waste gates</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 5.5 Auxiliary engines

**5.5.1** The auxiliary engines shall as a minimum be fitted with instrumentation and alarms according to Table 10 if not otherwise approved.
<table>
<thead>
<tr>
<th>System</th>
<th>Item</th>
<th>Gr 1 Indication alarm</th>
<th>Gr 2 Automatic start of stand-by pump with alarm</th>
<th>Gr 3 Shut down with alarm</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Fuel oil system</td>
<td>Leakage from jacketed high pressure pipes</td>
<td>A</td>
<td></td>
<td></td>
<td>Level monitoring of leakage tank or equivalent</td>
</tr>
<tr>
<td></td>
<td>Fuel oil pressure at engine inlet</td>
<td>IL, IR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fuel oil temperature at engine inlet 2)</td>
<td>IL, IR, A</td>
<td></td>
<td></td>
<td>Fuel oil viscosity is accepted as alternative</td>
</tr>
<tr>
<td>2.0 Lubricating oil system</td>
<td>Lubrication oil to main bearings, inlet pressure</td>
<td>IL, or IR, LA,</td>
<td>AS</td>
<td>SH 3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lubrication oil to main bearings, inlet temperature</td>
<td>IR, or IL, HA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0 Turbocharger system</td>
<td>Speed of turbocharger</td>
<td>IR or IL, HA</td>
<td></td>
<td></td>
<td>Applicable only when the T/C is served by group of cylinders &gt; 1 000 kW</td>
</tr>
<tr>
<td>4.0 Cylinder cooling medium</td>
<td>Cylinder cooling inlet pressure or flow</td>
<td>IR or IL, LA</td>
<td>AS</td>
<td></td>
<td>Monitoring of expansion tank level, with alarm at low level, is an acceptable alternative for engines with cylinder power &lt; 130 kW</td>
</tr>
<tr>
<td></td>
<td>Cylinder cooling water temperature at engine outlet</td>
<td>IR, or IL, HA, LR</td>
<td>SH</td>
<td></td>
<td>Either LR or SH</td>
</tr>
<tr>
<td>5.0 Exhaust gas system</td>
<td>Exhaust gas temp after each cylinder 4)</td>
<td>IR or IL, HA, LR 5)</td>
<td></td>
<td></td>
<td>SH may replace LR for electric power generating engines</td>
</tr>
<tr>
<td></td>
<td>Exhaust gas temp before T/C 5)</td>
<td>IR or IL, HA, LR</td>
<td></td>
<td></td>
<td>The LR is only required when the T/C is served by group of cylinders &gt; 2 500 kW SH may replace LR for electric power generating engines</td>
</tr>
<tr>
<td>6.0 Hydraulic oil system</td>
<td>Leakage from jacketed high pressure pipes for hydraulic operation of valves</td>
<td>A</td>
<td></td>
<td></td>
<td>Level monitoring of leakage tank or equivalent</td>
</tr>
<tr>
<td>7.0/8.0 Engine speed/direction of rotation</td>
<td>Engine speed</td>
<td>IL, IR</td>
<td></td>
<td></td>
<td>For engines other than for electric power generation, local indication is an acceptable alternative</td>
</tr>
<tr>
<td>System</td>
<td>Item</td>
<td>Gr 1</td>
<td>Gr 2</td>
<td>Gr 3</td>
<td>Comment</td>
</tr>
<tr>
<td>--------</td>
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<td>------</td>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indication</td>
<td>Automatic</td>
<td>Shut down</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>alarm</td>
<td>start of</td>
<td>with</td>
<td>Applicable if P ≥ 220 kW, see [5.3]. SH shall be activated automatically</td>
</tr>
<tr>
<td></td>
<td></td>
<td>load reduction</td>
<td>stand-by</td>
<td>alarm 1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>pump with</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>alarm 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overspeed protection</td>
<td></td>
<td></td>
<td></td>
<td>SH</td>
<td></td>
</tr>
<tr>
<td>Oil mist detection 9)</td>
<td></td>
<td>HA</td>
<td></td>
<td>SH 8)</td>
<td>Shall be activated automatically</td>
</tr>
<tr>
<td>Other systems than oil mist detection 10</td>
<td></td>
<td>A</td>
<td></td>
<td>SH 8)</td>
<td>Shall be activated automatically</td>
</tr>
<tr>
<td>Detection of misfire 11</td>
<td></td>
<td>A, LR</td>
<td></td>
<td>SH 12)</td>
<td>Depending on permissible misfire, LR is accepted as alternative to SH for auxiliary engines other than driving generators</td>
</tr>
</tbody>
</table>
### 5.6 Emergency engines

#### 5.6.1 The requirements of [5.6] apply to engines used as prime movers for emergency generators.

#### 5.6.2 The emergency generator prime movers shall as a minimum be fitted with instrumentation and alarms according to Table 11 if not otherwise approved.
### Table 11 Control and monitoring of engines for emergency duty

<table>
<thead>
<tr>
<th>System</th>
<th>Item</th>
<th>Gr 1 Indication</th>
<th>Gr 2 Automatic start of stand-by pump with alarm</th>
<th>Gr 3 Shut down with alarm</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Fuel oil system</td>
<td>Leakage from jacketed high pressure pipes</td>
<td>A</td>
<td></td>
<td></td>
<td>Level monitoring of leakage tank or equivalent</td>
</tr>
<tr>
<td>2.0 Lubricating oil system</td>
<td>Lubrication oil to main bearings, inlet pressure</td>
<td>IL, LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>lubrication oil temperature at engine inlet</td>
<td>IL, HA</td>
<td></td>
<td></td>
<td>HA applicable if P ≥ 220 kW</td>
</tr>
<tr>
<td>4.0 Cylinder cooling medium</td>
<td>cylinder cooling water temperature at engine outlet</td>
<td>IL, HA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>cylinder cooling water pressure / flow at engine inlet</td>
<td>IL, LA</td>
<td></td>
<td></td>
<td>LA applicable if P ≥ 220 kW</td>
</tr>
<tr>
<td>7.0/8.0 Engine speed</td>
<td>Engine speed</td>
<td>IL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overspeed protection</td>
<td></td>
<td></td>
<td>SH</td>
<td>Applicable if P ≥ 220 kW, see [5.3] Shall be activated automatically</td>
</tr>
<tr>
<td>9.0 Crankcase explosive condition 2)</td>
<td>Oil mist detection 3)</td>
<td>HA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other systems than oil mist detection 4)</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Gr 1** = Sensor(s) for indication, alarm, load reduction (common sensor permitted but with different set points and alarm shall be activated before any load reduction)

**Gr 2** = Sensor for automatic start of standby pump

**Gr 3** = Sensor for shut down

**IL** = Local indication (presentation of values), in vicinity of the monitored engine component or system

**IR** = Remote indication (presentation of values), in engine control room or another centralized control station such as the local platform/manoeuvring console

**A** = Alarm activated for logical value

**LA** = Alarm for low value

**HA** = Alarm for high value

**SH** = Shut down with corresponding alarm. May be manually (request for shut down) or automatically executed.

1) To be provided when stand-by pump is required, see Ch.1 of the Rules for Classification of Ships.

2) Applicable to engines of 2 250 kW and above, or with cylinder diameter > 300 mm.

3) Oil mist detectors shall be type tested in accordance with IACS UR M67.

4) Alternative methods of monitoring may be approved by the Society, see [5.7.10]
5.6.3 Manual stop devices for the emergency generator prime mover shall only be arranged in the same room as it is located and in close vicinity to the entrance door to the room.

5.6.4 Combined emergency and harbour generator
If the emergency generator is used as harbour generator, monitoring system shall be installed as required by auxiliary engines for unattended machinery operation. When operating as emergency generator the safety devices shall not cause interruption of the emergency power supply, except for protective functions listed in Table 11.

5.7 Oil mist detection/monitoring and alarm system (Oil mist detector)

5.7.1 For multiple engine installations each engine shall be provided with a separate oil mist detector and an individual alarm.

5.7.2 Oil mist detectors shall be type approved and tested in accordance with IACS UR M67.

5.7.3 The oil mist detector shall be installed in accordance with the engine designer’s and the system manufacturer’s instructions and recommendations.

5.7.4 Function tests shall be performed on the engine test bed at manufacturer’s workshop and on board under the conditions of "engine at standstill" and "engine running at normal operating conditions" in accordance with test procedures approved by the Society.

5.7.5 The oil mist detector shall include a self-checking device giving an alarm if the performance is deteriorated.

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

5.7.7 Arrangements of the oil mist detector shall be submitted for approval. The following particulars shall be included in the documentation:
— schematic layout of engine oil mist detector showing location of engine crankcase sample points and piping arrangement together with pipe dimensions to detector/monitor
— 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
— maintenance and test manuals
— information of type approval of the detection/monitoring system and functional tests at the particular engine.

5.7.8 A copy of the documentation supplied with the system such as maintenance and test manuals shall be provided on board ship.

5.7.9 The readings and the alarm information from the oil mist detector shall be capable of being read from a safe location away from the engine.

5.7.10 Alternative methods
Where alternative methods are provided to prevent the build-up of a potentially explosive condition within the crankcase (independent of the reason, e.g. oil mist, gas, hot spots, etc.), details shall be submitted for the consideration of the Society. The following information shall be included in the details and submitted for approval:
— engine particulars - type, power, speed, stroke, bore and crankcase volume
— details of arrangements preventing the build-up of potentially explosive conditions within the crankcase, e.g. bearing temperature monitoring, oil splash temperature, crankcase pressure monitoring, recirculation arrangements, crankcase atmosphere monitoring
— evidence that the arrangements are effective in preventing the build-up of potentially explosive conditions together with test details or details of in service experience
— operating instructions and maintenance and test instructions

5.7.11 Active safety measures
Where it is proposed to use alternative active technologies to minimize the risk for a potential crankcase explosion, details of the arrangement and the function description shall be submitted for approval.

6 Arrangement

6.1 Engine Alignment/Seating

6.1.1 Engines shall be mounted and secured to their shipboard foundations in conformity with Ch.2 Sec.1 [6].

6.1.2 Epoxy resin shall be type approved by the Society.

6.2 Accessibility of engines

6.2.1 Engines shall be so arranged in the engine room that all the assembly holes and inspection ports provided by the engine manufacturer for inspections and maintenance are accessible. A change of components, as far as practicable on board, shall be possible.

Guidance note:
Requirements related to space and construction has to be considered for the installation of the engines.

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6.3 Earthing

6.3.1 For main engines it is necessary to ensure that the limits specified by the engine manufacturers for the difference in electrical potential (Voltage) between the crankshaft/shafting and the hull are not exceeded in service. Appropriate earthing devices including limit value monitoring of the permitted voltage potential shall be provided.

6.4 Starting with compressed air

6.4.1 Reference is given to Ch.6 Sec.5 [9.3].
6.5 Electrical starting equipment

6.5.1 Reference is given to Ch.8.

6.6 Exhaust pipes

6.6.1 Where exhaust pipes are led overboard near the water line, means shall be provided to avoid the possibility of water entering the engine.

6.6.2 Exhaust pipes from several engines shall not be connected, but have separate outlets, unless precautions are taken to prevent the return of exhaust gases to a stopped engine.

6.6.3 All hot surfaces shall be properly insulated. There shall be no surface temperature in excess of 220°C, see [4.2.4].

6.6.4 Exhaust Gas Back Pressure
The back pressure of the exhaust system shall not exceed the maximum allowable limit as specified by the engine designer. In case several exhaust pipes are joined into one common pipe, the maximum back pressure shall not be exceeded with all combined engines operating at rated power, unless it can be documented that such a situation is not likely to occur under normal operational conditions.

The exhaust system is defined to include any component and piping installed in between the outlet of the exit of the exhaust gas system.

6.7 Lubrication and fuel oil systems

6.7.1 The combination of the oil drainage lines from the crankcases of two or more engines is not allowed.

6.7.2 Drip trays under filters for fuel, lubrication and hydraulic oils shall be provided.

6.7.3 Pipe connections in piping containing flammable liquids shall be adequately screened. The screening shall ensure that leakage from pipe connections does not reach potentially hot surfaces. Any insulated surface, where the temperature may exceed 220°C in the event that insulation is detached or otherwise is degraded, shall be regarded a potentially hot surface, see [2.6].

6.8 Crankcase ventilation pipes
The vent pipes and oil drain pipes of two or more engines shall not be combined. Exemptions may be approved if an interaction of the combined systems is inhibited by suitable means.

Guidance note:
Oil vapour from the ventilation pipes should preferably be led to free air.

7 Vibration

7.1 Torsional and axial vibration

7.1.1 Ch.2 Sec.2 and Ch.2 Sec.3 applies.
Acceptance criteria to be decided based on crankshaft calculation in [2.5].
8 Installation Inspections

8.1 Engine Seating
Engines shall be mounted and secured to their shipboard foundations in conformity with Ch.2 Sec.1 [6].

8.1.1 Installation is subject to survey in accordance with Ch.2.

8.2 Engine alignment
The crankshaft alignment shall be checked every time an engine has been aligned on its foundation by measurement of the crank web deflection and/or other suitable means.
For the purpose of subsequent alignments, notes shall be taken of:
— the draught/load condition of the vessel
— the condition of the engine - cold/preheated/hot.

9 Shipboard Testing

9.1 Shipboard testing (dock and sea trials)

9.1.1 After the conclusion of the running-in programme prescribed by the engine manufacturer engines shall undergo the trials specified below.

9.1.2 Unless otherwise stated, a surveyor shall attend the tests and inspections given in [9].

9.1.3 The scope of the shipboard trials may be extended in consideration of special operating conditions such as towing, trawling, etc.

9.2 General engine tests

9.2.1 The functioning of the cylinder lubricators (when applicable) shall be randomly demonstrated.

9.2.2 The suitability of main and auxiliary engines to burn residual oils or other special fuels shall be demonstrated if the machinery installation is designed to burn such fuels.

9.2.3 Starting tests shall be made in order to document the required starting air energy capacity.

9.2.4 The control, alarm and safety functions shall be tested, see Table 9. Items tested and documented in the engine workshop test, need not be retested.

9.2.5 Insulation of hot surfaces as required in [2.6] shall be checked during maximum load as defined in [9.3.1] by measuring surface temperature.

Guidance note:
Although use of conventional contact thermometers may be accepted at the discretion of the attending surveyor, it is advised to use Infrared Thermoscaning Video Equipment or similar for documentation. Such equipment may be required where there has been made revisions to the insulation interface.

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9.3 Testing of propulsion engines

9.3.1 Main propulsion engines driving fixed pitch propellers
The tests shall be carried out as follows:

a) at rated engine speed
   for at least 4 hours
   and

b) at 103% rated engine speed:
   for 30 minutes where the engine adjustment permits, see [4.1.4]

c) determination of the minimum on-load speed

d) starting and reversing manoeuvres, see [6.4]

e) in reverse direction of propeller rotation at a minimum speed of 70% rated engine speed:
   10 minutes

f) testing of the monitoring and safety systems

g) correct start and stop of auxiliary blowers.

h) check of barred speed range, see Ch.2 Sec.2 [3].

9.3.2 Propulsion engines driving controllable pitch propellers or reversing gears
[9.3.1] applies.
Controllable pitch propellers shall be tested with various propeller pitches. Where provision is made for operating in a combinator mode, the combinator curves shall be plotted and verified by measurements.

9.3.3 Main engines driving generators for propulsion
The tests shall be performed at rated speed with a constant governor setting under conditions of:

a) 100% power (rated electrical propulsion power)
   for at least 4 hours
   and
   at normal continuous cruise propulsion power for at least 2 hours

b) 110% power (rated propulsion power)
   for 30 minutes

c) in reverse direction of propeller rotation at a minimum speed of 70% of the nominal propeller speed
   for 10 minutes

d) starting manoeuvres, for pneumatic system see Ch.6 Sec.5 [9.3], for electric starting equipment see Ch.8 Sec.2 [5].

e) testing of the monitoring and safety systems.

Guidance note:
Tests shall be based on the rated electrical powers of the electric propulsion motors.

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During these tests shall each individual main engine driving a generator be run for at least 1 hour at full load.
9.4 Testing of engines driving auxiliaries and electrical generators

9.4.1 Full load test
These engines shall be subjected to an operational test for at least 4 hours. During the test the set concerned is required to operate at its rated power for at least 1 hour.

9.4.2 110% load test
It shall be demonstrated that the engine is capable of supplying 110% of its rated power for 15 minutes, and in the case of shipboard generating sets account shall be taken of the times needed to actuate the generator's overload protection system.

9.5 Engine vibration

9.5.1 For resiliently mounted engines, the engine movements shall be observed during the misfiring tests of the engine at as high load as possible. The engine shall not reach contact with the stoppers, see Ch.2 Sec.1 [6]. None of the engine connections such as exhaust pipe compensators, cooling water bellows, lubrication oil pipes, etc. shall restrict the engine movements.

9.6 Opening up after testing

9.6.1 For engines supplied and installed in assembled condition, there are no requirements for opening up after testing unless there is any reason to suspect any abnormal wear of, or damage to, engine components.

9.6.2 Unless otherwise approved, inspection according to [4.5] applies for propulsion engines supplied in sections and assembled onboard.

10 Gas only and dual fuel engines

10.1 General

10.1.1 The rules in this section apply to gas only engines or dual fuel engines installed in ships. The rules are applicable for engines where natural gas in gaseous state is used as fuel. If other gases are used as fuel special considerations shall have to be made, and additional requirements may be relevant.

10.1.2 Definitions
Definitions addressing gas as fuel as given in Pt.6 Ch.2 Sec.5.

\[\text{Gas admission valve} = \text{valve or injector on the engine which controls the gas supply to the engine according to the engine's actual gas demand.}\]

\[\text{Safety concept} = \text{the safety concept is a document describing the safety philosophy with regard to gas as fuel. It describes how risks associated with this type of fuel are controlled under normal operating conditions as well as possible failure scenarios and their control measures.}\]

10.2 Design

10.2.1 General Functional Requirements
In case of a normal stop or an emergency shutdown, the gas fuel supply shall be shut off not later than the ignition source. It shall not be possible to shut off the ignition source without first or simultaneously closing
the gas supply to each cylinder or to the complete engine. Shut off of the gas fuel shall not be dependent on the shut off of the ignition source.

Guidance note:
Firing of the gas-air mixture is not explicitly limited to the use of pilot fuel. Other ignition methods may be accepted if suitable.

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10.2.2 System Configuration
Gas fuelled engines shall either be designed to be installed in a gas safe machinery space or an ESD protected machinery space as defined in Pt.6 Ch.2 Sec.5 [3.2.2].
For installations in gas safe machinery spaces, the connection of gas piping and ducting to the gas admission valves shall provide complete coverage of the double ducting and make replacement and/or overhaul of gas admission valves and cylinder covers possible. The double ducting is also required for gas pipes on the engine itself, and all the way until gas is supplied into the chamber.

Guidance note:
If gas is supplied into the air inlet on a low pressure engine, double ducting may be omitted on the air inlet pipe on the condition that a gas detector is fitted above the engine.

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10.2.3 Functional requirements, gas-only engines

10.2.3.1 The starting sequence shall be such that fuel gas is not admitted to the cylinders until ignition is activated and the engine has reached a minimum rotational speed.

10.2.3.2 If combustion has not been detected by the engine monitoring system within 10 s after opening of the gas injection valve the gas supply shall be automatically shut off and the starting sequence terminated.

Guidance note:
More than 10 seconds may be accepted between gas injection start and automatic starting sequence shut off, if the gas is not injected directly to each cylinder or to each cylinder air inlet, but is mixed with combustion air in a common system. However, Safety Concept and FMEA should show acceptable level of risk.

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10.2.3.3 When restarting after a failed start attempt admission of fuel gas to the cylinders shall not be possible before the exhaust gas system has been purged with an air volume of at least 3 times the volume of the exhaust gas system before the turbocharger(s).

Guidance note:
Purging may be carried out by for example running the engine on starting air for a predetermined number of revolutions.

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10.2.4 Functional requirements, dual fuel engines

10.2.4.1 Dual fuel engines shall start, activate normal stop and perform low power operation on oil fuel only. Gas injection shall not be possible without a corresponding pilot oil injection. In case of shut-off of the gas fuel supply, the engines shall be capable of continuous operation by oil fuel only.

Guidance note:
If it can be documented that a dual fuel engine can safely start, stop and operate on low load in gas mode, this may be approved.

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10.2.4.2 Changeover to and from gas fuel operation shall only be possible at a power level where it can be done with acceptable reliability as demonstrated through testing. On completion of preparations for changeover to gas operation including checks of all essential conditions for changeover, the changeover process itself shall be automatic. Manual interruption should be possible in all cases.
10.2.4.3 Firing of the gas-air mixture in the cylinders shall be initiated by injection of pilot fuel. The amount of pilot fuel fed to each cylinder shall be sufficient to ensure a positive ignition of the gas mixture.

10.2.4.4 In case of shut-off of the gas fuel supply or engine failure related to gas operation, engines shall be capable of continuous operation by oil fuel only.

10.2.4.5 Engine power and speed shall not be influenced during fuel change-over process. An automatic system shall provide for a change-over procedure with minimal fluctuations in engine power and speed.

10.2.4.6 The change-over process from gas mode to oil mode shall be possible under all operating conditions.

10.2.5 Gas fuelled engine crankcase and safety equipment

10.2.5.1 The crankcase of gas engines shall be provided with crankcase explosion relief valves as specified in [2.3.1] and [11.4]. Smaller engines than specified in [2.3.1] shall either document that the crankcase has sufficient strength to withstand the worst case explosion or install sufficient type approved explosion relief valves.

10.2.5.2 The minimum required total relief area of crankcase explosion relief valves shall be calculated by engine maker considering explosions of fuel gas – air mixtures and oil mist.

10.2.5.3 For engines where the space below the piston is in direct communication with the crankcase a detailed evaluation regarding the hazard potential of fuel gas accumulation in the crankcase shall be carried out and included in the safety concept, see [10.5.3]. Each engine other than two-stroke crosshead diesel engines shall be fitted with vent systems for crankcases and sumps independent of other engines.

10.2.6 Gas fuelled engine mixture inlet and exhaust system

10.2.6.1 When gas is supplied in a mixture with air through a common manifold, sufficient flame arrestors shall be installed before each cylinder head.

10.2.6.2 The mixture inlet and exhaust system shall be designed to withstand explosions of gas air mixture. This shall be documented by means of either:

1) documentation demonstrating that the mixture inlet system has sufficient strength to contain the worst case explosion; or

2) explosion relief venting to prevent excessive explosion pressures. It should be ensured that the explosion relief venting is installed in a way that it discharges the combustion products safely. The explosion venting shall be led away from where personnel may be present.

10.2.6.3 The requirements in [10.2.6.2] can be omitted if the gas concentration within the manifolds is controlled and monitored and if combustion of unburned charge within the manifolds can be excluded. A justification of how this can be achieved shall in this case be submitted.

10.2.6.4 Explosion relief valves for inlet- and exhaust manifolds shall be approved for the application in accordance with [11.4] by the Society.

10.2.6.5 The arrangement of explosion relief valves shall be approved for each engine type. The following documents shall be submitted:

— drawing of arrangement of explosion relief valves (incl. number, type, locations, etc.)
— drawings of protected component (air inlet manifold, exhaust manifold, etc.) (incl. specification of max. working pressure, max. working temperature, max. permissible explosion pressure, etc.)
— evidence of effectiveness of flame arrestor at actual arrangement
**Guidance note:**
Evidence can be provided by suitable tests or by theoretical analysis.

---end---of---guidance---note---

**10.2.7 Purging system on gas fuelled engines**

10.2.7.1 Means shall be provided to ensure that any un-burnt fuel mixture can be purged from the manifolds through the exhaust system.

10.2.7.2 Unless otherwise specified in the Safety Concept documentation and FMEA, purging shall be carried out:

— prior to each engine start
— after starting failure
— after each gas operation of gas-fuelled engine.

10.2.7.3 The purging system shall be automatically operated.

**10.2.8 Arrangement of cooling water, lubricating oil and fuel systems**

10.2.8.1 Means shall be provided to degas fuel gas from the systems if there is a possibility that fuel gas can leak directly into the systems.

10.2.8.2 Gas detectors shall be provided, see [10.5.2].

10.2.8.3 Flame arrestors shall be provided at the vent pipes and pipes shall be led to a safe location.

**10.2.9 Fuel gas system**

10.2.9.1 The design and arrangement of fuel piping including secondary enclosures on gas engines shall comply with the requirements in Pt.6 Ch.2 Sec.5.

10.2.9.2 Activation of the double block and bleed valves prior to the gas engine as required by Pt.6 Ch.2 Sec.5 [9.3.8] shall be possible by the engine control system and safety system

10.2.9.3 Gas piping on an engine shall be designed and installed taking into account vibrations and movements during engine operation.

**Guidance note:**
Flexible bellows, single and double walled, may be used on the engine provided that it has been demonstrated that the bellow should not fail due to mounting misalignment and vibration. Endurance against high cycle fatigue has to be documented at least by the Expansion Joint Manufacturers Association, Inc. (EJMA) calculation or equivalent. (i.e. more than $10^7$ cycles).

---end---of---guidance---note---

10.2.9.4 Gas admission valves shall be located directly at each cylinder inlet.

10.2.9.5 High pressure gas shall be blown directly into the cylinders without prior mixing with combustion air.

10.2.9.6 The gas admission/injection valve shall be controlled by the engine control system according to the actual gas demand of the engine.

10.2.9.7 Gas admission by a common gas admission valve and mixing of gas combustion air before the cylinder inlet, may be acceptable subject to an acceptable level of risk being determined in the safety concept and system FMEA.
**10.2.10 Ignition system**

10.2.10.1 The ignition system shall provide proper ignition of the gas at all operating conditions.

10.2.10.2 The ignition system shall be provided with an automatic self-check which is operated prior to gas supply to the engine. If failure in the ignition has been detected, an alarm shall be given and supply of gas to the engine shall not be possible.

10.2.10.3 Safe and reliable operation of the ignition system shall be demonstrated and documented by a system FMEA.

10.2.10.4 During normal stop of the engine, the fuel gas supply shall be shut off automatically before the ignition source.

10.2.10.5 If ignition has not been detected in any cylinder on a spark ignited engine within an engine specific time after operation of the gas admission valve, gas supply shall be automatically shut off and the starting sequence terminated. Any unburned gas mixture shall be purged from the exhaust system.

**10.2.11 Electrical systems on the engine**

10.2.11.1 For electrical equipment and sensors in hazardous areas the explosion protection requirements in Ch. 8 applies.

**10.2.12 Type approval test for gas-fuelled engines**

10.2.12.1 Gas-fuelled engines shall be type approved by the Society.

10.2.12.2 The scope of type approval testing stated in [2.14] applies as far as applicable to gas-fuelled engines. Additional or differing requirements reflecting gas specific aspects are listed below. The type test program shall be approved by the Society.

10.2.12.3 Internal tests (Stage A):
- engine operation with limiting gas properties as specified by the engine manufacturer (methane number, lower heat value)
- gas concentration in the crankcase at different engine operation conditions. Results shall be determined and specified in a suitable manner.

10.2.12.4 Type tests (Stage B):
- load acceptance test and load cut off
- fuel change-over procedures (for dual fuel engines)
- combustion monitoring
- safety system
- alarm system
- monitoring system
- control system
- gas detection
- tightness tests of gas piping and double wall pipes and ducts
- ignition system
- automatic gas shut off
- turbocharger waste gate, by-pass, etc.
- ventilation system
- start, stop, emergency stop
- verification tests resulting from the system FMEA
— testing of start blocking.

10.3 Testing and inspection
See [3]

10.4 Workshop testing
In addition to the requirements of [4], the following items shall be tested during works trials of gas-fuelled engines:
— tightness test of gas system
— testing of systems for combustion monitoring
— testing of gas shut off and fuel change-over (dual-fuel engines) procedures
— testing of start blocking
For dual fuel engines the requirements in [4] shall be tested in both diesel and in gas mode. Additionally the following items shall be tested:
— Fuel change over at lowest possible load
— Fuel change over at highest possible load

Guidance note:
Fuel change over is to be done from diesel to gas and from gas to diesel

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

10.5 Control and monitoring

10.5.1 General requirements

10.5.1.1 Requirements regarding gas supply and automatic activation of gas supply valves (double block and bleed valves, master gas valve) to the engine are specified in Pt.6 Ch.2 Sec.5.

10.5.1.2 Combustion conditions of each cylinder shall be automatically detected, monitored and controlled to prevent knocking and misfiring.

10.5.1.3 The engine operating mode shall always be clearly indicated to the operating personnel.

10.5.1.4 In addition to the requirements given in Table 9, Table 10, and Table 11, control and monitoring as given in Table 12 is as a minimum required for gas engines.

Table 12 Control and monitoring of gas-fuelled engines

<table>
<thead>
<tr>
<th>System</th>
<th>Item</th>
<th>Valid for engine type</th>
<th>Gr.1 Indication alarm load reduction</th>
<th>Gr.2 Automatic start of standby pump with alarm 1)</th>
<th>Gr.3 Shutdown with alarm</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Ignition System</td>
<td>Spark ignition system or pilot injection system failure</td>
<td>G</td>
<td>GT 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DF</td>
<td>GT 6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0 Combustion monitoring</td>
<td>Misfire each cylinder 3)</td>
<td>G</td>
<td>A, GT 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DF</td>
<td>A, GT 6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System</td>
<td>Item</td>
<td>Valid for engine type</td>
<td>Gr.1 Indication alarm load reduction</td>
<td>Gr.2 Automatic start of standby pump with alarm</td>
<td>Gr.3 Shutdown with alarm</td>
<td>Comments</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>-----------------------</td>
<td>-------------------------------------</td>
<td>------------------------------------------------</td>
<td>-------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Knocking</td>
<td>G</td>
<td>A, LR</td>
<td></td>
<td></td>
<td>SH may replace LR for electric power generating engine</td>
</tr>
<tr>
<td></td>
<td>DF</td>
<td></td>
<td>A, GT (6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0 Fuel injection valve cooling system (5)</td>
<td>Cylinder lubrication flow (4)</td>
<td>DF</td>
<td>LA</td>
<td></td>
<td></td>
<td>Automatic start of standby pump is not required if main pump is engine driven</td>
</tr>
<tr>
<td></td>
<td>Fuel injection valve cooling medium temperature</td>
<td>DF</td>
<td>HA</td>
<td>AS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fuel injection valve cooling medium pressure</td>
<td>DF</td>
<td>LA, GT (6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.0 Gas injection valve sealing oil system</td>
<td>Gas injection valve sealing oil pressure</td>
<td>G</td>
<td>LA</td>
<td></td>
<td></td>
<td>For high-pressure injection only</td>
</tr>
<tr>
<td></td>
<td>DF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0 Gas fuel knock-out drums, if fitted</td>
<td>Gas fuel knock-out drums liquid level</td>
<td>G</td>
<td>HA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.0 Gas supply</td>
<td>Gas pressure in gas supply</td>
<td>G</td>
<td>IL or IR, LA, HA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.0 Crank case</td>
<td>Piston failure and abnormal piston blow-by</td>
<td>G</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### System | Item | Valid for engine type | Gr.1 Indication alarm load reduction | Gr.2 Automatic start of standby pump with alarm | Gr.3 Shutdown with alarm | Comments
---|---|---|---|---|---|---
Gr 1 | Common sensor for indication, alarm, load reduction
Gr 2 | Sensor for automatic start of standby pump
Gr 3 | Sensor for shut down.
LA | Alarm for low value
HA | Alarm for high value
A | Alarm activated
AS | Automatic start of standby pump with alarm
SH | Shut down.
LR | Load Reduction
GT | Gas trip
IL | Indication Local
IR | Indication Remote
G | Gas only engine
DF | Dual fuel engine

1) Only for propulsion engines
2) Automatic gas trip of the specific cylinder or the complete engine can be accepted.
3) Exhaust temperature deviation may be accepted as means of detecting ignition failure, individually on each cylinder
4) If applicable, each lubricator unit to be monitored
5) Dual fuel engines only, for all injection valves that require cooling
6) Automatic change-over to fuel oil mode is required.

### 10.5.2 Gas detection

10.5.2.1 A continuous gas detection system shall be provided, see Pt. 6 Ch. 2 Sec. 5

10.5.2.2 The gas detection system shall be in operation as long as fuel gas is supplied to the engine.

### 10.5.3 Safety concept and system FMEA

10.5.3.1 The safety concept shall describe the safety philosophy with regard to gas as fuel and in particular address how risks associated with this type of fuel is controlled. The safety concept shall also describe possible failure scenarios and the associated control measures.

10.5.3.2 In the system FMEA possible failure modes related to gas as fuel shall be examined and evaluated in detail with respect to their consequences on the engine and the surrounding systems as well as their likelihood of occurrence and mitigating measures. Verification tests shall be defined. Aspects to be examined include, but shall not be limited to:

- gas leakage, both engine internal and release of gas to the engine room
- shut off of gas supply
- incomplete/ knocking combustion
- deviation from the specified gas composition
— malfunction of the ignition system
— uncontrolled gas admission to engine
— switch over process from gas to fuel and vice versa for dual fuel engines
— explosions in crankcase, scavenging air system and exhaust gas system
— uncontrolled gas air mixing process, if outside cylinder
— interfaces to other ship systems, e.g. control system, gas supply

10.6 Arrangement
See [6]

10.7 Vibration
See [7]

10.8 Installations inspections
See [8]

10.9 Shipboard testing

10.9.1 General engine tests
Gas fuelled engines shall be tested according to the below requirements, in addition to [9]
— test of gas detection systems
— leakage test of gas fuel system
— test of ventilation systems
— test of starting interlock devices
— test of gas trip
— test of monitoring and safety system during gas operation

10.9.2 Dual fuel engine tests
dual fuel engines shall be tested according to the below requirements, in addition to [9] and [10.9.1]
— 1 hour at 100% rated power (constant speed)
— 1 hour at 100% rated speed (propeller curve)
— 10 min at lowest load specified by the engine manufacturer
— fuel change-over (dual-fuel engines) procedures
— fuel change over at highest possible load
— fuel change over at lowest possible load
For dual fuel engines, starting in gas mode shall not be possible, also after a shutdown in gas mode operation, see [10.2.4]

Guidance note:
The 4 hour performance test at 100% rated power / speed ([9.3]), can be carried out to include 1 hour in gas operation

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

10.10 Retrofit
Acceptance criteria and procedure for conversion of existing oil-fuelled diesel engines into gas-fuelled or dual-fuel engines shall be individually agreed with the Society.
11 Auxiliary equipment and components

11.1 Turbochargers

11.1.1 Application and document requirements

11.1.1.1 Turbochargers are categorised in three categories depending on power served by each turbocharger:

Category A = \( \leq 1\,000\,\text{kW} \)
Category B = \( >1\,000\,\text{kW} \) and \( \leq 2\,500\,\text{kW} \)
Category C = \( >2\,500\,\text{kW} \)

11.1.1.2 Certification required
Turbochargers of category B and C shall be delivered with a product certificate according to Table 13, that is based on the applicable elements of design approval in [11.1.1] to [11.1.3].

Table 13 Certification required

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbocharger</td>
<td>NA</td>
<td>NA</td>
<td></td>
<td>Category A</td>
</tr>
<tr>
<td>PC</td>
<td>Manufacturer</td>
<td></td>
<td></td>
<td>Category B</td>
</tr>
<tr>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
<td>Category C</td>
</tr>
</tbody>
</table>

*Unless otherwise specified the certification standard is the Society’s Rules

11.1.1.3 Documentation required
Turbochargers of category A, B and C shall be documented as follows:

Table 14 Documentation of turbochargers

<table>
<thead>
<tr>
<th>Additional description</th>
<th>Documentation type</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross sectional drawing with principal dimensions(^A)(^B)(^C)</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>FI</td>
</tr>
<tr>
<td>Type Test program (^B)(^C)</td>
<td>Z252 – Test procedure at manufacturer</td>
<td>AP</td>
</tr>
<tr>
<td>Type Test report (^B)(^C)</td>
<td>Z262 - Report from test at manufacturer</td>
<td>AP</td>
</tr>
<tr>
<td>Containment test report (^A)</td>
<td>Z262 - Report from test at manufacturer</td>
<td>AP</td>
</tr>
<tr>
<td><strong>Additional description</strong></td>
<td><strong>Documentation type</strong></td>
<td><strong>Info</strong></td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Documentation of containment(^{B)}(^{C)})</td>
<td>Z262 - Report from test at manufacturer</td>
<td></td>
</tr>
</tbody>
</table>
| Operational data and limitations \(^{B)}\(^{C)}\):  
  - maximum allowable operating speed (r/min)  
  - alarm level for overspeed (r/min)  
  - maximum allowable exhaust gas temperature before turbine  
  - alarm level for exhaust gas temperature before turbine  
  - maximum allowable compressor pressure ratio  
  - minimum lubrication oil inlet pressure and alarm level  
  - minimum lubrication oil inlet pressure (design level)  
  - details (name and address) of the subcontractors for rotating parts and casings  
  - details (name and address) of the licensees, if applicable, who are authorised by the licensor to produce and deliver turbochargers of a certain type  
  - maximum lubrication oil outlet temperature and alarm level as applicable, see Table 9  
  - maximum allowable vibration level (both self- and externally generated) | Z100 – Specification | FI |
| Operational data and limitations \(^{C)}\):  
  - maximum allowable list and trim (degrees)  
  - maximum allowable pitching and rolling (degrees/s) | Z100 – Specification | FI |
| Drawings of the rotating parts \(^{C)}\) (shaft, turbine wheel, compressor wheel, blades) and details of blade fixing and housing | C030 – Detailed drawing | FI |
| Material specification \(^{C)}\), including mechanical and chemical properties of  
  - rotating parts (shaft, turbine wheel, compressor wheel, blades)  
  - casing and additionally, an evaluation of the material properties versus the temperature it shall be exposed for \(^{B)}\(^{C)}\) | M010 – Material specification, metals | AP |
| Welding details and welding procedures for rotating parts and casing \(^{B)}\(^{C)}\) | M060 – Welding procedures (WPS) | AP |
| Arrangement and flow diagram of lubrication system \(^{B)}\(^{C)}\) | S010 – Piping diagram (PD) | AP |
| Maintenance manual \(^{C)}\) | Z163 – Maintenance manual | FI |
| Operation manual \(^{C)}\) | Z161 – Operation manual | FI |
| Information on lifetime, considering creep, low cycle fatigue and high cycle fatigue \(^{C)}\) | Z100 – Specification | FI |
| Documentation of safe torque transmission when the disc is connected to the shaft with interference fit \(^{C)}\), see \([11.1.2.7]\) | Z100 – Specification | FI |

AP = For approval; FI = For information

A) Applicable to Turbocharger group A; Turbochargers serving cylinder groups ≤1 000 kW  
B) Applicable to Turbocharger group B; Turbochargers serving cylinder groups >1 000 kW and ≤ 2 500 kW  
C) Applicable to Turbocharger group C; Turbochargers serving cylinder groups > 2 500 kW

For general requirements to documentation, including definition of the Info codes, see Pt.1 Ch.3 Sec.2.  
For a full definition of the documentation types, see Pt.1 Ch.3 Sec.3.
11.1.1.4 Type Approval

Turbochargers of category B and C shall be type approved either separately or as a part of the engine, see also [1.3.3] and Table 14

Although there is no requirement for type approval or the Society Product Certificate, the requirement for containment safety in [11.1.2.2] is also valid for turbochargers of category A.

Guidance note:
Turbochargers of category A can be type approved based on the same document requirements as applicable for turbochargers of category B.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

11.1.2 Design

11.1.2.1 Operating conditions
The turbocharger shall be designed to operate under the conditions given in Ch.1.
The turbocharger component lifetime and the alarm level for turbocharger speed shall be based on 45°C air inlet temperature, if not otherwise agreed.

11.1.2.2 Containment safety
The turbocharger shall be self-contained (no part may penetrate the casing of the turbocharger or escaping through the air intake in case of rotor burst. This shall be verified by testing. For documentation purposes (test/calculation), it shall be assumed that the discs disintegrate in the worst possible way. Fulfilment of this requirement can be granted to a series of turbochargers on the basis of containment validation for one specific unit. However it shall be documented that the containment validation is representative for the complete series.
The turbocharger rotors need to be designed according to the criteria for natural burst speed. The burst speed of the turbine shall be lower than the burst speed of the compressor in order to avoid an excessive turbine overspeed after compressor burst due to loss of energy absorption in the compressor.
The minimum test speed (relative to the maximum permissable operating speed) for validation of containment shall be:
— ≥ 120% for compressor
— ≥ 140% or natural burst for turbine (whichever is lower).
If these speeds cannot be achieved due to interference between static and rotating parts, burst shall be validated at the highest achievable speed.
The containment test shall be performed at working temperature.

Guidance note:
Containment testing of a large unit is preferred, as this is considered conservative for all smaller units of the same series.
A numerical proof of sufficient containment integrity of the casing based on calculations by means of a simulation model may be accepted as an alternative to testing, provided that:
— The numerical simulation model has been tested and its applicability/accuracy has been proven by direct comparison between calculation results and practical containment test for a reference application (reference containment test). This proof has to be provided once by the manufacturer who wants to apply for acceptance of numerical simulation
— The corresponding numerical simulation for the containment is performed for the same speeds, as specified for the containment test (see above)
— The design of the turbocharger regarding the geometry and kinematics is similar to that of one turbocharger which has passed the containment test. Totally new designs shall call for new containment tests
— Application of the simulation model may give hints that rotor speeds lower than above specified minimum test speeds may be more critical for the casing's integrity, due to special design features and different kinematic behaviour. In such cases the integrity properties of containment for the casing shall be proven for the worst case scenario
— Material properties for high-speed deformations are to be applied in the numeric simulation. The correlation between normal properties and the properties at the pertinent deformation speed are to be substantiated

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---
11.1.2.3 Air inlet
The air inlet of the turbocharger shall be fitted with an air filter in order to minimize the entrance of dirt or water.

11.1.2.4 Fire protection
All exposed surfaces shall be kept below the maximum permissible temperature of 220°C. Surfaces that reach higher temperatures shall be insulated with material having non oil-absorbing surface, or equivalently protected so that flammable fluids hitting the surface cannot be ignited.
Pipe connections in lubrication oil lines for turbochargers with pressure above 1.8 bar shall be screened or otherwise suitably protected to avoid as far as practicable oil spray or oil leakage onto potentially hot surfaces, into machinery air intakes, or other sources of ignition. The number of joints in such piping shall be kept at a minimum.

11.1.2.5 Bearing lubrication
Bearing lubrication shall not be impaired by exhaust gases or by adjacent hot components. Leakage oil and oil vapours shall be evacuated in such a way that they do not come into contact with parts at temperatures equal or above their self-ignition temperature.
Gas flow from turbocharger to adjacent components containing explosive gases, e.g. crankshaft casing shall be prevented by an adequate ventilating system.

Guidance note:
For turbochargers which share a common lubrication system with the engine and which have got an electrical lubrication oil pump supply, it is recommended to install an emergency lubrication oil header tank.

11.1.2.6 Compressor characteristics
Turbochargers shall have a compressor characteristic that allows the engine, for which the turbocharger is intended, to be operated without surging in all normal operating conditions, also after a long time in operation. For abnormal, but within permissible operating conditions, such as misfiring and sudden load reduction, no continuous surging shall occur.

11.1.2.7 Materials
The materials in the rotating parts shall be able to withstand the stresses, strains and temperatures to which they shall be exposed.
This shall be analysed with regard to stresses, strains and temperatures in the rotating parts and lifetime calculations of these parts:
a) The calculations shall be based on low cycle fatigue, high cycle fatigue and creep-rupture analyses as applicable and they shall cover the limits of operation (see Guidance note). As an alternative, reliability documented by operational experience may be accepted.
b) For a generic range of turbochargers, a calculation summary report in accordance with a) shall be submitted for one larger turbocharger. The report shall include objectives, a brief description of method, limits of operation, assumptions and conclusion. The calculation methodology shall be representative for the complete series to be awarded. The type testing requirements apply to one selected size.

Guidance note:
The limits of operation are the operating conditions in which the (cyclic) stress range or strain range is maximum, i.e. which contribute to largest accumulated damage or shortest life, based on the criteria above and combined with temperature effect. Typical limits are alarm level speed, alarm level turbine inlet temperature, maximum permissible compressor inlet (or ambient) temperature for steady state operation and maximum permissible rates of acceleration and deceleration during start-up and shutdown operation. The limits of operation shall include any combination of the above which are realistic operating conditions, see also \[11.1.2\]. Load profile definition should be specified and documented.
11.1.2.8 Disc-shaft shrinkage fit
In cases where the disc is connected to the shaft with interference fit, documentation is required to substantiate the disc’s capability to transmit the required torque throughout the operation range, meaning: maximum speed, maximum torque, maximum gradient and minimum interference fit.

11.1.2.9 Type testing
The type test for a generic range of turbochargers, may be carried out at either on an engine, for which the turbocharger is intended, or in a test rig.
As part of the type test, the turbocharger shall be subjected to at least 500 load cycles at the limits of operation, see guidance note to [11.1.2.7]. This test may be waived if the turbocharger together with the engine is subjected to this kind of low cycle testing.
The rotor vibration characteristic shall be measured and recorded. The result shall be within the maker’s specification.
The extent of the surveyor’s presence shall be decided by the Society in consultation with the maker before the test.
The type test shall be completed by a hot running test at maximum temporary speed and maximum temporary temperature. The duration shall be at least one hour and the hot running test shall be witnessed by a surveyor.
After the test, the turbocharger shall be opened for examination.
The type test report, which includes the test objectives, procedures, acceptance criteria, results and conclusions, shall be submitted for approval.
The type test requirements might be reduced upon documentation of relevant operational experience.
Manufacturers who have facilities to test the turbocharger on a diesel engine for which the turbocharger shall be approved, may consider to substitute the hot running test by a one hour test run at overload (110% of the rated diesel engine power output)

11.1.3 Testing of materials and components
11.1.3.1 General
Turbochargers of category B and C shall be tested, inspected and documented with regard to:
— condition of supply and heat treatment of materials
— chemical composition and mechanical properties of materials
— non-destructive testing (NDT) of rotating parts
— dimensional inspection
— pressure tests
— overspeed test of compressor wheels
— dynamic balancing of rotor
— workshop test.
The manufacturer’s quality system shall ensure that the designer’s specifications are met, and that manufacturing is in accordance with type approved drawings. The manufacturer’s documentation of fulfilment of these requirements shall normally be verified by means of periodic Society product audits.
The materials shall conform to specifications approved in connection with the type approval in each case.
The requirements related to testing, inspection and certification of the turbocharger and its components are listed in Table 15.

11.1.3.2 Material testing
All materials shall be manufactured by sufficiently proven techniques, whereby it is ensured that the required properties are achieved. Where new technologies are applied, a preliminary proof of their suitability shall be submitted to the Society. According to the decision of the Society, this may be done in terms of special tests for procedures and/or by presentation of the work’s own test results as well as by expertise of independent testing bodies.
11.1.3.3 Condition of supply and heat treatment of materials
Materials shall be supplied in the prescribed heat treated condition. Where the final heat treatment shall be performed by the supplier, the actual condition in which the material is supplied shall be clearly stated in the relevant material certificate. The final verification of material properties for components needs to be adapted and coordinated according to production procedures. Deviations from the heat treatment procedures have to be approved by the Society separately.

11.1.3.4 Chemical composition and mechanical properties of materials
Materials and products shall satisfy the requirements relating to chemical composition and mechanical properties specified in the Pt.2 Ch.2 or, where applicable, in the approved relevant manufacturer’s specifications.

11.1.3.5 Non-destructive testing (NDT)
Non-destructive testing for crack detection shall be applied for rotating parts (turbine, compressor wheel and shafts) including welded joints. Another equal production control may be accepted for welded joints. The testing shall be performed by the manufacturer and the results together with details of the test method shall be evaluated according to recognized quality criteria and documented in the product certificate (PC).

11.1.3.6 Material certificates
Material certificates shall contain at least the following information:
— quantity, type of product, dimensions where applicable, types of material, supply condition and weight
— name of supplier together with order and job numbers, if applicable
— construction number, where known
— manufacturing process
— heat numbers and chemical composition
— supply condition with details of heat treatment
— identifying marks
— results of mechanical property tests carried out on material at ambient temperature.

Depending on the produced component of turbocharger material certificates shall be issued by the Society respectively the manufacturer. The required certificates are summarized in Table 15.

11.1.3.7 Dimensional control
Rotating parts, turbine, compressor wheels and shaft, of turbochargers are subjected for dimension control before assembly of the turbocharger.

11.1.3.8 Pressure tests
Cooling water spaces as well as the emergency lubrication oil system for gas inlet and gas outlet casings shall be subjected to a hydrostatic pressure test of \( pp = 4 \) bar, but not less than \( pp = 1,5 \times pc \) (\( pp = \) test pressure; \( pc = \) design pressure).

11.1.3.9 Overspeed test
Compressor wheels shall undergo an overspeed test with a duration of 3 minutes at 20% above the alarm level speed at room temperature, or 10% above the alarm level speed at 45°C when tested in the actual housing with the maximum permissible pressure ratio.

If each forged compressor wheel is individually controlled by an approved non-destructive method, the overspeed test may be waived. For wheels without a bore, the overspeed test may be omitted.

11.1.3.10 Dynamic balancing
Each shaft and bladed wheel, compressor and turbine, as well as the complete rotating assembly has to be dynamically balanced individually in accordance with the approved quality control procedure. For assessment of the balancing conditions the DIN ISO 1940 standard or comparable regulations may be referred to.
Table 15 Certification, Testing and inspection requirements for turbocharger and its components

<table>
<thead>
<tr>
<th>Object</th>
<th>Additional description</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete rotating assembly</td>
<td>Dynamic balancing, see [11.1.3]</td>
<td>PC</td>
<td>Manufacturer</td>
<td></td>
</tr>
<tr>
<td>Shaft</td>
<td>M+C</td>
<td>Category C</td>
<td>MC</td>
<td>Society</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Category B</td>
<td>MC</td>
<td>Manufacturer</td>
</tr>
<tr>
<td></td>
<td>NDT</td>
<td></td>
<td>Manufacturer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dimensional control, see [11.1.3]</td>
<td>PC</td>
<td>Manufacturer</td>
<td></td>
</tr>
<tr>
<td>Turbine wheel including blades</td>
<td>M+C</td>
<td>Category C</td>
<td>MC</td>
<td>Society</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Category B</td>
<td>MC</td>
<td>Manufacturer</td>
</tr>
<tr>
<td></td>
<td>NDT</td>
<td></td>
<td>Manufacturer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dimensional control, see [11.1.3]</td>
<td>PC</td>
<td>Manufacturer</td>
<td></td>
</tr>
<tr>
<td>Compressor wheel including blades</td>
<td>M+C</td>
<td>Category C</td>
<td>MC</td>
<td>Society</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Category B</td>
<td>MC</td>
<td>Manufacturer</td>
</tr>
<tr>
<td></td>
<td>NDT</td>
<td></td>
<td>Manufacturer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dimensional control, see [11.1.3]</td>
<td>PC</td>
<td>Manufacturer</td>
<td></td>
</tr>
<tr>
<td>Casing</td>
<td>M</td>
<td></td>
<td>MC</td>
<td>Manufacturer</td>
</tr>
<tr>
<td></td>
<td>Pressure testing, see [11.1.3]</td>
<td>PC</td>
<td>Manufacturer</td>
<td></td>
</tr>
</tbody>
</table>

*M = Mechanical properties of the material
M+C = Material properties include chemical composition, and mechanical properties, see [11.1.3]
NDT = Non-destructive examination, see [11.1.3]
MC = Material Certificate, see [11.1.3]
PC = Product Certificate

*Unless otherwise specified the certification standard is the rules.

For general certification requirements see Pt.1 Ch.3 Sec.4.

For a definition of the certification types see Pt.1 Ch.3 Sec.5.

11.1.4 Workshop test

Each turbocharger has to pass a test run in the presence of the surveyor.
The test run shall be carried out during 20 minutes with an overload (110% of the rated diesel engine power output) on the engine for which the turbocharger is intended for in workshop testing. In case of a replacement turbocharger for testing onboard, the test shall be carried our at the maximum available engine power.

This test run may be replaced by a separate test run of the turbocharger unit for 20 minutes at the alarm level speed and maximum permissible working temperature.
In case of sufficient verification of the turbocharger’s performance during the test, a subsequent dismantling is required only in case of abnormalities such as high vibrations or excessive noise or other deviations of operational parameters such as temperatures, speed, pressure.

11.1.5 Manufacturers of turbochargers

11.1.5.1 Recognition of manufacturer of turbochargers
Manufacturer of turbochargers shall be recognized by the Society.

The scope of inspection, testing and certification of components and the complete turbocharger may be agreed upon in a Manufacturer Survey Agreement (MSA), based on successful Manufacturer Production Quality Assessment (MPQA). Details to be found in DNVGL-CG-0337.

Upon agreement will the manufacturer receive a Recognition Certificate as manufacturer of turbochargers.

11.1.5.2 Recognition of manufacturer of turbochargers under license agreement
Manufacturer of turbochargers under license agreement shall be recognized by the Society, see [11.1.5.1] - Approval of manufacturers.

The licensee must have valid type approval certificates of the turbochargers to be produced.

The recognition becomes invalid if the license agreement expires or is withdrawn.

11.1.5.3 Turbochargers for Category A1 engines
Recognized manufacturer of turbochargers for Category A1 engines, ref DNVGL-CG-0483, may document material properties according to ISO 10474/EN 10204 - 3.1.

11.1.5.4 Turbochargers for other engines than Category A1 engines
Scope of inspection, testing and certification of turbochargers for other engines than Category A1, can be agreed upon individually in the MSA.

11.2 Torsional vibration dampers

11.2.1 For torsional vibration dampers the following requirements apply:
— subcontracted dampers of standard design (including design concept) shall be type approved
— dampers of tailor made (unique) design may be case by case approved.
— dampers produced by the engine manufacturer shall be type approved either as a separate product or as a part of the engine.

11.2.2 Certification required
Torsional vibration damper shall be delivered with a product certificate according to Table 16.
**Table 16 Certification required**

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard*</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torsional vibration damper</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td>Applicable to case-by-case approved, spring tuned dampers</td>
</tr>
</tbody>
</table>

*PC  =  Product Certificate
*Unless otherwise specified the certification standard is the Society’s Rules

For general certification requirements see **Pt.1 Ch.3 Sec.4.**

For a definition of the certification types see **Pt.1 Ch.3 Sec.5.**

**11.2.3** The drawings of torsional vibration dampers shall specify all details which deal with the functions and limitations of the damper.

For spring tuned dampers the spring materials and properties shall be specified.

For rubber and silicone type dampers, and for some steel spring dampers the dynamic properties shall be documented by means of relevant type testing (e.g. in stationary or rotating pulsators where torque and twist are plotted).

**11.2.4** Torsional vibration dampers shall be specified with regard to damping, stiffness, permissible vibration level and heat load properties as functions of their main influence parameters. The tolerances of the damping and stiffness and the limitations of the influence parameters shall also be specified.

**11.2.5** The manufacturer shall specify inspection and service intervals as well as the permissible limits for wear (spring tuned dampers), rubber and silicone condition, oil viscosity (viscous dampers), oil pressure (if oil supplied), etc.

**11.2.6** Spring tuned dampers shall be designed to avoid fretting in vital elements. For such dampers the springs shall be designed with a safety factor against high cycle fatigue of minimum 1.8, but higher values apply for spring areas under tension stresses and hard contact with other parts. For designs where fretting in vital elements cannot be excluded, these elements shall be subjected to fatigue type testing. Stress levels and number of stress cycles shall be especially considered, leading to specific intervals for either inspection or torsional vibration measurements. If the latter is selected, acceptance criteria shall be approved.

**11.2.7** Spring tuned torsional vibration dampers shall be tested, inspected and documented as stated in the approved specification.

**11.3 Axial vibration dampers**

**11.3.1** Axial vibration dampers shall be documented by means of a sectional drawing and a system description of the adjustment.

**11.4 Explosion relief valves**

**11.4.1 General requirements**

**11.4.1.1** Relief valves shall be type approved by the Society.

**11.4.1.2** Relief valves shall close after an explosion event.
11.4.1.3 The relief valves shall be provided with a flame arrester that permits pressure relief and prevents passage of flame following an explosion.

11.4.1.4 The outlet of explosion relief devices shall discharge to a safe location from any source of ignition. The arrangement shall minimize the risk of injury to personnel.

11.4.2 Crankcase explosion relief valves

11.4.2.1 Crankcase explosion relief valves shall be type tested and documented in accordance with IACS UR M66.

11.4.2.2 The free area of each crankcase safety relief valve shall not be less than 45 cm$^2$.

11.4.2.3 Crankcase safety relief valves shall be designed and built to open quickly and be fully open at an overpressure of not more than 0.2 bar.

11.4.2.4 Crankcase safety relief valves shall be provided with lightweight spring-loaded valve discs or other quick-acting and self-closing devices to relieve a crankcase of pressure in the event of an internal explosion and to prevent inrush of air thereafter.

11.4.2.5 The valve discs in crankcase safety relief valves shall be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

11.4.2.6 Safety devices shall be provided with suitable markings that include the following information:
- name and address of manufacturer
- type designation and size
- relief area
- month/year of manufacture
- approved installation orientation.

11.4.3 Other explosion relief valves

11.4.3.1 Explosion relief valves for inlet- and exhaust manifolds shall be approved by the Society for the application.

11.4.3.2 For the approval of relief valves the following documentation shall be submitted:
- drawings of explosion relief valve (sectional drawings, details, assembly, etc.)
- specification data sheet of explosion relief valve (incl. specification of operating conditions such as max working pressure, max. working temperature, opening pressure, effective relief area, etc.)
- evidence for effectiveness of flame arrester at actual arrangement
- evidence for effectiveness of pressure relief at explosion (sufficient relief velocity, sufficient relief pressure)
- test reports.

**Guidance note:**
Evidence can be provided by suitable tests or by theoretical analysis.

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SECTION 2 GAS TURBINES

1 General

1.1 Application

1.1.1 The requirements in this section apply to gas turbine arrangements used for the functions listed in Ch.2 Sec.1 [1.1].

For Naval Surface Craft Pt.5 Ch.13 applies in addition to these rules.

Gas turbines shall be designed, constructed, tested, certified and installed on board in accordance with the requirements given in this section. The requirements address manufacturers, builders and operators.

1.1.2 Gas turbines installed on ships and are not serving the functions described in [1.1.1] are not subjected to the rules of this section. They have nevertheless to fulfil all requirements related to passive safety (fire protection, containment, safety devices for rendering to a safe state after malfunction or failure of components).

1.1.3 Acceptance and certification is based on test bed results for a prototype and manufacturer’s documentation and successful performance test after installation in presence of the Society. Further documentation may be requested for appraisal purposes upon agreement between the Society, manufacturer and shipyard.

1.1.4 Gas turbines, as described in [1.1.1] including their foundation, enclosure, piping, fuel, lubrication, cooling as well as safety, control, monitoring and alarm systems are subjected to classification.

The installation, connection and foundation of the complete manifold on the ship’s side are project specific. Foundation shall be documented as required in Ch.2.

A gas turbine installation carrying a valid type approval certificate shall be supplemented by relevant drawings for the specific installation.


1.2 Definitions

1.2.1

Table 1 Definitions

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>essential main propulsion</td>
<td>the gas turbine serves as exclusive driver for the driven propulsion units and is essential for the safety and manoeuvrability of the ship. The gas turbine is equally classified, when serving power production for the purposes of dynamic positioning.</td>
</tr>
<tr>
<td>non-essential main propulsion</td>
<td>other propulsion drivers, e.g. internal combustion engines or other driving units, provide the safety and manoeuvrability of the ship and the gas turbine in question is only temporarily used as booster to achieve maximum ahead speed.</td>
</tr>
<tr>
<td>driving of auxiliaries</td>
<td>the gas turbine is not directly involved in the propulsion of the ship, but drives essential auxiliaries such as generators or other auxiliary units of the machinery systems.</td>
</tr>
</tbody>
</table>
### Term | Definition
--- | ---
**maximum permissible power** (type related) | the maximum permissible power is the maximum power of the applied type of gas turbine in the actual upgrade version, independent of project dedicated application. This is the base for design calculations and type approval procedure.

**maximum continuous rating** (project related) | maximum continuous rating means 100% gas turbine power (mcr condition) for the specific application. The gas turbine shall be limited to the specified maximum continuous rating after performance test in the manufacturer’s facilities (fat) and/or onboard after installation.

**gas turbine** | an internal combustion engine, consisting of upstream rotating compressors coupled to downstream turbines, and a combustion chamber in-between. The power turbine in multiple shaft configurations is also included.

**gas turbine arrangement** | a gas turbine together with its enclosure and fixation arrangements, including systems external to the gas turbine, such as fire detection and extinguishing system, ventilation system, carbon blasting system, anti-icing system, compressor washing system.

**time between overhaul (TBO)** | the period which the gas turbine is expected to run prior to removal for overhaul, assuming normal recommended shipboard maintenance procedures have been followed, air quality specification has been met, limiting pressures, temperatures and power ratings have not been exceeded and lubricating (when applicable) and fuel oils specified in the type approval certificate have been used. All essential parts that are normally not carried on board for regular on board maintenance shall have a lifetime exceeding the TBO.

**OEM** | Original Equipment Manufacturer.

**FAT** | Factory Acceptance Test, testing of the gas turbine under load conditions at the manufacturer’s facilities.

### 1.3 Certification

**1.3.1** Gas turbines as described in [1.1] and which are of a proven design with a documented service experience shall be certified as per Table 2.

**Table 2 Certification requirements**

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard*</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas turbine</td>
<td>PC</td>
<td>Society</td>
<td>See [6.8]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TA</td>
<td>Society</td>
<td>See [6.4]</td>
<td></td>
</tr>
</tbody>
</table>

*Unless otherwise specified the certification standard is the Society’s rules.

For general certification requirements, see Pt.1 Ch.3 Sec.4.

For a definition of the certification types, see Pt.1 Ch.3 Sec.5.

**1.3.2** Novel, or new designs may receive a preliminary (time limited) design approval so as to allow initial operation. They may further receive a “Provisional Acceptance of Gas Turbine” so as to allow initial operation. This acceptance is regarded as equivalent with the product certificate with respect to gas turbine safety. The availability is however not yet proven. Hence the Society only accepts a “Provisional Acceptance of Gas Turbine” for multi-gas turbine installations, or for installations where the related function of the gas turbine is covered up by other means in case of failure.

Gas turbines that can document more than 2 500 hours trouble-free operation on similar applications shall receive a product certificate directly after the certification test, see [6.8]. In the case that a new
turbine, without testing or with limited scope of testing as mentioned above, has been installed on a ship in compliance to these rules, this shall be noted in the Appendix to the classification certificate or given as a memorandum to owners (MO).

1.3.3 It is required that the manufacturer documents 2 500 hours of in-service experience of one unit, without major faults or replacement of components before the type approval certificate shall be issued. For gas turbines with non-essential main propulsion or for propulsion / power generation of yachts or other non-commercial vessels the in service experience required for issuing a type approval certificate may be reduced accordingly, but shall not be less than 500 h of service. The in-service experience shall be relevant for the application that type approval is applied for, with respect to working profile and rating. The product certificate for each individual gas turbine is issued on the base of an existing type approval certificate or on a "case by case" base after testing of the gas turbine under relevant load conditions in the manufacturer’s facilities for a limited time, as set out under [6.7] - FAT.

1.3.4 In the described process of certification a "Manufacturing Survey Arrangement" (MSA) may be integrated on separate application.

1.3.5 Where the rule requirements defined herein are not explicitly complied with, or documented, the Society shall, upon request, evaluate alternative and or equivalent solutions in accordance with Pt.1 Ch.1 Sec.1 [2.5].

Guidance note:
This implies e.g. that during the design assessment credit may be given for extensive relevant operational experience, approval by other recognised bodies such as CAA, FAA, etc.

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1.4 Documentation requirements - Manufacturer

1.4.1 The manufacturer shall provide the documentation required by Table 3 (gas turbine, multiple shafts) or Table 4 (gas turbine single shaft). The documentation shall be reviewed by the Society as a part of the certification contract.

Table 3 Documentation requirements for gas turbines, multiple shafts – manufacturer

<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas turbine</td>
<td>C020 – Assembly or arrangement drawing</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z100 – Specification</td>
<td>Including key parameters as given in table 5 and application constraints as given in table 6</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z100 – Specification</td>
<td>Performance, see [2.3.7]</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z161 – Operation manual</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z163 – Maintenance manual</td>
<td>See [2.3.9]</td>
<td>FI</td>
</tr>
<tr>
<td>Gas generator casing</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>Including bearing housings, guide vanes and nozzles</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>C030 – Detailed drawing</td>
<td>For journal bearings, see [2.2.9]</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>C040 – Design analysis</td>
<td>See [2.2.4]</td>
<td>AP</td>
</tr>
<tr>
<td>Object</td>
<td>Documentation type</td>
<td>Additional description</td>
<td>Info</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------</td>
<td>------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Compressor wheels</td>
<td>C030 – Detailed drawing</td>
<td>See [2.2.1]</td>
<td>AP</td>
</tr>
<tr>
<td>Gas generator turbine</td>
<td>C030 – Detailed drawing</td>
<td>See [2.2.1]</td>
<td>AP</td>
</tr>
<tr>
<td>Gas generator shaft arrangement</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>Including bearings and shaft</td>
<td>FI</td>
</tr>
<tr>
<td>Turbine seals</td>
<td>C030 – Detailed drawing</td>
<td>See [2.2.2]</td>
<td>FI</td>
</tr>
<tr>
<td>Compressor guide vanes</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>See [2.2.8]</td>
<td>FI</td>
</tr>
<tr>
<td>Gas generator shaft bearings</td>
<td>S040 – Control diagram</td>
<td>See [2.2.9]</td>
<td>FI</td>
</tr>
<tr>
<td>Gas generator radial bearings</td>
<td>C030 – Detailed drawing</td>
<td>See [2.2.9]</td>
<td>FI</td>
</tr>
<tr>
<td>Gas generator thrust bearings</td>
<td>C030 – Detailed drawing</td>
<td>See [2.2.9]</td>
<td>FI</td>
</tr>
<tr>
<td>Combustor Starting system</td>
<td>C030 – Detailed drawing</td>
<td>Burner, flame tube and nozzles, see [2.2.5]. See [2.3.1]</td>
<td>AP</td>
</tr>
<tr>
<td>Lubrication system oil</td>
<td>Z100 – Specification</td>
<td>See [2.3.2]</td>
<td>AP</td>
</tr>
<tr>
<td>Control and monitoring system</td>
<td>I200 – Control and monitoring system documentation</td>
<td>See [3.1] and [3.2]</td>
<td>AP</td>
</tr>
<tr>
<td>Fuel system</td>
<td>S011 – Piping and instrumentation diagram (P&amp;ID)</td>
<td>See [2.3.3]</td>
<td>FI</td>
</tr>
</tbody>
</table>

AP = For approval; FI = For information

**Table 4 Documentation requirements for gas turbine, single shaft – Manufacturer**

<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas turbine</td>
<td>C020 – Assembly or arrangement drawing</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z100 – Specification</td>
<td>Including key parameters as given in table 5 and application constraints as given in table 6.</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z100 – Specification</td>
<td>Performance, see [2.3.7]</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z252 – Test procedure at manufacturer</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td>Object</td>
<td>Documentation type</td>
<td>Additional description</td>
<td>Info</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------</td>
<td>----------------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Z161 – Operation manual</td>
<td></td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td>Z163 – Maintenance manual</td>
<td>See [2.3.9]</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td>C020 – Assembly or arrangement drawing</td>
<td>Including bearing housings, guide vanes and nozzles For journal bearings, see [2.2.9]</td>
<td>FI</td>
<td></td>
</tr>
<tr>
<td>C030 – Detailed drawing</td>
<td></td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>C040 – Design analysis</td>
<td>See [2.2.4]</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>S040 – Control diagram</td>
<td>Compressor guide vanes</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td>C030 – Detailed drawing</td>
<td>See [2.2.1]</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>C030 – Detailed drawing</td>
<td>Turbine wheel, see [2.2.1]</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>C020 – Assembly or arrangement drawing</td>
<td>Including bearings and shaft</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td>C030 – Detailed drawing</td>
<td>Shaft, see [2.2.2]</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>C020 – Assembly or arrangement drawing</td>
<td>Seals preventing leakage of gases and lubrication oil internally and externally, and preventing mixing of gases and lubrication oil.</td>
<td>FI</td>
<td></td>
</tr>
<tr>
<td>C020 – Assembly or arrangement drawing</td>
<td>See [2.2.8]</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td>S040 – Control diagram</td>
<td></td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td>C030 – Detailed drawing</td>
<td>See [2.2.9]</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td>C030 – Detailed drawing</td>
<td>See [2.2.9]</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td>C030 – Detailed drawing</td>
<td>Burner, flame tube and nozzles, see [2.2.5].</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>C020 – Assembly or arrangement drawing</td>
<td>See [2.3.1]</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>Z100 – Specification</td>
<td></td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>S011 – Piping and instrumentation diagram (P&amp;ID)</td>
<td>See [2.3.2].</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>S011 – Piping and instrumentation diagram (P&amp;ID)</td>
<td>See [2.3.3]</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td>I200 – Control and monitoring system documentation</td>
<td>Including safety system See [3.1], [3.2] and [3.3]</td>
<td></td>
<td>AP</td>
</tr>
</tbody>
</table>

AP = For approval; FI = For information
1.4.2

Table 5 Key parameters

<table>
<thead>
<tr>
<th>Mass (kg)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Time between overhaul (hrs / cycles or equivalent hours)</td>
<td></td>
</tr>
</tbody>
</table>

RATING

<table>
<thead>
<tr>
<th>IDLE</th>
<th>MCR ISO(^1)</th>
<th>MCR(^2)</th>
<th>PEAK(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Maximum continuous ratings (kW)

Maximum air mass flow rate (kg/s)

Temperature at all main sections of the gas turbine, see Figure 2 (°C)

Pressure at all main sections of the gas turbine, see Figure 2 (bar)

Gas generator speed(s) (rpm)

Power turbine speed (rpm)

<table>
<thead>
<tr>
<th>NORMAL</th>
<th>PEAK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Maximum permissible rate of load increase and load decrease (kW/s)

Maximum permissible rate of acceleration and deceleration (gas generator and power turbine) (r/min/s)

MCR at standard ISO 2314 ambient conditions, see [6.4.7]

Maximum parameter value for continuous running independent of ambient conditions

If applicable, maximum parameter value for time limited peak or emergency operation for naval surface craft (independent of ambient conditions)

Table 6 Application constraints

<table>
<thead>
<tr>
<th>Subject</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max allowable list and trim</td>
<td>(degrees)</td>
</tr>
<tr>
<td>Max allowable pitch and roll</td>
<td>(degrees/s)</td>
</tr>
<tr>
<td>Max allowable shear force on output shaft</td>
<td>(N)</td>
</tr>
<tr>
<td>Max allowable axial force on output shaft</td>
<td>(N)</td>
</tr>
<tr>
<td>Max allowable bending moment at output shaft</td>
<td>(Nm)</td>
</tr>
<tr>
<td>Max allowable acceleration loads, see [2.1.2]</td>
<td>(g)</td>
</tr>
<tr>
<td>Fuel type designation</td>
<td></td>
</tr>
<tr>
<td>Max allowable salt content in inlet air</td>
<td>(wppm)</td>
</tr>
</tbody>
</table>

1.5 Documentation requirements – Builder

1.5.1 The builder shall provide the documentation required by Table 7. Further documents may be required by the Society, depending on special ship’s related arrangement features.
<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas turbine arrangement</td>
<td>C040 – Design analysis</td>
<td>Turbine and driven equipment: Lateral, torsional and turbine vibrations, see [5].</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z030 – Arrangement plan</td>
<td>Engine room with enclosure, ventilation system, gas turbine hook-ups and adjacent components.</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z253 – Test procedure for quay and sea trial</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z266 – Measurement report</td>
<td>Turbine and system (including ancillaries and piping) vibration levels, see [5], [6].</td>
<td>AP</td>
</tr>
<tr>
<td>Enclosure</td>
<td>C020 – Assembly or arrangement drawing</td>
<td>Including doors, pumps, valves, starting system and electric panels. Including material specification of enclosure, see [2.4].</td>
<td>AP</td>
</tr>
<tr>
<td>Fire detection and extinguishing system</td>
<td>G130 – Cause and effect diagram</td>
<td>Including specification of measures to prevent personnel being exposed to fire extinguishing medium constituting a health hazard.</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>G200 – Fixed fire extinguishing system documentation</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z030 – Arrangement plan</td>
<td>Including:</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— measures to prevent personnel being exposed to fire extinguishing medium constituting a health hazard</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>— fuel spray shields, applicable for turbines not fitted within an enclosure</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>— pipes, hoses, filters, valves and pumps in relation to potential ignition sources</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>— fire insulation type, method and arrangement</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>— fuel trays and handling of fuel and lubrication oil leaks</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>— fire detectors location and types</td>
<td></td>
</tr>
<tr>
<td>Ventilation system</td>
<td>Z030 – Arrangement plan</td>
<td>Including ducting, fans, blowers and fire dampers. Including material specification of fire dampers. Upon request, air distribution.</td>
<td>AP</td>
</tr>
<tr>
<td>Carbo blasting system</td>
<td>Z100 – Specification</td>
<td>[2.3.5]</td>
<td>AP</td>
</tr>
<tr>
<td>Anti-icing system</td>
<td>C020 – Assembly or arrangement drawing</td>
<td></td>
<td>AP</td>
</tr>
</tbody>
</table>
2 Design and Construction

2.1 General

2.1.1 For general design principles for machinery, see Ch.1 and Ch.2. The gas turbine design shall be suitable for reliable operation in marine applications.

2.1.2 The design and construction shall enable the gas turbine to meet the general requirements in Ch.1, with regard to environmental conditions, functional capability and to reliability and availability. The gas turbine shall be capable of withstanding environmentally induced acceleration loads during operations. The manufacturer shall provide a two-dimensional design envelope, see Figure 1, made up of what may be sustained during normal operation and what may be experienced occasionally (e.g., storm conditions). The gas turbine shall not suffer unreasonable distortion (or stress) if these loads are applied repeatedly. See also [5].

Guidance note:
Example of design envelope diagram:
2.1.3 For new developed turbines, or turbines originally designed for other purposes than marine applications, design analysis calculations shall be submitted to support drawing approval process in respect of strength / fatigue analysis. Such design calculations are expected to be based on the maximum permissible loads, as well as load variations, e.g. frequent idle (or start) - full load – idle (or stop) sequences and permissible rates of gas turbine load increase and decrease.

2.1.4 In the case of major modifications or upgrading of already introduced and certified gas turbines calculations shall be submitted, but shall not release the requirement for new or extended design approval as far as the gas turbine:

— has been thoroughly tested during the development phase or
— the test program has been extended to cover uncertainties in the design analysis or
— the modifications are supported by analyses, and more than 2500 hours of relevant operation without major faults can be documented.

However, the allowable modifications in such cases are limited as follows:

— 20°C increase of maximum turbine inlet temperature
— 5% increase of mass flow
— 5% increase of r/min
— minor changes to structural integrity components
— minor changes to operational profile.

The precise design assessment scope needed shall be agreed with the Society on a case by case basis.

2.1.5 Gas turbines, subjected to certification, shall have a TBO in excess of 2500 running hours. This should be substantiated through design and operating experience.

Guidance note:
A TBO’s exceeding this value may be requested in the cases that the turbines are part of a planned machinery maintenance system for the vessel and follows this fixed time schedule for overhaul / maintenance purposes.

2.1.6 Gas turbines shall be designed to permit fast start-up from cold conditions. Further possibilities shall be provided enabling manual re-start despite control system constraints after acknowledgement of the cause of tripping or start failure.
2.2 Component design requirements – manufacturer

2.2.1 Rotor Assembly incl. turbine and compressor bladed discs (calculations)
Design calculations shall be submitted to support drawing approval process. Such calculations shall be based on FEM methods and include low (static) as well as high (dynamic) cycle fatigue criteria unless other equivalent calculation methods following the manufacturer’s practice have been agreed to. The calculations shall support the evaluation of forces and thermal load distribution, in a way as to be capable of being verified by inspection during type approval test process.
In cases where the disc is connected to the shaft with interference fit, documentation is required to substantiate the disc's capability to transmit the required torque. This documentation shall include the effect of centrifugal forces, thermal loads, thermal expansion at the interfaces and interference tolerances.
The disc burst speed shall be documented, and shall be higher than that achievable while the unit is governed by the control system.
Upon request, proof shall be provided for the correlation of the first three harmonics of the rotational speed as well as nozzle passing frequency to the main vibration modes over the whole operating speed range (Campbell diagram or similar).

2.2.2 Rotor Assembly incl. turbine and compressor bladed discs (balancing)
Each shaft as well as the complete rotating assembly of compressor and turbine shall be individually dynamically balanced in accordance with the approved quality control procedure.
The balancing specification and the results of the balancing procedure shall be documented in accordance with [6.7]. The requirements as set out in DIN ISO 1940 apply, specifically class G2.5 or equivalent standards.

2.2.3 Blades
A blade strength calculation for the maximum permissible output/speed shall be submitted by means of finite element analysis (FEM) or other sound engineering methods for review on request. Centrifugal, gas and thermal forces shall also be considered.
The calculations shall contain the design equivalent full load operation hours or if applicable the assumed load profile. Cleaning equipment shall be provided during gas turbine operation for removal of blade deposits from compressor and turbine.

2.2.4 Casing
The casing shall fulfil the containment requirements, e.g. typically 1/3 bladed disk loss for impellers and one blade loss for axial units which shall not result in casing penetration / disintegration. This theoretical or experimental proof shall consider initial speeds as recognized as most critical by the maker dedicated to the special design.
The casing shall have sufficient inspection openings to enable Borescope inspection of the combustor as well as for the compressor’s and turbine’s individual stages.

2.2.5 Combustion Unit and Burners
The combustor shall have a dual ignition system. Igniters shall not remain in the primary combustion zone during operation. Optical and / or thermal flame sensors shall enable monitoring of the flame during operation.
Provisions shall be made for inspection of the combustor system such that all important sections can easily be inspected, particularly the burner area and combustor outlet (gas collector, NGV's).
The expected life time of the combustor, usually as a result of stress calculations under pressure, external and thermal loads, shall be documented and related to the recommended maintenance schedule of the gas turbine.
For the burners the maximum fuel delivery temperatures and pressures, together with the compressor air delivery temperature, the maximum mass flow rate of the fuel and the expected airflow (fuel air ratio) shall be specified.
Fuel nozzles shall be easily accessible and removable without disassembly of the combustor system. Burner lifetime shall be specified together with the nominal / recommended exchange intervals.

2.2.6 Adjustable vanes
When the compressor air flow is controlled by means of variable guide vanes (VGV), inlet guide vanes (IGV) and/or variable stator vanes (VSV) the corresponding mass flow charts over the guide vane angle / travel shall be documented in the form of a chart or table.

The actuator shall be designed in a way to be capable to operate the adjusting mechanism of the vanes under all conditions. Corresponding charts / tables shall be available.

2.2.7 Internal air cooling system
The design shall be such as to enable an adequate air flow capacity to keep the temperature in the power turbine safely within the design limits under full load conditions. The following parameters shall be specified: maximum and minimum flow rate, temperature, pressure of cooling air. Depending on design, monitoring of the cooling air supply shall be monitored according to Table 8.

2.2.8 Bleed Valves
The arrangement of bleed valves shall be documented in a drawing, indicating their position and size. The associated (maximal) power loss of the turbine shall be specified for the maximal flow rates of the bleed valves.

For variable bleed valves the characteristic of compressor mass flow as function of bleed valve opening shall be documented. Any single failure in the actuating control system shall not have detrimental effect on the compressor.

In case that bleed air is used for anti-icing purposes, this system and its associated technical parameters such as flow rate, supply pressure, maximum air temperature and simplified heat balance, shall be submitted for information purposes.

2.2.9 Bearings
Bearings shall be designed in accordance to the manufacturer's standards for loads resulting from the turbine's full output operation for an adequate life time. For propulsion the bearing design shall be such as to withstand unbalance forces due blade-loss loss in the time interval where these forces shall act, i.e. until shutdown or load down step to idle. If relevant, the recommended maintenance / exchange intervals shall be given in the maintenance manual. Bearings shall be equipped with adequate, replaceable sealing devices and shall be capable to operate reliably also under normal or exceptional transient conditions, such start-stop, shut-down due to trip, blackout, etc.

For journal and thrust bearings the clearances in new condition as well as the wearout limit for exchange shall be documented

2.3 Systems Design requirements - package provider / builder

2.3.1 Starting system
For single propulsion gas turbines the starting system, electrically, pneumatically or hydraulically driven, shall have redundancy in technical design and physical arrangement. This do not apply for redundant propulsion gas turbines provided with their own starting systems and for turbines installed in plants which in combination with other power units such as diesel engines or electric motors shall maintain the function.

The capacity of the starting system shall be designed to enable six (6) consecutive starts of gas turbines for main propulsion, respectively three (3) consecutive starts of gas turbines for non-essential propulsion and driving of auxiliaries. Regarding requirements for starting air capacity, see Ch.6 Sec.5 [9.3]

Prior to ignition process, automatic purging shall be arranged prior to all starts and restarts. The purge phase shall be of sufficient duration to remove all the accumulated fuel.

The starting control system shall be fitted with ignition detection devices. In case of ignition failure (light-off) within a pre-set time, the control system shall abort the ignition automatically, shut-off the main fuel valve and release a purge cycle.
The start system shall have its own protective system to ensure prevention of damage due to overspeed or failure to reach ignition speed.

### 2.3.2 Lubricating oil system

Heat balance calculations for the lubrication oil system shall be submitted. The heat balance shall be considered at seawater cooler inlet temperature of 32°C, an ambient air temperature of 45°C unless otherwise specified.

The system shall include sufficient filtering, heat exchanger capacity, magnetic chip detectors located as necessary, and water separator arrangements.

Any shutdown of the gas turbine, either due to a normal shutdown, shutdown due to turbine trip, or due to a blackout of the vessel, shall not result in damage to any turbine bearings.

If the lubrication oil system is common with other machinery components (e.g. gear or generator), provisions shall be taken to prevent possibly contaminated oil to be exchanged between the equipment.

Gas turbines with anti-frictional bearings shall have a separate lubrication oil system.

The lubrication equipment of a gas turbine shall be arranged and protected such that leakage of lubricating oil shall not reach surfaces with a temperature of above 220°C nor any rotating parts.

The lubrication oil system shall be equipped with a filter device allowing exchange or purification without restricting the oil flow to the gas turbine if a stopping a unit implies loss of function. The condition of the filter(s) shall be monitored by indication of the pressure difference or other adequate means. Tanks shall be equipped with oil stand indications combined with a low level alarm. Re-filling of oil shall be possible without interrupting the operation. Means for taking of representative samples for analysis purposes shall be provided.

When applying synthetic lubricants attention shall be given to the compatibility to the sealing material and heat exchangers.

### 2.3.3 Fuel System

**Guidance note:**
Gas turbine fuel system is defined as gas turbine manufacturer’s scope of supply. The border line might be set at fuel booster pump inlet.

Application of gaseous fuels has an impact on design of some peripheral components, such as combustion unit and burners. In case that the specific turbine type shall be TA approved for both gaseous and fuel operation, the respective drawings, maintenance manual and performance characteristics should be submitted for design approval as separate options. In the TA certificate the two options should be addressed separately, followed by maker’s labelling.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

Fuel nozzles shall be replaceable as complete units without requiring major adjustments works after replacement.

The system shall be equipped with suitable drain facilities for the fuel manifold and fuel nozzle to safely handle excessive fuel originating from shutdown (normal and emergency) of the gas turbine fuel system.

**Guidance note:**

The requirements for a separate drainage systems may be waived if the gas turbine design itself can be proven to hinder unwanted fuel accumulation.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

The combustors shall be equipped with a separate drainage system, preventing accumulation of fuel after a failed start.

The day tank for the fuel supply of the gas turbine shall have adequate capacity referenced to the ship’s destination and the purpose of installation of a gas turbine for main propulsion. The day tank shall contain fuel in accordance to the specifications of the gas turbine maker, adequately conditioned for immediate use. The manufacturer shall specify the different fuel qualities that the gas turbine is designed for. When heavy fuel is intended to be used the manufacturer shall document the turbine's ability to maintain serviceability at full power, without significant loss of component life. If special maintenance is required to
reduce degradation of the turbine, the methods used to clean the turbine shall be submitted to the Society for information.

2.3.4 Inlet and outlet passages
The air intake shall be arranged and located such that the risk of ingesting foreign objects is minimised.

Guidance note:
Depending on the arrangement, the Society may require that a grid be fitted on the air intake.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

The inlet ducting and components in way of inlet airflow, such as filters, silencers and anti-icing devices shall be constructed and mounted to minimise the risk of loose parts entering the gas turbine.

Icing at air intake shall be prevented by suitable means.

When the gas turbine makers’ sets requirements for inlet air quality, the air intake system shall incorporate an effective filtration system being capable of fulfilling these requirements. Pressure drop across filter shall be monitored in accordance with Table 8.

Guidance note:
Maximum salt content entering the compressor should not to exceed 0.01 wppm

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

Air intakes shall be placed such that effect of sea water spray due to ship motion and weather is kept within acceptable limits. The air inlet ducts shall incorporate a system for drainage of water.

Air intakes and exhaust outlet shall be so located that suction of combustion gases in the air intakes is avoided.

The flow path of the inlet air shall be as straight and clean as possible, with a minimum of obstacles, sharp corners and duct curving. This shall minimise the creation of vortex flow, pressure drops and uneven air distribution in the compressor inlet.

Guidance note:
Inlet airflow analyses or model tests may be required when the ducting are not according to the above.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

Pressure losses in air intake and exhaust ducting shall not exceed the specifications given by the gas turbine manufacturer.

Multi-gas turbine installations shall have separate inlets and outlets for each gas turbine unless the inlets and outlets are arranged to ensure the following:
— no induced circulation through a stopped gas turbine
— simultaneous operation of gas turbines shall not harm the operation condition of any gas turbine (e.g. due to intake underpressure, turbulence, etc.).

Any active measures fitted in the ducts shall have a fail to safe action as to the integrity of the turbine.

In case of a heat exchanger mounted in the exhaust duct, it shall be ensured that the gas turbine back-pressure does not exceed the maximum value specified by the gas turbine manufacturer.

Welds in exhaust ducts shall not be located in areas with stress concentration such as corners and dimension changes.

2.3.5 Carbo blast system
The operation of the carbo blast system shall ensure that the gas turbine’s hot section temperatures during blasting do not exceed maximum allowable operation temperatures.

Guidance note:
It is recommended to consider specific risks for hot spots.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

Back flow of hot gases into the carbo blast piping shall be prevented by suitable means.

Clogging of cooling passages shall be avoided.
2.3.6 Turning gear
Main propulsion turbines shall be equipped with turning gear both for the gas generator as well as for the power turbine.
The rotors of turbines for driving auxiliaries shall at least be capable of being turned by hand.

2.3.7 Performance
Documentation of the performance shall include:

a) Compressor characteristics including a documented surge margin for all running conditions and transients. Avoidance of choke to be documented or tested.

b) Overall gas turbine performance curves. These shall be based on the overall efficiency (ht) and the quasidimensionless mass flow group m√T05/p05 as function of the pressure ratio p05/p06. This shall be presented for various values of the quasidimensionless speed group N/√T05, where 5 and 6 denote turbine inlet and outlet conditions (see Figure 2). Equivalent performance curves are acceptable.

c) Performance characteristics including gas turbine power and speed dependency on ambient temperature.

d) The normal performance or power loss as a function of running time. The turbine in this case is assumed to be running within design specification.

e) The expected recoverable performance of a used gas turbine (after a complete overhaul).

The turbine shall be designed to permit rapid start from cold conditions, without working outside the performance envelope of the either the gas generator or power turbine.
The design shall take into consideration thermal gradients for all modes of operation including trips, and shall permit immediate restart (within control system constraints, e.g. thermal interlock) when a function is required to be restored.

![Figure 2 Station numbering, basic cycle](image)

2.3.8 Failure mode and effect analysis (FMEA)
The FMEA shall identify critical components and systems together with failure modes and consequences. The analysis shall, as a minimum, cover the following as applicable:

- gas path components
- bearings
- seals
- fuel system
- lubricating oil system
- turbine hot section cooling system (e.g. blade and disk cooling)
- turbine cooling and ventilation system (shell and casing)
- control system
- control system power supply
- instrumentation system (e.g. vibration, temperature, pressure)
- mechanical control system (e.g. variable guide vanes)
— anti-icing system*
— heat recovery system (only that portion in the exhaust gas path)*
— inlet air systems (e.g. filtration)*
— heat absorption system (cooling water for the lubrication oil system).*
* To be included in FMEA if defined as part of type approved system, only.

Coupling shaft failure and its consequences shall be identified and documented.
The analysis should be presented in a format that is clear, e.g. tabulated in the form of name components and system, type of expected failures, consequences, expected frequency of failure. See also [3.1.4].

2.3.9 Maintenance
Maintenance manuals shall cover:
— illustrated list of parts,
— assembly and disassembly process with tools and procedures, such as clearances, pre-tightening procedures, torque limits etc.,
— time between inspection, overhaul and change out of major components, e.g. blades, disks, nozzles, burners etc.,
— methods used to identify the remaining lifetime on the component,
— acceptance and rejection criteria of major components, e.g. maximum blade crack length, for acceptance without repair, with repair, and reject, clearances / wear of bearings, etc.

Overhaul shall be accomplished at the gas turbine manufacturer's plant or at an OEM's approved plant. It shall include disassembly, examination, cleaning and repair of the gas turbine and accessories.
The turbine manufacturer shall provide a list of their approved overhaul depots for the respective gas turbine types.

2.4 Enclosure, Fire Safety

2.4.1 Gas turbine enclosure
An enclosure shall be fitted when the temperature of accessible surfaces is above 220°C. The enclosure shall meet the following requirements, also applicable when an enclosure is provided for other purposes.
— The enclosure shall include a system for fire detection and automatic fire extinguishing.
— The enclosure ventilation or cooling air of the gas turbine shall be supplied from full redundant fans (2 times 100%) with separated electrical power supply.
— The distribution of ventilation air shall ensure that an acceptable temperature profile of the gas turbine is maintained, and that any local accumulation of combustible gas mixtures is prohibited.
— In case of emergency, closing of the ventilation ducts of the plant shall be feasible in a controlled way and within short time, avoiding further damages due to local overheating.
— In case personnel are allowed to enter the enclosure when the gas turbine is in operation, at least two exits should be arranged in the opposite ends of the enclosure, or in a manner providing easy escape routes from all relevant positions inside the enclosure.
— Interlocks on doors shall be provided to ensure that fire extinguishing medium hazardous to personnel is not released, when personnel are inside the enclosure.
— The enclosure tightness shall be such that any personnel staying in the engine room shall have sufficient time to evacuate if a fire extinguishing medium hazardous to personnel is released inside the enclosure.

Guidance note:
Carbon dioxide in excess of three percent by volume is considered hazardous to personnel.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

A gas turbine start shall be interlocked when personnel are inside the enclosure and the enclosure doors are open. During operation the doors shall be closed. Signboard shall be displayed on all the enclosure doors to restrict or prohibit the entrance to the enclosure during operation.
2.4.2 Fire safety

These requirements are additional to the Ch.11.

Fire ignition shall be prevented by use of the following means:

— all surfaces that may reach a temperature of 220°C shall be insulated
— the insulation material shall be impervious to liquid fuel and vapour.
— flammable fluids shall be prevented from leaking onto hot surfaces (e.g. through insulation openings, joints).

If it cannot be documented (by tests) that the above conditions are fulfilled, an enclosure shall be fitted.

For gas turbines not fitted inside an enclosure, fuel oil piping joints shall be screened or otherwise suitably protected to avoid fuel spray or leakage onto ignition sources in the machinery room.

In addition to the machinery room firefighting system, an approved automatic fire extinguishing system shall be provided for each gas turbine enclosure.

Enclosure ventilation ducts shall be automatically closed when a confirmed fire is detected.

Inside of enclosure a sufficient number of flame detectors, at least four, shall be provided. They shall be arranged focusing on location that are prone to ignition, e.g. detector above the front end of turbine (cold end) looking at the fuel manifold and turbine hot section (2 detectors), one detector, viewing the turbine from below, pointing at the fuel metering valve and fuel lines. Fire detectors shall be type approved. Type of detector and sensitivity shall reflect the expected ambient temperature and airflow under normal operation.

Alarm from two or more detectors shall be regarded as a confirmed fire.

A confirmed fire in an enclosure of the engine room shall initiate an alarm and automatically stop the fuel oil pumps (that are not gas turbine driven) and quick closing valves as required in the Ch.6 Sec.5 [4.5]. Ventilation fans shall stop automatically upon confirmed fire. Where extinguishing gas systems is used provided as the fire extinguishing system, additional amount shall be provided to compensate for gas lost until ventilation is stopped.

Dampers in any gas turbine enclosure shall be automatically closed upon confirmed fire. Dampers shall close in less than 15 s.

Supply and exhaust ducts for gas turbines may be accepted without dampers, provided their integrity is maintained throughout the spaces they penetrate. Supply ducts need not be fire insulated outside the machinery spaces, provided their integrity is maintained inside the machinery spaces.

An automatic fire extinguishing system shall be provided for any gas turbine enclosure. The system shall be designed based on a recognised standard e.g. “Rules for CO2 systems”, MSC/Circ. 848 (gas systems), IMO MSC/Circ.913 (water based systems) or MSC/Circ.668/728 (water based systems).

The system shall operate automatically upon a confirmed fire in the gas turbine enclosure and is additional to the main fire-fighting system. Manual release shall be provided from a safe position outside the structural boundaries of the machinery room or a fire protected enclosure.

The local fire extinguishing system for the enclosure is required in addition to the machinery space fire extinguishing system, which also shall be designed to protect the enclosed space.

Guidance note:
Other system designs that provide a backup for fire extinguishing inside the enclosure may be agreed to.

Portable fire extinguishers, one 12 kg powder extinguisher or equivalent shall be positioned outside each entrance to the gas turbine enclosure.

Maximum two gas turbines are allowed to be fitted within a common enclosure. The following conditions prevail for a common enclosure:

— each gas turbine shall have a rating below 10 MW
— means shall be provided to prevent fuel spray from one gas turbine to hit the other
— in case of an emergency shutdown due to fire detection inside a common enclosure, redundant drivers shall maintain propulsion.
3 Control and Monitoring

3.1 Gas Turbine Control

3.1.1 Gas turbines shall be delivered with a type approved control and monitoring system, see Ch.9.

3.1.2 Control systems for gas turbines shall be certified in accordance with Ch.9 before being installed on board or being hooked up to the turbine.

3.1.3 FMEA Control System
A Failure Mode and Effect Analysis is required for the verification of the logical interconnections within the control system of gas turbines for essential main propulsion. Single failure of any system or control during operation at any mode shall not lead to loss of control of safety related properties of the ship, e.g. loss of control of propulsion, maneuverability for propulsion units, loss of electrical supply for auxiliary turbines, etc. Safe operation of the ship shall be demonstrated within the FMEA after partly or complete failure or malfunction of a gas turbine unit, subjected to these rules.

3.1.4 Minimum monitoring requirements
Ref. to Table 8. Note that the table covers both the gas turbine and the gas turbine package with auxiliaries. Subject to consideration by the Society the parameter list may be adjusted to accommodate gas turbine design issues.

Table 8 Monitoring requirements

<table>
<thead>
<tr>
<th>Control parameter</th>
<th>Parameter value</th>
<th>Action 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clogged air intake filter, differential pressure</td>
<td>High</td>
<td>Alarm</td>
</tr>
<tr>
<td>Anti-icing system failure, pressure</td>
<td>Low</td>
<td>Alarm</td>
</tr>
<tr>
<td>Fuel service tank level</td>
<td>Low</td>
<td>Alarm</td>
</tr>
<tr>
<td>Lubricating oil, pressure</td>
<td>Low</td>
<td>Alarm</td>
</tr>
<tr>
<td>Lubricating oil, temperature</td>
<td>High</td>
<td>Alarm</td>
</tr>
<tr>
<td>Lubricating oil level</td>
<td>Low</td>
<td>Alarm</td>
</tr>
<tr>
<td>Clogged lubricating oil filter, differential pressure</td>
<td>High</td>
<td>Alarm</td>
</tr>
<tr>
<td>Cooling Water Pressure</td>
<td>Low</td>
<td>Alarm</td>
</tr>
<tr>
<td>Fuel metering valve position out of synchronisation</td>
<td>Deviation</td>
<td>Alarm 2)</td>
</tr>
<tr>
<td>Power turbine rotor overspeed</td>
<td>High</td>
<td>Alarm</td>
</tr>
<tr>
<td>Gas Generator rotor overspeed</td>
<td>High</td>
<td>Alarm</td>
</tr>
<tr>
<td>Gas generator overspeed</td>
<td>High</td>
<td>Alarm</td>
</tr>
</tbody>
</table>

1) Action: 1) alarm, 2) alarm with step to idle

#### Part 4 Chapter 3 Section 2

<table>
<thead>
<tr>
<th>Control parameter</th>
<th>Parameter value</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anti-surge system, if applicable</td>
<td>Indicated surge</td>
<td>Alarm</td>
</tr>
<tr>
<td>Flame out detection</td>
<td>Flame out</td>
<td>Shutdown</td>
</tr>
<tr>
<td>Vibration</td>
<td>High</td>
<td>Alarm</td>
</tr>
<tr>
<td>Inlet guide vanes, bleed valves, variable stator vanes actual position not in synchronisation with command value, as applicable</td>
<td>High</td>
<td>Alarm if anti surge system, otherwise step to idle</td>
</tr>
<tr>
<td>Power turbine inlet temperature</td>
<td>High</td>
<td>Alarm</td>
</tr>
<tr>
<td>Power turbine inlet temperature spread out of specification</td>
<td>High</td>
<td>Alarm</td>
</tr>
<tr>
<td>Bearing temperature (material or oil outlet)</td>
<td>High</td>
<td>Alarm</td>
</tr>
<tr>
<td>Thrust bearings temperature (material or oil outlet)</td>
<td>High</td>
<td>Alarm</td>
</tr>
<tr>
<td>Power loss of control and monitoring system</td>
<td></td>
<td>Shutdown</td>
</tr>
<tr>
<td>Loss of cooling air supply</td>
<td>Low</td>
<td>Alarm</td>
</tr>
<tr>
<td>Failure to ignite</td>
<td></td>
<td>Shutdown</td>
</tr>
<tr>
<td>Failure to reach idle speed</td>
<td></td>
<td>Shutdown</td>
</tr>
<tr>
<td>Compressor inlet pressure</td>
<td>Low</td>
<td>Step to idle</td>
</tr>
<tr>
<td>Fire Detection (inside enclosure)</td>
<td></td>
<td>Shutdown</td>
</tr>
</tbody>
</table>

1) All “Step to Idle” to result in a “Shutdown” if the fault is still critical after a defined operation time at Idle. Provided it can be documented that safety is maintained “Step to Idle” might be replaced with “unloading to a safe power level” or direct shutdown for auxiliary gas turbines or multi gas turbine propulsion application

2) Alarm might be replaced with shutdown for auxiliary gas turbines or multi-gas turbine propulsion applications

3) There shall be at least one temperature sensor per combustor and no less than six temperature sensors per gas turbine. Action at Hi-Hi to be decided for each gas turbine type; either alarm or step to idle. Direct shutdown if the system can detect partial flameout.

4) So far applicable.

Note: For requirement to monitoring of axial displacement and vibration, see [5]. Proximity probes may be required to be fitted in gas turbine power turbine module or other locations along the driven high speed string.

### 3.1.5 Power supply

The control system shall be equipped with an uninterruptible power supply designed to function even under black-out conditions. Total loss of control system power shall lead to a controlled turbine shutdown.

### 3.1.6 Independency

Control systems shall be arranged so as to allow local control and operation of the gas turbine, irrespective of the state of the overall (e.g. vessel) control system.

### 3.1.7 Fail to start

Start sequence shall be interrupted and main fuel valve closed within a pre-determined time, when ignition has failed.
3.1.8 Purge after star failure
All gas turbine control systems shall implement purging as part of normal start up and start failure. The extent of purging required shall be of a duration sufficient to displace the exhaust system volume three times before attempting re-start.

3.1.9 Start and load
Gas turbines which main purpose is standby, shall permit rapid starting and loading.

3.1.10 Speed Control
Gas turbines within the scope of these rules shall be fitted with a speed governor which, in the event of a sudden load drop, prevents the revolutions from increasing to the trip speed.

3.1.11 Overspeed
Gas turbine control systems shall be provided with hardwired (or equivalently fast) overspeed protection preventing the turbine speed from exceeding the maximum permissible speed as defined by the manufacturer. The speed increase of gas turbines driving electric generators subsequent to a load drop from 100% to idling shall not exceed 10% of the nominal speed and shall return to the steady state with a maximal deviation of 5% of the nominal value within 2 s. The transient increase shall in any case remain safely within the overspeed margin.

3.1.12 Fuel Cut Off
The fuel control system shall include shutoff valve, separate from the fuel control valve, that blocks all fuel flow to the turbine on any shutdown condition. The valve shall have means for local and remote activation.

3.1.13 Driving main or emergency electric generators
For gas turbines driving main or emergency electric generators, see Sec.1 [5.2].

3.2 Monitoring and instrumentation system

3.2.1 For instrumentation and automation, including computer-based control and monitoring, reference is made to Ch.9.

3.2.2 FMEA Safety System
Details of the manufacturers specified automatic safety devices, intended to safeguard against hazardous conditions arising in the event of malfunctions in the gas turbine installation, shall be submitted for approval together with the system's failure mode and effect analysis (FMEA), see [2.3.8] and [[3.1.4].

3.2.3 Independency
The safety system shall be independent from the gas turbine control system. In the case of activation of a safety device, the gas turbine shall be blocked against a new start, before manual acknowledgement. The devices for de-blocking shall be arranged such that a quick re-start attempt of the gas turbine is possible.

3.2.4 Overspeed
Gas turbine safety system shall provide overspeed protection, preventing the turbine speed from exceeding 115% of the maximum continuous speed (project related speed).

3.3 Auxiliary system controls

3.3.1 The following turbine feeding systems shall be equipped with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the main gas turbine:
— lubricating oil supply
— fuel oil supply (alternatively automatic control of oil fuel viscosity)
3.4 Control stations

3.4.1 The operation of the gas turbine, including start and stop, shall be possible by remote control from the machinery control centre (MCC). The wiring for control purposes shall be independent and shall have means for electrical disconnection from other systems.

3.4.2 An additional manual control shall be provided directly at the gas turbine’s enclosure and shall include a shut-down release. This shall interrupt the fuel supply instantaneously.

3.4.3 For propulsion gas turbines, additional navigating bridge and bridge wings control shall be arranged.

3.4.4 Any additional control station shall be equipped with adequate instrumentation to enable control of gas turbine’s load, revolutions and emergency stop.

4 Arrangement

4.1 Alignment and reaction forces

4.1.1 For coupling alignment requirements, see Ch.4 Sec.4.
Coupling alignment specification shall be submitted for approval. Thermal expansion and elastic deflections between gearbox and gas turbine shall be considered.
In case that the power turbine is fitted with a clearance adjustment by moving the power turbine axially, it shall be documented that the movements are within tolerances for any couplings.

4.1.2 Gas turbines shall be aligned so that the shear force, axial force and bending moment at the gas turbine output shaft are within the specification for the gas turbine.

4.1.3 For gas turbine drive train, the alignment shall be within the permissible values under all relevant operational conditions, see Table 9. It is assumed that there is always a flexible coupling between the gas turbine and any driven unit.
For applications that may experience thrust load directional variations, an axial proximity probe for monitoring of vibration and position shall be fitted in the high speed driven string.
Operational and extreme loads as defined in Table 9 shall not cause the gas turbine to move permanently on its foundation.

4.2 Mounting in general

4.2.1 The loads given in Table 9 shall be considered in the design of the foundation system. Foundation shall be in compliance with Ch.2 Sec.1 [6] with additional requirements as given in [4.2]

4.2.2 Preferably, the gas turbine casing shall not absorb deflections in vessel structure. This might however be accepted if it can be shown by calculations that casing deflections are within acceptable limits as specified by the gas turbine manufacturer.

4.2.3 The foundation system shall be designed with a minimum separation margin of 20% to dominant frequencies of the gas turbine and adjacent equipment. Calculations shall be submitted.

Table 9 Operational and extreme loads

<table>
<thead>
<tr>
<th>Operational loads</th>
<th>Extreme loads</th>
</tr>
</thead>
</table>

Part 4 Chapter 3 Section 2


Rotating machinery - drivers

a) Mass. Maximum environmental conditions such as list and trim shall be considered for determination of mass reaction forces. (See Ch.1).
b) Maximum operational acceleration loads.
c) Reaction forces due to gas turbine torque (including short circuit torque in case of electrical generators).
d) Forces transferred to foundation members due to deflection of ship structure.
e) Forces derived from thermal expansion of gas turbine or interfacing components.
f) Any other operational loads that may be significant for the individual application, e.g. for Naval Surface Craft.

A combination of the above loads shall be considered

The following prevails for the worst expected operational loads (left column):
Gas turbine supports (struts) shall have documented a safety factor of minimum 2.5 against buckling.
Stresses on foundation members shall be well below the fatigue curve for the material, and maximum deflections shall be within limitations set by the gas turbine and adjacent components (e.g. flexible coupling).
In case of extreme loads (right column), the foundation integrity shall be maintained.

Guidance note:
The foundation should be designed to take advantage of supports in the ship structure such as bulkheads and stiffeners.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

4.3 Rigid mounting

4.3.1 For mounting on epoxy resin, the surface pressure due to mass and bolt tension shall be within approved values for the applicable epoxy resin. Calculation of surface pressure due to peak loads shall be submitted upon request. The thickness of the epoxy resin shall be within the approved limitations. The epoxy resin shall be type approved.

4.3.2 The pre-tension of the holding down bolts shall be specified with regard to tightening torque as well as the tightening sequence. The friction forces shall be able to prevent dynamic movements in the base plate connection.

4.3.3 Side and end stoppers shall be arranged as safety devices to prevent movement between gas turbine and foundation caused by loosened bolts or excessive loads due to gas turbine breakdown. End stoppers may be waived if fitted bolts or equivalent solutions are used.

4.4 Resilient mounting

4.4.1 For dynamic analyses see [5].

4.4.2 Resilient mounts shall be type approved.

4.4.3 All connections to the gas turbine such as couplings, intake and exhaust ducts, fuel pipes lubricating oil pipes and electrical wires shall be designed for the maximum possible gas turbine movements as limited by the elastic mounts.
4.4.4 The resilient mounts shall be able to support the worst expected operational loads, see Table 9, without exceeding the approved specification.

4.4.5 The static positions of the gas turbine on the elastic mounts shall be calculated under consideration of the static loads listed in Table 9.

4.4.6 Excessive movements due to extreme loads, see Table 9, shall be prevented by either dual characteristic mounts or by stoppers. The stoppers shall not be reached as a consequence of operational loads.

   Guidance note:
   For dual characteristic mounts the “second” level may be utilised provided that this is foreseen in the dynamic analysis.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

5 System vibration

5.1 General

5.1.1 Vibration behaviour for gas turbines shall be evaluated on the following design levels;
   — component, see [2.2]
   — gas turbine, see [2.3] and [4]
   — system behaviour, see [4].

The evaluation shall consist of a combination of analytical calculations and test measurements.

5.2 Documentation of vibration analysis

5.2.1 In vibration calculations the source of all essential data shall be listed. For data that cannot be given as constant parameters, the assumed parameter dependency and tolerance range shall be specified.

5.2.2 Lateral vibration calculations

The natural frequencies of the rotor-bearing-support system shall not exist inside the normal speed range of the turbine from idle to trip speed, with a separation margin of 15%. If this occurs, calculations showing that the response of the rotor shall not exceed the manufacturer have specified limits shall be submitted for approval.

The calculation report shall contain a summary of the total analysis. As a minimum the analysis shall include plots of mode shapes for all natural modes of vibration which can be excited.

5.2.3 In case forced vibrations are required, the following applies:

Appropriate unbalance shall be used in the analysis (commonly, maximum permissible residual unbalance). The unbalance shall be located at shaft positions where the residual unbalance can occur (heavy disks).

Response plots indicating displacement shall also show the locations of the couplings, bearings, and seals. The minimum seal clearances should be noted on the plots.

Critical speeds shall preferably be calculated by damped harmonic method or other methods to reveal the stability margins and be verified by damped unbalance response analysis of the rotor. The response of critical speeds inside the operation range shall be confirmed by measurements. The excitation sources shall be investigated by analytical methods and shall as a minimum be:

   — unbalance in the rotor system
   — oil film instabilities by input of bearing cross-coupling effects.

In addition the response to 2nd harmonic of the speeds over the available, operational speed range shall be evaluated.
5.2.4 Torsional vibration

Torsional resonance frequencies for the complete power turbine rotor train shall have a separation margin of 10% of any possible excitation frequency within the normal running range of the plant. If this separation margin is not obtained, forced response calculations in conjunction with stress calculations are required to prove that failure of the shafting shall not occur as a result of high cycle fatigue.

The excitation sources shall be investigated by analytical methods and shall as a minimum be (if applicable):

— synchronous (1st order) running frequencies for all applications
— propeller pulses with respect to 1st and 2nd harmonics (blade frequency)
— waterjet pulses with respect to 1st harmonic (rotational speed and blade frequency)

Further, transient torsional vibration calculations, such as:

— clutching-in impacts.
— load shed due to waterjet aeration.
— short circuiting in generators.

required for evaluation purposes upon request.

5.3 gas turbine vibration

5.3.1 Extent and method of calculation of resiliently mounted gas turbines, see also [4.4].

Resiliently mounted gas turbines shall be calculated with respect to natural frequencies for all six degrees of freedom. The influence of the shaft connections (elastic couplings) and piping shall be accounted for.

Calculation of forced responses are required if excitation frequencies (whole operating speed range) and natural frequencies are closer than 20% for ships and 30% for HSLC.

For HS, LC and NSC the response due to peak amplitude acceleration shall be calculated. All machinery shall be designed to operate under relevant acceleration due to heavy sea in vertical, transverse and longitudinal directions. The admissible limits for the core unit, as specified by the maker, shall be compared to the response in the ship, taking into account the specification of maximal amplitudes for the vessel itself.

Guidance note:
The specified acceleration data for the vessel will vary widely following the vessel’s purpose. For Navy Vessels additional shock requirements may apply, see also Naval Surface Craft. See Pt.5 Ch.13.

5.3.2 Acceptance criteria

The acceptance criteria for resilient mount deflections considering the combined static and dynamic responses are given in [4.4].

The acceptance criteria for gas turbine connections such as couplings and piping are given in [4.4.2]. If the gearbox also is resiliently mounted, the combined (relative) movements of gas turbine and gearbox shall be considered for the coupling misalignment.

6 Tests and trials

6.1 Tests, General

6.1.1 For testing and certification purposes the following tests apply:

Material tests (destructive and non-destructive test on relevant components to check material quality and properties, before or after machining and exposure to thermal processes), see [6.2]

Component test, carried out in manufacturer’s work shop. The test aims to prove that the component shall safely fulfil some functional properties, such as tightness, spinning, balancing, pressure test etc., see [6.3]
Type approval test, is referring to one specific type of gas turbine (new or upgraded design) and does not cover a range of substantial design variations. Type approval test, see [6.4], is the operational / testing part of an integral type approval process.

Type approval test is carried out for the first gas turbine of a series. It comprises an extended process of trials under stationary and dynamic conditions, as well as overload, in the manufacturer's work shop. It is followed by an internal inspection of the prototype gas turbine and shall be documented in a type test report by the manufacturer.

The process is terminated with issuance of a type approval certificate. The control and safety system for this test may be not the same as for the intended marine application. Therefore control and safety systems shall be type approved and certified independently.

The required procedure is described under [6.4]

Certification Test (Factory Acceptance test), is referring to survey and test of every individual gas turbine. Basis for this test at the maker's facilities is the type approval test of the same version of unit. The process for FAT is described under [6.5], the testing program depends on the individual application.

Quay Test and Sea trial Tests aims to prove the operational ability of the gas turbine in combination with the ship's systems in installed condition and when driving the dedicated driven units. The required extent of sea trial test depends on the kind and purpose of the gas turbine. The process is described in [6.10]. Some quay tests test may be accepted as sea trial tests so far the conditions at quay are regarded as representative.

Typically the following parameters shall be registered as a minimum during the mentioned test procedures:

**Table 10 Gas turbine and system data acquisition**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type test</th>
<th>Certification test</th>
<th>Quay trial</th>
<th>Sea trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (thermodynamic) 1)</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X 5)</td>
</tr>
<tr>
<td>Gas generator, and power turbine speed 2)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Shaft torque at drive end (power turbine output)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical power at drive end (generator set only)</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compressor inlet pressure and temperature 4), 3)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Compressor discharge pressure and temperature 4), 3)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Turbine inlet temperature 1), 6)</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Gas generator exit pressure and temperature 4), 3)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Gas generator exit gas temperature spread</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Power turbine exhaust pressure and temperature 4), 3)</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Lubrication oil temperature and pressure 4)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Fuel temperature and pressure, at the fuel inlet</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Hydraulic fluid pressure</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coolant temperature and pressure 4)</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Temperature of external surfaces of the gas turbine</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Bearing metal temperatures 7)</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Intake pressure loss</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Exhaust pressure loss</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Vibration levels</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Parameter</td>
<td>Type test</td>
<td>Certification test</td>
<td>Quay trial</td>
<td>Sea trial</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
<td>-----------</td>
<td>--------------------</td>
<td>------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Position of variable stator vanes, or bleed valve opening, as applicable</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

1) To be corrected to standard reference conditions (ISO 2314). Note that both raw and corrected parameters shall be recorded.
2) If more spools are involved, their respective speed shall be recorded.
3) These values may be derived values from other measured points.
4) At locations specified by the manufacturer.
5) May be substituted by torque measurement at power turbine output.
6) Measurement not required, calculation acceptable.
7) Lubricating oil temperature measurement after bearing is also acceptable.

### 6.2 Testing of material and components

#### 6.2.1 Material certificates

Material certificates for the components listed in Table 11 shall be provided. Agreements related to the manufacturing procedures and suppliers shall be agreed on in each case. The extent of tests shall at least comply with the approved quality scheme of the manufacturer.

#### 6.2.2 Non-destructive examination

Non-destructive examination shall be applied to the rotors, blades, disks and welded joints of rotating parts unless another production control process has been agreed or welded joints. The examination shall be performed by the manufacturer and the results together with details of the test method shall be evaluated according to recognised criteria of acceptability and documented in the test report.

### Table 11 Certification requirements for gas turbines and its components

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification Standard*</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blades</td>
<td>MC</td>
<td>Society</td>
<td></td>
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</table>
6.2.3 For general certification requirements, see Pt.1 Ch.3 Sec.4.

6.2.4 For a definition of the certification types, see Pt.1 Ch.3 Sec.5.

6.3 Tests on components (manufacturer’s works)

6.3.1 The following component tests shall be performed for every gas turbine:
— Pressure and tightness test
Turbine casings shall be tested with 1.5 times the design pressure. Design pressure is the highest expected pressure within the casing under nominal operating conditions (at least 1.25 times maximum allowable working pressure under nominal conditions).
The tightness test of the turbine casing may be replaced by other alternative means with the agreement of the Society.
Further pressure equipment, such as coolers, heatexchangers, etc. shall undergo a pressure test with 1.5 times of their design pressure.
— Rotor balancing
Before final installation all completed rotors including mounted discs shall be dynamically balanced. The balance procedure as well as the results before and after balancing shall be documented. For assessment DIN ISO 1940 or comparable regulations may be used.
— Cold overspeed test
Turbine and compressor wheels shall be tested at a speed at least 15% above the rated speed for not less than three minutes.
The Society may accept mathematical proof of the stresses in the rotating parts at overspeed as a substitute for the overspeed test itself provided that the design is such that reliable calculations are possible and the rotating parts have been subjected to thorough non-destructive testing to ascertain their freedom from defects.

6.4 Type approval test (manufacturer’s works)

6.4.1 Type approval test procedure
Type testing serves the primary purpose of substantiating the gas turbine’s design documentation. It is furthermore intended to validate that the gas turbine shall provide acceptable performance under the worst-case operational conditions of its intended service.

6.4.2 The complete type testing program is subject to approval. The tests shall be witnessed by the Society, however, the precise extent shall be agreed in each case. In case of proven and already introduced gas turbines, a report of the type test may be accepted by the Society as substitute of new type test, so far the scope of type test is complete and in accordance to these rules, the test has been verified by another third party and the complete documentation is handed over to the Society for appraisal and reference purposes.

6.4.3 Type testing is valid for only one specific type of gas turbine, and does not cover a range of design variations. The maximum speeds of the spools, firing temperature, turbine inlet temperature, exhaust temperatures, mass flow rate, etc. are fixed for a given type of turbine, and shall be specified on the type approval certificate.
6.4.4 Type testing shall preferably be made with the type of fuel oil for which the gas turbine is intended, or equivalent. If this is not possible then there shall be prior agreement with Society as to the fuel used for the test, and its consequences to the results of the test. For gas turbines intended for running on heavy fuel oil, the test verification of the gas turbine’s suitability for this may be postponed to the sea trial.

6.4.5 If no special turbine application considerations apply (such as e.g. fitness for purpose testing, significant application limitations, or extensive relevant operational experience), the type test program shall be arranged as outlined in [6.5]. If special considerations apply, the test program shall be agreed between the Society and the manufacturer on a case by case basis, but shall be based on the elements in [6.5].

6.4.6 If a type tested gas turbine that has proven reliability in service, is design approved for an increase of power by less than 5%, and does not require internal (manufacturer) design review, a new type test is not necessary. The percentage refers to increases since the last type testing, not to the last approved level. It is assumed that the original design calculation of the gas turbine has taken into consideration the intended increase in power.

6.4.7 All test results shall be corrected to standard reference conditions as defined by ISO 2314. The type test shall be performed as close to standard reference conditions as possible in order to minimise correction errors.

The method for correction of parameters could be as described by ISO2314, or an accepted manufacturer developed alternative

The standard reference conditions are (ISO 2314):

- Temperature = 15°C
- Humidity = 60% relative
- Barometric pressure = 1.013 bar (760 mmHg).

6.4.8 Control settings of the gas turbine, such as alarm and shutdown shall be agreed upon with the Society. Set points that shall be used in the test that are inappropriate in relation to those used in normal running require written agreement.

6.4.9 Variation in control parameters (compressor discharge temperature, turbine inlet temperature, etc.) during data acquisition shall not exceed ±1% (or the manufacturer’s specification.). Shaft power shall not vary more than 3% (or that agreed upon in the contract specification).

6.4.10 If during the test, the observed data is obviously inconsistent with expected data or outside of specifications from the manufacturer, all possible effort shall be made to rectify the inconsistency during the testing. This shall be done in a mutually agreed upon manner between the manufacturer and the Society. Failure to reach an agreement shall require a retest. Even if the inconsistency is rectified during the test, a re-test or test extension shall be required by the Society.

6.4.11 When measured test parameters do not conform with design specification (e.g. high temperature spread), then formal changes in the design specification shall be documented before acceptance shall be given for the test. If not, the test shall be considered as failed.

6.4.12 Test data shall be recorded only after steady state conditions have been reached by the gas turbine, for the specific test point. Steady state is achieved when all key control parameters of the gas turbine have reached a steady state for that specific test condition. Steady conditions shall be defined for the specific test arrangement; load fluctuations shall not exceed 3% of the nominal values, registering of data shall reflect mean values over a period of at least 2 min after reaching stationary conditions.
6.4.13 For gas turbines driving electric generators, the requirements in Sec.1 [5.4] shall be verified by testing.

6.5 Type testing program

6.5.1 It is assumed that:

1) The investigations and measurements required for reliable gas turbine operation have been carried out during internal tests, according to the manufacturer established and documented procedures.
2) As a final validation of a new gas turbine design, the gas turbine shall be tested at the limit of the intended operation, see the guidance note.

   The length of the validation testing shall in each case be determined based on the extent of design changes from parent gas turbine, but 100 hours shall be considered as minimum. No major faults shall occur during this test.

   After the completion of the test, the gas turbine shall be dismantled for inspection. Test procedure and report shall be submitted to the Society for approval.

Guidance note:

Thermal stress cycles obtained by idle (or start) – full load – idle (or stop) sequences are a decisive design criterion and may be limiting for the total lifetime of the unit. Since this start-stop sequence is determining the amplitude of the thermal stresses, the type test should include several procedures for checking purposes. The number of start-full load-stop cycles should be demonstrated during type test and agreed upon with the Society within the approval procedure of the type test program. The purpose of this test should validate the design concept.

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3) Design assessment acceptance by the Society has been obtained for the gas turbine in question based on documentation requested, and the Society has been informed about the nature and extent of investigations carried out during the pre-production stages.

6.5.2 Type approval of gas turbines involves the following type tests: start test, mechanical running test, and performance test. These tests shall be carried out in the presence of the Society. They may be conducted separately, or be integrated so as to combine items from the three tests into one.

The recorded test results shall be endorsed by the attending surveyor upon completion of the type test.

6.5.3 Before and after the test, the lubricating oil shall be sampled for testing of contamination of metallic wear particles. The result shall be in accordance with the specification of the manufacturer.

6.5.4 Functional tests and collection of operating values including test hours shall be documented in the test report. The relevant results shall be presented to attending surveyor during the type test.

6.5.5 Component inspections after completion of the test program shall be conducted or witnessed by the Society, see [6.4.3].

6.5.6 The gas turbine designer shall compile results in a type test report, which shall be submitted for approval. If deviation from design specifications exists, this shall be agreed upon between the gas turbine designer and the Society.

For emergency operating situation, the following tests shall be performed:

— quick start
— override functions
— test run at emergency (or peak) rating (10 minutes).
6.5.7 Start test
Seven starts shall be carried out, of which one start shall be preceded by at least a two-hour gas turbine shutdown. There shall be at least one false gas turbine start, pausing for the manufacturer’s specified minimum fuel drainage time, before attempting a normal start. There shall be at least three normal restarts with not longer than 15 minutes (unless otherwise stated) since gas turbine emergency shutdown. All variations of pre-programmed start sequences shall be tested (e.g. quick start if applicable).

6.5.8 Starts done during the type tests can be incorporated in the start test to reach the sum of seven, provided that time interval between consecutive restarts are according [6.5.6].

6.5.9 Gas turbine emergency shutdown
The following emergency shut-downs shall be tested:
a) Hot shutdown, at full load (as soon as permitted by the manufacturer’s instructions). Restart shall be achieved before lockout and within 30 minutes.
b) Failure to ignite, resulting in aborted start sequence.
c) Flame out.

6.5.10 Testing of abnormal operation
Testing of operation at the limits of the protection system (set points for step to idle and shutdown) shall be performed including testing the power turbine overspeed limit.

6.5.11 Lubricating oil pressure and temperature shall be monitored and recorded during the test. The parameters shall be within the manufacturer’s recommended values. The recommended values shall be stated in the operating instructions.

6.5.12 The lubricating oil filtration shall be as specified by the manufacturer.

6.5.13 The control and monitoring system used in the test shall be representative of the type approved control and monitoring system, to the extent related to the gas turbine (see [5.1]). Deviations from the type approved control and monitoring system, and the reasons for the changes shall be presented to the Society in due time before testing.

6.5.14 The test shall document the lateral vibration behaviour in the range 0% to 100% of rated speed for all gas generator shafts. Vibration levels shall be recorded from 0% to 100% of rated shaft speed, down to idle, and finally through coast down and stop.
If 100% speed cannot be obtained due to ambient conditions, documented results from previous tests can substantiate the verification of upper speed range vibrations.
The measurements shall provide a reasonable match with analyses.
The Society may require additional measurements at certain specific speeds. In such cases, the readings shall be taken at steady state conditions.

6.5.15 The manufacturer shall provide the Society with the vibration acceptance criteria that shall be used during the test.

6.5.16 Broadband vibration measurements with frequency analyses presented by cascade plots shall be performed in addition to order tracking measurements.

6.5.17 The mechanical running test shall be considered complete if no damage occurs to the turbine, and tested functions and operating parameters are within specified limits and the vibration requirements are met. If, after the test, modifications to the design are considered necessary, a complete new test shall be performed.

6.5.18 Performance test: See [2.3.7].
The performance test shall be carried out in a manner equivalent to standards recognised by the Society, e.g. ISO 2314 *Gas turbines acceptance tests* or ANSI and ASME PTC 22 *Gas turbine power plant, performance test codes*. In the case of conflict between the standards and these rules, the rules prevail.

A leak check shall be performed prior to all runs.

The gas turbine shall be operated according to an estimated power/speed curve for the intended application (e.g. a waterjet curve for mechanical propulsion drive).

The data to be measured and recorded when testing the gas turbine at the various load points, and shall include all major parameters for the gas turbine operation (see also [6]). The operating time per load point depends on the gas turbine size (achievement of steady state condition) and on the time for collection of the operating values.

At least 4 load points shall be tested with approximately equal intervals (between 50% and 100% load). The gas turbine shall be tested for at least 4 hours at maximum load as limited by the control system. The load shall not be limited by factors external to the gas turbine (e.g. test cell capacity).

For high speed, light craft and naval surface craft application, further testing may be required under certain circumstances, and shall be mutually agreed upon between the Society and the manufacturer.

Gas turbine and control system shall demonstrate trouble free running without load for a minimum of 20 minutes, before testing at load conditions.

6.5.19 The acceleration and deceleration test of the gas turbine according to the manufacturer internal procedure shall be witnessed by the Society. The parameters of the control system governing these sequences shall be in compliance with the approved sequences and time constants.

6.5.20 For dual fuel installations, the performance test shall be carried out using the least favourable fuel. Gas turbines intended for dual fuel service shall demonstrate the capability to change from one fuel to the other, e.g. liquid to gas, and vice versa, while at load specified in operating manual, without detrimental change in operational parameters. For the purposes of type approval representative tests shall be demonstrated for both kinds of fuel. The certification test (see [6.5]) may be applied as operational test for the second kind of fuel.

6.5.21 Any deviations to the gas turbine internals, e.g. blades, disks, combustors, bearings, etc. from that submitted to the Society during the design review, shall be presented to the Society in due time before the actual test. The deviations shall be recorded in the test report. Additional testing and measurements may be required by the Society should there be significant changes to critical components e.g. blades, disks, combustors, bearings, etc.

**6.6 Inspection of condition of parts (Borescope / tear down)**

**6.6.1** Borescope inspection shall be conducted following both type and certification test (FAT). Borescope inspection may be required by the Society after sea trial.

**6.6.2** No cracks or major wear shall be seen in rotating parts after testing of a new gas turbine. Minor cracks, indents or tear in uncritical stationary parts may be accepted based on documented acceptance criteria.

Borescope inspection of the following parts shall be conducted to the extent allowed by gas turbine design (e.g. Borescope ports placement):

- compressor (blades and nozzles)
- combustor
- fuel burners
- gas generator turbines (blades and nozzles)
- power turbine (blades and nozzles).

Proper instruments and necessary personnel shall be on site during the inspection.
6.6.3 The Borescope inspection shall be taped or photographed, as documentation during the inspection. Documentation shall be retained at the manufacturers, and made available to the Society upon request. The taped final Borescope inspection is part of the final report to the type test. It may be also requested for the certification test (FAT) and after endurance test during sea trials.

6.6.4 Further inspection up to and including tear-down of the turbine may be required by the attending surveyor, should there be cause to do so, such as damaged blades or nozzles, or any other parts mentioned in the Borescope inspection. Tear-down may also be required, should the turbine fail its test due to not meeting performance requirements, not meeting manufacturer’s specification, or if required by the surveyor. After type test run sensitive parts of the gas turbine shall be visually inspected after dismantling. The extent of dismantling shall be agreed upon between Manufacturer and Society individually. But the dismantling should be at least such, that a visual inspection of blading, bearings and internal part of casing is feasible.

6.6.5 A report summarising findings from inspection and tear-down shall be submitted for information, part of the report is also the documentation of the Borescope taping.

6.7 Certification testing (FAT, manufacturer’s works)

6.7.1 Certification testing procedure
Each gas turbine to be certified shall be tested in the factory. The purpose of the factory testing shall verify the design premises such as performance, safety (against fire), adherence to maximum temperatures, speeds, pressures, functionality and product quality.

6.7.2 The test bed shall be equipped in a way to provide adequate measuring data for documentation and reporting purposes (see Table 8).

6.7.3 The gas turbine manufacturer shall prior to testing document that all instrumentation is calibrated. The gas turbine manufacturer shall compile all results in a test protocol that shall be endorsed by the attending surveyor and submitted to the Society for later reference.

6.7.4 The certification test shall include vibration measurements. Steady state vibration levels shall be recorded for different speeds and outputs, in accordance to the manufacturer’s specification. The manufacturer shall provide the Society with the vibration acceptance criteria that shall be used during the test.

6.7.5 The control and monitoring systems used in the test shall be representative of the type approved control and monitoring system, to the extent related to the gas turbine. Deviations from the type approved control and monitoring system, and the reasons for the changes shall be presented to the Society in due time before testing.

6.7.6 For case by case approved gas turbines the workshop testing may be extended up to the full type testing if found necessary by the Society.

6.7.7 Certification testing shall be performed on the complete gas turbine. In the case that the gas generator and the power turbine have been tested separately, the Society accepts that the certification testing of the complete gas turbine is performed on board (see [6.10]).

6.7.8 The complete intended test procedure (performance), including description of measuring capabilities of test bed, description of safety and control system of test bed and extent of reporting (tables) shall be submitted to the Society in advance for approval.

6.7.9 Any deviation to the gas turbine design and gas turbine dressing from that of the type test shall be stated in the test report, together with the reason for the changes.
6.8 Certification test program

6.8.1 The certification test shall include testing found necessary by the Society to demonstrate:
— starting, idling, acceleration, deceleration, stopping
— safe operating characteristics throughout its specified operating envelop.

The certification test shall simulate the conditions in which the gas turbine is expected to operate in service, including typical start-stop cycles and load points.

The gas turbine shall be run for at least 90 minutes at the maximum continuous power in service.

6.8.2 Prior to the start of the certification test, the gas turbine and the control and monitoring system shall demonstrate trouble free running at no load for 20 minutes.

6.8.3 Before and after test, lube oil shall be sampled for testing of contamination of metallic wear particles. The result shall be in accordance with the specification of the manufacturer.

6.8.4 Test profile for propulsion gas turbine

The gas turbine shall be tested at power levels to be agreed upon with the Society. The number of steady points of operation shall be sufficient to establish gas turbine's characteristic operational values in accordance to the intended application (see below). Prolonged operation at the 100% point is required for certification purposes. The operating time per load point depends on the gas turbine size (achievement of steady state condition) and on the time for collection of the operating values. To be agreed prior to testing.

Guidance note:
The steady state points are typically 100%, 90%, 75%, 50%, 25% and 10% of gas turbine's output (load). Additionally prove of overload operation (110%) is required. The set speed for the power turbine should follow the application.

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The propeller curve based on the propeller law (variable revolutions)

This applies if driving a fixed pitch propeller, water jet or controllable pitch propeller with variable r/min and pitch limited to nominal value, or other combinatory curve.

a) At constant speed
   This applies if driving a controllable pitch propeller with constant speed or an electric generator for propulsion.

b) For gas turbines driving generators an additional test of dropping load from 100% to 0% is required. This test aims to prove that the gas turbine shall not trip due to overspeed in the case of sudden load drop. It is recommended to apply same test for gas turbines driving water jets. It shall not trigger the overspeed protection function (no trip).

Guidance note:
The precise test details should take test facility capabilities into account. If the facilities are incapable of providing the load shed, alternative solutions may be agreed with the Society.

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6.8.5 Test profile for gas turbine driving electrical generator

In addition to the tests described above [6.8], the requirements in Sec.1 [5.2.2] shall be verified by testing incorporating the intended type of generator. If this cannot be done in the workshop, the test shall be postponed to shipboard testing.

In case the tests were carried out in the type testing (see [6.5]) with the intended type of generator, the test can be waived.
6.9 Inspection of condition of parts (Borescope)

6.9.1 For type approved gas turbine, after conducting of FAT in accordance to [6.8], Borescope inspection is required. The scope of the inspection may be reduced, compared to the type approval procedure, see [6.6], in agreement with the attending surveyor.

6.9.2 A taped report for the Borescope inspection shall not be required. The attending surveyor shall confirm carrying out of Borescope inspection. Tear out for visual check of parts shall not be required by the Society for type approved gas turbines, and so far Borescope inspection is carried out to the satisfaction of the surveyor.

6.10 Shipboard trials

6.10.1 Gas turbines, subject to certification, shall be tested after installation when connected to the ship’s systems and driven units. Additionally the control, monitoring and safety system of the installation shall only in exceptional cases be the same as the manufacturer’s test bed equipment. Aim of the shipboard trials shall prove safe and reliable operation in the dedicated marine environment but also to enable testing under all possible operating conditions.

6.10.2 Although all required tests for final certification could be checked during sea trials, it may be agreed upon with the Society to verify the correct functioning under low load, idling or even standstill conditions of the propulsion plant.

Guidance note:
For logistic but also to reduce risks during sea trials, many tests are carried out at the quay. Typically, operational tests for turbine driven generators may be carried out at the quay, while for direct propulsion units, sea trial remain the only alternative for high load or dynamic condition testing. For the purposes of approval by the Society only the sea trial schedule shall be submitted for approval. Quay tests may be accepted as final trials, as far as operation of the ship on sea is irrelevant for the applied criteria. This can be agreed upon with attending surveyor, separate submission of a Quay Trial program for approval purposes is not required, but should be reviewed on application.

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6.10.3 Quay testing after or during installation shall focus on typical installation items, which cannot easily be traced back in case of occurrence of malfunctions during sea trials. Such are alarms, safety and control functions, cleanliness and availability of lubricants etc. Additionally, low load or idling operation of the gas turbine, so far applicable, may give the opportunity for first operational tests, correct supply lines, checking of sensors. For Generator turbines further load sharing matters and speed control behaviour may be checked.

6.10.4 Sea trial procedure
The sea trial procedure shall be approved by the Society prior to testing.
The sea trial shall include testing found necessary by the Society to demonstrate:
— starting, idling, acceleration, deceleration, stopping
— safe operating characteristics throughout its specified operating envelope.
The sea trial shall simulate the conditions in which the gas turbine is expected to operate in service, including typical start-stop cycles.

As a minimum, the gas turbine shall be run for 4 hours at the maximum continuous power in service.
For gas turbine installations incorporating back-up or emergency fuel supply and lubrication oil supply, the changeover of supplies shall be tested. Changeover of fuel supply shall be performed at full load.

There shall be at least one false gas turbine start, pausing for the manufacturer’s specified minimum fuel drainage time, before attempting a normal start. Minimum time required for restart of gas turbine shall be checked in order to verify that start can be achieved before thermal interlock occurs.
6.10.5 Vibration measurements

The sea trial shall include vibration measurements.

During sea trials vibration measurements shall be performed for the gas turbine. The measurements shall be carried out according to the manufacturer's specification and aim to prove normal operation in comparison to the limits given by the maker and the results of the measurements of the type test and FAT. In case of doubts or observation of abnormally high vibrations, especially of fast rotating shafts and their supports, the attending surveyor may require more sophisticated measurements, including frequency analysis and other techniques in order to detect and eliminate the causes.

Guidance note:

Especially for fast turning parts unbalances and incorrect alignment may be a main cause for vibrations, highly amplified, in cases of vicinity of a bending resonance. These effects may be traced back also under low load conditions, since mainly dependable on the revolutions. For this reason checking of the plant at the quay for such vibrations, before sea trials, is highly recommended, so far the gas turbine can be run at variable speed without load.

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In special cases where the installation is of such character that the dynamic characteristic can be considered identical with the certification test set-up, only order tracking measurements shall be required. The manufacturer shall provide the Society with the vibration acceptance criteria that shall be used during the test (see also [5]).

6.10.6 The acceleration and deceleration of the gas turbine shall be witnessed by the Society. The parameters of the control system governing these sequences shall be that of the sequences and time constants covered by the type approval.

6.10.7 The temperature of hot surfaces shall be checked during full load testing, except when the gas turbine is fitted in an enclosure, see [2.4]. Where surface temperatures exceed 220°C, remedial actions as described in [2.4] are required. It is advised to use thermographic analyses for documentation.

6.10.8 Sea trial of mechanical drive propulsion gas turbines

In addition to the test profile defined in [6.8] the gas turbine shall be tested at power levels agreed with the Society prior to the sea trial. The number of points shall be sufficient to establish the speed – power relationship. Crash-stop conditions shall be tested from full speed ahead, this shall be performed in the fastest time permitted by the controls of the gas turbine.

6.10.9 Sea trial of gas turbines for generating sets

Tests as necessary to verify requirements in Ch.2 Sec.4 shall be carried out if not performed during certification test or type test together with the actual generator. Such trials may be also carried out as quay tests, with full installed power sharing, control and safety equipment. However, if the generator sets are serving propulsion motors, an additional final test under sea trials conditions is required (esp. load sharing, drop of load).

6.10.10 Sea trials of gas turbines for high speed, light craft and naval surface craft

For high speed, light craft and naval surface craft, the test shall include full speed turn (shortest radius) in both port and starboard directions. Vibration levels shall not increase significantly.

6.10.11 Inspection after sea trials

A Borescope inspection may be required by the Society. In such case, and if the behaviour of the gas turbine does not call for further inspections, it is recommended to focus the Borescope inspection on already registered files of the FAT for the same unit (see also [6.9]).
SECTION 3 STEAM TURBINES

1 General

1.1 Application

1.1.1 The requirements in this section apply to steam turbines used for the functions listed in Ch.2 Sec.1 [1.1]. The steam turbines are subject to certification, installation survey and shipboard testing.


1.2 Certification requirements

1.2.1 Products shall be certified as required by Table 1

<table>
<thead>
<tr>
<th>Table 1 Certification requirements</th>
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<tbody>
<tr>
<td><strong>Object</strong></td>
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<tr>
<td>Steam turbine</td>
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</tbody>
</table>

Unless otherwise specified the certification standard is DNVGL Rules

1.2.2 For general certification requirements see Pt.1 Ch.3 Sec.4.

1.2.3 For a definition of the certificate types see Pt.1 Ch.3 Sec.5.

1.3 Documentation requirements - Manufacturer

1.3.1 The manufacturer shall submit the documentation required by Table 2. The documentation shall be reviewed by the Society as a part of the class contract.

<table>
<thead>
<tr>
<th>Table 2 Documentation requirements for the manufacturer</th>
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<tbody>
<tr>
<td><strong>Object</strong></td>
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<tr>
<td>Steam turbine</td>
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<tr>
<td>Rotor</td>
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<tr>
<td>Blade</td>
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<tr>
<td>Casing</td>
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</tbody>
</table>
1.3.2 For general requirements for documentation, including definition of the info codes, see Pt.1 Ch.3 Sec.2.

1.3.3 For a full definition of the documentation types, see Pt.1 Ch.3 Sec.3.

1.3.4 For details about NDT specification, see Ch.2 Sec.1 [3.1.2].

1.4 Documentation requirements - Builder

1.4.1 The builder shall submit the documentation required by Table 3. The documentation shall be reviewed by the Society as a part of the certification contract.

Table 3 - Documentation requirements - Builder

<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
<th>Info</th>
</tr>
</thead>
</table>

1.4.2 For general requirements for documentation, including definition of the info codes, see Pt.1 Ch.3 Sec.2.

1.4.3 For a full definition of the documentation types, see Pt.1 Ch.3 Sec.3.

2 Design

2.1 General

2.1.1 For general design principles concerning machinery, see Ch.2 Sec.3. Special attention should be paid to Ch.2 Sec.3 [1.1.2]. For general design requirements regarding piping and ancillary equipment, such as pipes, filters, coolers etc., see Ch.6 and Ch.7, as found applicable.

2.1.2 Means for going astern
The main propulsion machinery shall possess sufficient power for running astern. The astern power is considered to be sufficient if, given free running astern, it is able to attain astern revolutions equivalent to at least 70% of the rated ahead revolutions for a period of at least 30 minutes.
For main propulsion machinery with reverse gearing, controllable pitch propellers or an electrical transmission system, astern running shall not cause any overloading of the propulsion machinery.
2.2 Component design requirements

2.2.1 Rotors shall have a separation margin of at least 25% (of rated speed) between critical speed and operating speed range.

2.2.2 Turbines shall be able to withstand the temperature variations that can arise when starting, stopping and manoeuvring.

2.2.3 The pipes of the gland-sealing system shall be self-draining, and precaution shall be taken against the possibility of condensed steam entering the glands and turbines. The steam supply to the gland sealing shall be fitted with an effective drain trap. In the air ejector re-circulating water system, the connection to the condenser shall be so located that water cannot impinge on the low pressure rotor or casing.

2.2.4 The casings shall be designed so as to provide containment in case of a blade loss. See Ch.2 Sec.1 [2.1.5] This requirement does not exempt the blade fastening from being designed so as to sustain any permissible over-speed.

2.2.5 All blades and other relevant moving parts shall have sufficiently large axial and radial clearances, so that no harmful interference with static members can occur under any operating condition.

2.2.6 Condensers

The condenser shall be so designed that the inlet steam speed does not result in prohibitive stressing of the condenser tubes. Excessive sagging of the tubes and vibration shall be avoided, e.g. by the incorporation of tube supporting plates.

The water chambers and steam space shall be provided with openings for inspection and cleaning. Anti-corrosion protection shall be provided on the water side. In the case of single-plane turbine installations, suitable measures shall be taken to prevent condensate from flowing back into the low pressure turbine.

3 Inspection and testing

3.1 General

3.1.1 Products shall be certified as required by Table 4.

Table 4 Certification required

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Turbine</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotor</td>
<td>MC</td>
<td>Society</td>
<td></td>
<td>Manufacturer if auxiliary service</td>
</tr>
<tr>
<td>Individual discs</td>
<td>MC</td>
<td>Society</td>
<td></td>
<td>Manufacturer if auxiliary service</td>
</tr>
<tr>
<td>Couplings</td>
<td>MC</td>
<td>Society</td>
<td></td>
<td>Manufacturer if auxiliary service</td>
</tr>
<tr>
<td>Casing</td>
<td>MC</td>
<td>Manufacturer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blades</td>
<td>MC</td>
<td>Manufacturer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diaphragms</td>
<td>MC</td>
<td>Manufacturer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steam Valve Casings</td>
<td>MC</td>
<td>Manufacturer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.1.2 For general certification requirements, see Pt.1 Ch.3 Sec.4.

3.1.3 For a definition of the certification types, see Pt.1 Ch.3 Sec.5.

3.1.4 The manufacturer shall have a quality control system that is suitable for the type of turbine. This shall also cover subcontractors.

The extent of quality control that shall be documented to the Society by work (W) certificates, or to be inspected and certified by the Society is given in the following.

If found necessary, due to service experience, an extended scope of testing and inspection may be required.

3.1.5 Results from the testing and inspection shall be evaluated against the acceptance criteria in the applicable NDT specifications included in the documents listed in Table 1.

3.1.6 Hydraulic testing applies for both propulsion and auxiliary turbines as given in Table 5.

3.1.7 Devices for the attachment of heat insulation (bolts, hooks, etc.) shall be welded on to the turbine casing before the final heat treatment of the casing.

3.1.8 All rotors shall be dynamically balanced in minimum two planes.

**Table 5 Hydraulic testing**

<table>
<thead>
<tr>
<th>Component</th>
<th>Test pressure</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.5 p 1)</td>
<td></td>
</tr>
<tr>
<td>Main flow valves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP/LP crossover pipe</td>
<td>x</td>
<td>See Ch.6</td>
</tr>
<tr>
<td>Turbine casings</td>
<td>x</td>
<td>May be suitably subdivided. Not less than 2 bar</td>
</tr>
</tbody>
</table>

1) p = working pressure

4 Workshop testing

4.1 General turbine tests

4.1.1 The turbine shall be tested in the workshop and a complete test report shall be given to the surveyor.

4.1.2 Turbines shall undergo running tests that cover the whole speed range up to 110% of rated speed. For propulsion turbines this applies to both ahead and astern operation.
4.1.3 Vibration levels shall be recorded in the whole speed range (up to 110%) at several speed settings.

4.1.4 The control and monitoring systems shall be tested according to Ch.9 Sec.1 as far as it has been arranged during the workshop testing.

4.1.5 Both before and after the test a lubricating oil sample shall be tested for traces of metallic particles.

4.1.6 A visual inspection of internal parts shall be carried out to the extent as requested by the surveyor.

4.1.7 For main propulsion turbines, the following inspection procedures apply after testing:

— Axial clearances in thrust bearing and clearances between blades and stationary parts shall be checked by sample testing after the test run. The measured clearances shall be compared with equivalent measurements made during assembly, and approved plans.

— The rotors shall be lifted. Bearings, blades, wires and shroud rings shall be examined, and it shall be verified that no damaging contact has taken place between rotating and stationary parts.

Scope of inspection of turbines for purposes other than main propulsion shall be subject to special consideration. Opening up shall be required when any abnormalities are discovered during testing.

5 Control and monitoring

5.1 General

5.1.1 The requirements in [5] are additional to those given in Ch.9.

5.2 Speed governing

5.2.1 Turbines shall be equipped with speed governors. For propulsion turbines which incorporate a reversing gear, electric transmission, controllable pitch propeller or other free-coupling arrangement, the governor(s) shall be able to control the speed of any turbine that can become unloaded.

For auxiliary turbines driving generators, see Sec.1 [5.2].

The speed governors shall be able to control the turbine speed so as to avoid any relevant load shed to activate the separate overspeed protective device.

5.2.2 In addition to the speed governor, a separate over-speed protection device shall be provided and shall be adjusted so as to avoid transient speed beyond 115% of rated speed or beyond the permissible transient speed, whichever is less.

Where two or more propulsion turbines are coupled to the same reduction gear, and without any free coupling device, only one over-speed protection device is required.

5.2.3 For propulsion turbines

Automatic or semiautomatic control systems shall provide controlled load changes to avoid thermal shocks and other unacceptable transients.
5.3 Safety functions and devices

5.3.1 Arrangement shall be provided for shutting off the steam to the propulsion turbines by suitable hand trip gear situated at the manoeuvring stand and at the turbine itself. Hand tripping for auxiliary turbines shall be arranged in the vicinity of the turbine over-speed protective device.

**Guidance note:**
The hand trip gear is understood to be any device which is operated manually irrespective of the way the action is performed, i.e. mechanically or by means of external power.

5.3.2 Where exhaust steam from auxiliary systems is led to the propulsion turbine, the steam supply shall be cut off at activation of the over-speed protective device.

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

5.3.4 Starting interlock shall be provided when turning gear is engaged.

5.4 Monitoring

5.4.1 For monitoring of propulsion steam turbines, see Table 6.

Table 6 Control and monitoring of propulsion turbines

<table>
<thead>
<tr>
<th>System</th>
<th>Item</th>
<th>Gr 1 Indicationalarm load reduction</th>
<th>Gr 2 Automatic start of stand-by pump with alarm</th>
<th>Gr 3 Shut down with alarm</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Lubricating oil</td>
<td>Inlet pressure (after filter)</td>
<td>IR, IL, LA</td>
<td>AS</td>
<td>SH 1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inlet temperature</td>
<td>IR, HA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Filter differential pressure</td>
<td>IR, HA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Level in system tank</td>
<td>LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0 Bearings</td>
<td>Bearing temperature</td>
<td>IR, HA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0 Turbine speed</td>
<td>Overspeed</td>
<td>(LR)</td>
<td>SH</td>
<td></td>
<td>LR or SH, if applicable, to be activated automatically, see [5.2]</td>
</tr>
<tr>
<td>4.0 Condenser system</td>
<td>Vacuum</td>
<td>IR, LA</td>
<td>SH</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vacuum pump stopped</td>
<td>AS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Level</td>
<td>IR, HA</td>
<td>AS</td>
<td>SH</td>
<td></td>
</tr>
<tr>
<td>System</td>
<td>Item</td>
<td>Gr 1</td>
<td>Gr 2</td>
<td>Gr 3</td>
<td>Comment</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indication</td>
<td>Automatic start</td>
<td>Shut down</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>alarm</td>
<td>of stand-by pump</td>
<td>with alarm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>load reduction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level</td>
<td></td>
<td>IR, LA</td>
<td></td>
<td></td>
<td>If non-cavitating condensate pump</td>
</tr>
<tr>
<td>Salinity</td>
<td></td>
<td>HA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0 Cooling water (main condenser)</td>
<td>Inlet/outlet differential pressure</td>
<td>IR, LA</td>
<td></td>
<td>AS</td>
<td></td>
</tr>
<tr>
<td>6.0 Slow turning arrangement</td>
<td>Overspeed</td>
<td></td>
<td></td>
<td>SH</td>
<td></td>
</tr>
<tr>
<td>7.0 Gland steam</td>
<td>Inlet pressure to turbine</td>
<td>IR, LA, HA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exhaust fan stopped</td>
<td></td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.0 Hydraulic system</td>
<td>Pressure</td>
<td>IR, LA</td>
<td></td>
<td>AS</td>
<td></td>
</tr>
<tr>
<td>9.0 Vibration</td>
<td>Level</td>
<td>HA</td>
<td></td>
<td>SH</td>
<td></td>
</tr>
<tr>
<td>10.0 Rotor</td>
<td>Axial displacement</td>
<td>IR, HA</td>
<td></td>
<td>SH</td>
<td></td>
</tr>
</tbody>
</table>

Gr 1 = Sensor(s) for indication, alarm, load reduction (common sensor permitted but with different set points and alarm shall be activated before any load reduction)

Gr 2 = Sensor for automatic start of standby pump

Gr 3 = Sensor for shut down

IL = Local indication – (presentation of values) in vicinity of the monitored component

IR = Remote indication – (presentation of values) in engine control room or another centralized control station such as the local platform/manoeuvring console

A = Alarm activated for logical value

LA = Alarm for low value

HA = Alarm for high value

AS = Automatic start of standby pump with corresponding alarm

LR = Load reduction, either manual or automatic, with corresponding alarm

SH = Shut down with corresponding alarm. May be manually (request for shut down) or automatically executed if not explicitly stated above.

For definitions of Load reduction (LR) and Shut down (SH), see Ch.1.

1) The shut down shall be so arranged as not to prevent admission of steam to the astern turbine for braking.

5.4.2 For monitoring of auxiliary steam turbines, see Table 7.
# Table 7 Control and monitoring of auxiliary turbines

<table>
<thead>
<tr>
<th>System</th>
<th>Item</th>
<th>Gr 1 Indication alarm load reduction</th>
<th>Gr 2 Automatic start of stand-by pump with alarm</th>
<th>Gr 3 Shut down with alarm</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Lubricating oil</td>
<td>Inlet pressure (after filter)</td>
<td>IR or IL, LA</td>
<td></td>
<td></td>
<td>SH</td>
</tr>
<tr>
<td></td>
<td>Inlet temperature</td>
<td>IR or HA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Level in system tank</td>
<td>LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0 Turbine speed</td>
<td>Overspeed</td>
<td></td>
<td></td>
<td></td>
<td>SH, if applicable, to be activated automatically, see [5.2]</td>
</tr>
<tr>
<td>3.0 Condenser system</td>
<td>Pressure</td>
<td>IL or IR, HA</td>
<td></td>
<td></td>
<td>SH</td>
</tr>
<tr>
<td>4.0 Steam inlet</td>
<td>Pressure</td>
<td>IL or IR, LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0 Rotor</td>
<td>Axial displacement</td>
<td>IL or IR, HA</td>
<td></td>
<td></td>
<td>SH, If driving electric generator</td>
</tr>
</tbody>
</table>

### Glossary

- **Gr 1** = Sensor(s) for indication, alarm, load reduction (common sensor permitted but with different set points and alarm shall be activated before any load reduction)
- **Gr 2** = Sensor for automatic start of standby pump
- **Gr 3** = Sensor for shut down
- **IL** = Local indication – (presentation of values) in vicinity of the monitored component
- **IR** = Remote indication – (presentation of values) in engine control room or another centralized control station such as the local platform/manoeuvring console
- **A** = Alarm activated for logical value
- **LA** = Alarm for low value
- **HA** = Alarm for high value
- **AS** = Automatic start of standby pump with corresponding alarm
- **LR** = Load reduction, either manual or automatic, with corresponding alarm
- **SH** = Shut down with corresponding alarm. May be manually (request for shut down) or automatically executed if not explicitly stated above.

For definitions of Load reduction (LR) and Shut down (SH), see Ch.1.

1) Only for turbines driving generators, may be omitted if LA for boiler steam pressure is provided.

# 6 Arrangement

## 6.1 General arrangement

### 6.1.1 The turbine exterior and the immediate environment shall be such as to prevent conceivable hazardous situations from occurring.

All exterior surface temperature shall be less than 220°C.
6.1.2 Non-return valves, or other approved means that shall prevent steam and water returning to the turbines, shall be fitted in bled steam connections.

6.1.3 The fastening of the turbine shall be designed so as to cope with all forces due to thermal expansion, including inlet and outlet piping. Foundation shall be in compliance with Ch.2 Sec.1 [6]

6.2 Arrangement of propulsion machinery

6.2.1 The turbine installation shall allow for efficient changeover between ahead and astern running. The manoeuvring system shall not cause any harmful effects.

6.2.2 Any probable single failure in any of the turbines shall for an extended period of time not result in loss of manoeuvrability, see [6.2.6].

6.2.3 Provision for turning continuously shall be arranged.

6.2.4 Efficient steam strainers shall be provided close to the inlets to ahead and astern high pressure turbines or alternatively at the inlets to manoeuvring valves.

6.2.5 Propulsion turbines shall be provided with a satisfactory emergency supply of lubricating oil that shall come into use automatically when the pressure drops below a predetermined value. The emergency supply may be obtained from a gravity tank containing sufficient oil to maintain adequate lubrication until the turbine is brought to rest or by equivalent means. If emergency pumps are used these shall be arranged so that their operation is not affected by failure of the power supply. Suitable arrangement for cooling the bearings after stopping may also be required.

6.2.6 In single screw ships fitted with cross compound steam turbines, the arrangement shall be such as to enable safe navigation (minimum 40% of full speed along the theoretical propeller curve) when the steam supply to any one of the turbines is required to be isolated. For this emergency purpose the steam may be led directly to the L.P. turbine, and either the H.P. or M.P. turbine can exhaust directly to the condenser. Adequate arrangements and controls shall be provided for these operating conditions so that the pressure and temperature of the steam shall not exceed those that the turbine and condenser can withstand safely. Necessary pipes and valves for these arrangements shall be readily available and properly marked.

A fit up test is required, see [8.1.2].

Guidance note:
With reference to Ch.2 Sec.1 [2.1.5] these possible operation modes need not be tested during sea trial.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

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

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

7 Vibrations

7.1 Torsional vibrations

7.1.1 For propulsion plants torsional vibrations calculations comprising the whole plant shall be submitted for approval.

The calculations shall contain determination of natural frequencies and corresponding critical speeds. Regarding assumptions on propeller excitation, see Ch.2 Sec.2 [2.5.9].
Speed ranges where gear hammer may occur, shall be barred for continuous operation. See Ch.2 Sec.2 Table 5.

8 Installation inspections

8.1 General

8.1.1 Alignment between turbine and gearbox shall be checked in the presence of the surveyor.

8.1.2 Proper functioning of safety functions and devices (see [5.3] and [6.2]) shall as far as practicable be checked prior to the sea trial. A fit up test of all combinations of pipes and valves as required in [6.2.6] shall be performed prior to the first sea trials.

9 Shipboard testing

9.1 General

9.1.1 The turbines shall be tested according to an agreed programme. Upon completion of the sea trial, the complete test report shall be given to the surveyor.

9.1.2 The control, safety and monitoring systems shall be tested according to [5] and Ch.9 Sec.1.

9.1.3 Turbine vibration levels shall be measured at the same positions as in [4.1.3]. The results shall be compared, and in case of acceptance dispute, frequency analysed in order to eliminate turbine alien frequencies shall be carried out.

9.1.4 Oil filters shall be examined for metal particles after the sea trial.

9.1.5 The temperature of hot surfaces shall be checked during full load testing. Where surface temperatures exceed 220°C insulation of non-absorbent material covered by sheet metal shall be fitted. It is advised to use thermographic analyses for documentation.

9.2 Auxiliary turbines

9.2.1 Turbine generator sets shall be tested to verify that requirements in Ch.2 Sec.4 are met.

9.3 Propulsion turbines

9.3.1 The minimum full load test duration is 4 hours ahead and 20 minutes astern.

9.3.2 Gears shall be checked for possible gear hammering. See Ch.4 Sec.2 [9.2].
CHANGES – HISTORIC

October 2015 edition

General
This is a new document.
The rules enter into force 1 January 2016.
Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16 000 professionals are dedicated to helping our customers make the world safer, smarter and greener.