Requirements concerning

MACHINERY INSTALLATIONS
### CONTENTS

<p>| M1 | Cylinder overpressure monitoring of internal combustion engines | Deleted Aug 2004 |
| M2 | Alarm devices of internal combustion engines | 1971 |
| M3 | Speed governor and overspeed protective device | Rev.5 Feb 2006 |
| M4 | Deleted |
| M5 | Mass production of internal combustion engines, procedure for inspection | Deleted Feb 2015 |
| M6 | Test pressures for parts of internal combustion engines | Deleted Feb 2015 |
| M7 | Re-categorized as “Recommendation” No. 26 |
| M8 | Re-categorized as “Recommendation” No. 27 |
| M9 | Crankcase explosion relief valves for crankcases of internal combustion engines | Corr.2 Sept 2007 |
| M10 | Protection of internal combustion engines against crankcase explosions | Rev.4 July 2013 |
| M11 | Protective devices for starting air mains | 1972 |
| M12 | Fire extinguishing systems for scavenge manifolds | 1972 |
| M13 | Re-categorized as “Recommendation” No. 28 |
| M14 | Mass production of internal combustion engines: definition of mass production | Deleted Feb 2015 |
| M15 | Re-categorized as “Recommendation” No. 29 |
| M16 | Devices for emergency operation of propulsion steam turbines | Rev.1 Jan 2005 |</p>
<table>
<thead>
<tr>
<th>M17</th>
<th>Deleted 1 July 1998</th>
</tr>
</thead>
<tbody>
<tr>
<td>M18</td>
<td>Parts of internal combustion engines for which material tests are required Deleted Feb 2015</td>
</tr>
<tr>
<td>M19</td>
<td>Parts of internal combustion engines for which nondestructive tests are required Deleted Feb 2015</td>
</tr>
<tr>
<td>M20</td>
<td>Periodical survey of machinery Deleted Nov 2001</td>
</tr>
<tr>
<td>M21</td>
<td>Mass production of internal combustion engines: type test conditions Deleted Feb 2015</td>
</tr>
<tr>
<td>M22</td>
<td></td>
</tr>
<tr>
<td>M23</td>
<td>Mass production of engines: mass produced exhaust driven turboblowers Deleted Feb 2015</td>
</tr>
<tr>
<td>M24</td>
<td>Requirements concerning use of crude oil or slops as fuel for tanker boilers Rev.1 1976</td>
</tr>
<tr>
<td>M25</td>
<td>Astern power for main propulsion Rev.3 July 2003</td>
</tr>
<tr>
<td>M26</td>
<td>Safety devices of steam turbines Corr.1 Feb 2005</td>
</tr>
<tr>
<td>M27</td>
<td>Bilge level alarms for unattended machinery spaces 1976</td>
</tr>
<tr>
<td>M28</td>
<td>Ambient reference conditions 1978</td>
</tr>
<tr>
<td>M29</td>
<td>Alarm systems for vessels with periodically unattended machinery spaces Rev.3 1997</td>
</tr>
<tr>
<td>M30</td>
<td>Safety systems for vessels with periodically unattended machinery spaces Rev.1 1997</td>
</tr>
<tr>
<td>M31</td>
<td>Continuity of electrical power supply for vessels with periodically unattended machinery spaces 1978</td>
</tr>
<tr>
<td>M32</td>
<td>Definition of diesel engine type Deleted Feb 2015</td>
</tr>
<tr>
<td>M33</td>
<td>Scantlings of intermediate shafts</td>
</tr>
<tr>
<td>M34</td>
<td>Scantlings of coupling flanges</td>
</tr>
<tr>
<td>M35</td>
<td>Alarms, remote indications and safeguards for main reciprocating internal combustion engines installed in unattended machinery spaces</td>
</tr>
<tr>
<td>M36</td>
<td>Alarms and safeguards for auxiliary reciprocating internal combustion engines driving generators in unattended machinery spaces</td>
</tr>
<tr>
<td>M37</td>
<td>Scantlings of propeller shafts</td>
</tr>
<tr>
<td>M38</td>
<td>k-factors for different shaft design features (intermediate shafts)</td>
</tr>
<tr>
<td>M39</td>
<td>k-factors for different shaft design features (propeller shafts)</td>
</tr>
<tr>
<td>M40</td>
<td>Ambient conditions – temperatures</td>
</tr>
<tr>
<td>M41</td>
<td>Superseded by UR E10 (1991)</td>
</tr>
<tr>
<td>M42</td>
<td>Steering gear</td>
</tr>
<tr>
<td>M43</td>
<td>Bridge control of propulsion machinery for unattended machinery spaces</td>
</tr>
<tr>
<td>M44</td>
<td>Documents for the approval of diesel engines</td>
</tr>
<tr>
<td>M45</td>
<td>Ventilation of machinery spaces</td>
</tr>
<tr>
<td>M46</td>
<td>Ambient conditions – inclinations</td>
</tr>
<tr>
<td>M47</td>
<td>Bridge control of propulsion machinery for attended machinery spaces</td>
</tr>
<tr>
<td>M48</td>
<td>Permissible limits of stresses due to torsional vibrations for intermediate, thrust and propeller shafts</td>
</tr>
<tr>
<td>M49</td>
<td>Availability of machinery</td>
</tr>
<tr>
<td>------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>M50</td>
<td>Programme for type testing of non–mass produced i.c. engines</td>
</tr>
<tr>
<td>M51</td>
<td>Factory Acceptance Test and Shipboard Trials of I.C. Engines</td>
</tr>
<tr>
<td>M52</td>
<td>Length of aft stern bush bearing</td>
</tr>
<tr>
<td>M53</td>
<td>Calculation of crankshafts for i.c. engines</td>
</tr>
<tr>
<td>M54</td>
<td>Deleted 1997</td>
</tr>
<tr>
<td>M55</td>
<td>Planned maintenance scheme (PMS) for machinery</td>
</tr>
<tr>
<td>M56</td>
<td>Marine gears – load capacity of involute parallel axis spur and helical gears</td>
</tr>
<tr>
<td>M57</td>
<td>Use of ammonia as a refrigerant</td>
</tr>
<tr>
<td>M58</td>
<td>Charge air coolers</td>
</tr>
<tr>
<td>M59</td>
<td>Control &amp; safety systems for dual fuel diesel engines</td>
</tr>
<tr>
<td>M60</td>
<td>Control and safety of gas turbines for marine propulsion use</td>
</tr>
<tr>
<td>M61</td>
<td>Starting arrangements of internal combustion engines</td>
</tr>
<tr>
<td>M62</td>
<td>Rooms for emergency fire pumps in cargo ships</td>
</tr>
<tr>
<td>M63</td>
<td>Alarms and safeguards for emergency diesel engines</td>
</tr>
<tr>
<td>M64</td>
<td>Design of integrated cargo and ballast systems on tankers</td>
</tr>
<tr>
<td>M65</td>
<td>Draining and pumping forward spaces in bulk carriers</td>
</tr>
</tbody>
</table>
M66  Type testing procedure for crankcase explosion relief valves  Rev.3 Jan 2008

M67  Type testing procedure for crankcase oil mist detection and alarm equipment  Rev.2 Feb 2015

M68  Dimensions of propulsion shafts and their permissible torsional vibration stresses  Rev.2 Apr 2015

M69  Qualitative failure analysis for propulsion and steering on passenger ships  June 2008

M70  Under Development

M71  Type Testing of I.C. Engines  Corr.1 June 2016

M72  Certification of Engine Components  Rev.1 Mar 2016

M73  Turbochargers  Corr.1 June 2016

M74  Installation of Ballast Water Management Systems  Rev.1 May 2016

M75  Ventilation of emergency generator rooms  Feb 2016

M76  Location of fuel tanks in cargo area on oil and chemical tankers  Apr 2016

M77  Storage and use of SCR reductants  Sep 2016
Cylinder overpressure monitoring of internal combustion engines

Deleted in Aug 2004

Alarm devices of internal combustion engines

Main and auxiliary engines, above 37 kW, must be fitted with an alarm device with audible and luminous signals for failure of the lubricating oil system.

Speed governor and overspeed protective device

M3.1 Speed governor and overspeed protective device for main internal combustion engines

1. Each main engine is to be fitted with a speed governor so adjusted that the engine speed cannot exceed the rated speed by more than 15%.

2. In addition to this speed governor each main engine having a rated power of 220 kW and above, and which can be declutched or which drives a controllable pitch propeller, is to be fitted with a separate overspeed protective device so adjusted that the engine speed cannot exceed the rated speed by more than 20%. Equivalent arrangements may be accepted upon special consideration.

3. When electronic speed governors of main internal combustion engines form part of a remote control system, they are to comply with UR M43.8 and M43.10 or M47 and namely with the following conditions:
   – if lack of power to the governor may cause major and sudden changes in the present speed and direction of thrust of the propeller, back up power supply is to be provided;
   – local control of the engines is always to be possible, as required by M43.10, and, to this purpose, from the local control position it is to be possible to disconnect the remote signal, bearing in mind that the speed control according to UR M3.1, subparagraph 1, is not available unless an additional separate governor is provided for such local mode of control.
   – In addition, electronic speed governors and their actuators are to be type tested according to UR E10.
NOTE:
The rated power and corresponding rated speed are those for which classification of the installation has been requested.

M3.2  Speed governor, overspeed protective and governing characteristics of generator prime movers

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

   In the case when a step load equivalent to the rated output of a generator is switched off, a transient speed variation in excess of 10% of the rated speed may be acceptable, provided this does not cause the intervention of the overspeed device as required by 3.1.1

2. At all loads between no load and rated power the permanent speed variation should not be more than ±5% of the rated speed.

3. Prime movers are to be selected in such a way that they will meet the load demand within the ship’s mains.

   Application of electrical load should be possible with 2 load steps and must be such that prime movers – running at no load – can suddenly be loaded to 50% of the rated power of the generator followed by the remaining 50% after an interval sufficient to restore the speed to steady state. Steady state conditions should be achieved in not more than 5 seconds.

   Steady state conditions are those at which the envelope of speed variation does not exceed +1% of the declared speed at the new power.

   Application of electrical load in more than 2 load steps can only be permitted, if the conditions within the ship’s mains permit the use of such prime movers which can only be loaded in more than 2 load steps (see Fig. 1) and provided that this is already allowed for in the designing stage.

   This is to be verified in the form of system specifications to be approved and to be demonstrated at ship’s trials. This applies analogously also for generators to be operated in parallel and where the power has to be transferred from one generator to another in the event of any one generator has to be switched off.

4. Emergency generator sets must satisfy the governor conditions as per items 1 and 2 even when:

   a) their total consumer load is applied suddenly, or

   b) their total consumer load is applied in steps, subject to:

      - the total load is supplied within 45 seconds since power failure on the main switchboard
      - the maximum step load is declared and demonstrated
      - the power distribution system is designed such that the declared maximum step loading is not exceeded
      - the compliance of time delays and loading sequence with the above is to be demonstrated at ship’s trials.

5. In addition to the speed governor, each prime mover driving an electric generator and having a rated power of 220 kW and above must be fitted with a separate overspeed protective device so adjusted that the speed cannot exceed the rated speed by more than 15%.

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

   For an a.c. generating set intended to operate in parallel, facilities are to be provided to adjust the governor sufficiently fine to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.

NOTE:
For guidance, the loading for 4-stroke diesel engines may be limited as given by Figure 1.
Fig. 1
Limiting curves for loading 4-stroke diesel engines step by step from no-load to rated power as function of the brake mean effective pressure

M4  Deleted

Limits of flash point of oil fuel are covered by F35 as revised and should be referred to.
Mass production of internal combustion engines, procedure for inspection

Deleted Feb 2015, replaced by UR Z26.
Test pressures for parts of internal combustion engines ¹)

Deleted Feb 2015, replaced by UR M72.
M7 Re-categorised as “recommendation” No.26
(1972)
(Rev.1 1987)
M8 Re-categorised as “recommendation” No.27

M8 (1972)
(Rev.1 1989)

End of Document
Crankcase explosion relief valves for crankcases of internal combustion engines

M9.1 Internal combustion engines having a cylinder bore of 200 mm and above or a crankcase volume of 0.6 m³ and above shall be provided with crankcase explosion relief valves in accordance with UR M9.2 to UR M9.13 as follows:

M9.1.1 Engines having a cylinder bore not exceeding 250 mm are to have at least one valve near each end, but, over eight crankthrows, an additional valve is to be fitted near the middle of the engine.

M9.1.2 Engines having a cylinder bore exceeding 250 mm but not exceeding 300 mm are to have at least one valve in way of each alternate crankthrow, with a minimum of two valves.

M9.1.3 Engines having a cylinder bore exceeding 300 mm are to have at least one valve in way of each main crankthrow.

M9.2 The free area of each relief valve is to be not less than 45 cm².

M9.3 The combined free area of the valves fitted on an engine must not be less than 115 cm² per cubic metre of the crankcase gross volume.

M9.4 Crankcase explosion relief valves are to be provided with lightweight spring-loaded valve discs or other quick-acting and self closing devices to relieve a crankcase of pressure in the event of an internal explosion and to prevent the inrush of air thereafter.

M9.5 The valve discs in crankcase explosion relief valves are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

NOTE

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

2. Engines are to be fitted with components and arrangements complying with Revision 3 of this UR, except for M9.8, M9.9 and the second bullet point in M9.10, when:

   1) an application for certification of an engine is dated on/after 1 January 2006; or
   2) installed in new ships for which the date of contract for construction is on or after 1 January 2006.

   The requirements of M9.8, M9.9 and the second bullet point in M9.10 apply, in both cases above, from 1 January 2008.

3. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to IACS Procedural Requirement (PR) No. 29.
M9.6  Crankcase explosion relief valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than $0.02 \text{ N/mm}^2$ (0.2bar).

M9.7  Crankcase explosion relief valves are to be provided with a flame arrester that permits flow for crankcase pressure relief and prevents passage of flame following a crankcase explosion.

M9.8  Crankcase explosion relief valves are to type tested in a configuration that represents the installation arrangements that will used on an engine in accordance with UR M66.

M9.9  Where crankcase relief valves are provided with arrangements for shielding emissions from the valve following an explosion, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

M9.10 Crankcase explosion relief valves are to be provided with a copy manufacturer’s installation and maintenance manual that is pertinent to the size and type of valve being supplied for installation on a particular engine. The manual is to contain the following information:

- Description of valve with details of function and design limits.
- Copy of type test certification.
- Installation instructions.
- Maintenance in service instructions to include testing and renewal of any sealing arrangements.
- Actions required after a crankcase explosion.

M9.11 A copy of the installation and maintenance manual required by UR M9.10 is to be provided on board ship.

M9.12 Plans of showing details and arrangements of crankcase explosion relief valves are to be submitted for approval in accordance with UR M44.

M9.13 Valves are to be provided with suitable markings that include the following information:

- Name and address of manufacturer
- Designation and size
- Month/Year of manufacture
- Approved installation orientation
Protection of internal combustion engines against crankcase explosions

M10.1 Crankcase construction and crankcase doors are to be of sufficient strength to withstand anticipated crankcase pressures that may arise during a crankcase explosion taking into account the installation of explosion relief valves required by UR M9. Crankcase doors are to be fastened sufficiently securely for them not be readily displaced by a crankcase explosion.

M10.2 Additional relief valves are to be fitted on separate spaces of crankcase such as gear or chain cases for camshaft or similar drives, when the gross volume of such spaces exceeds 0.6 m$^3$.

M10.3 Scavenge spaces in open connection to the cylinders are to be fitted with explosion relief valves.

M10.4 Crankcase explosion relief valves are to comply with UR M9.

M10.5 Ventilation of crankcase, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted except for dual fuel engines where crankcase ventilation is to be provided in accordance with UR M59.3.2.(1).

M10.5.1 Crankcase ventilation pipes, where provided, are to be as small as practicable to minimise the inrush of air after a crankcase explosion.

M10.5.2 If a forced extraction of the oil mist atmosphere from the crankcase is provided (for mist detection purposes for instance), the vacuum in the crankcase is not to exceed $2.5 \times 10^{-4}$ N/mm$^2$ (2.5 m bar).

M10.5.3 To avoid interconnection between crankcases and the possible spread of fire following an explosion, crankcase ventilation pipes and oil drain pipes for each engine are to be independent of any other engine.

Note:

1. The requirements of M10 Rev. 3 are to be uniformly implemented by IACS Societies for engines:
   i) when an application for certification of an engine is dated on or after 1 January 2010; or
   ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2010.

2. The requirements of M10 Rev.4 are to be uniformly implemented by IACS Societies for engines:
   i) when an application for certification of an engine is dated on or after 1 January 2015; or
   ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2015.

3. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.
M10.6 Lubricating oil drain pipes from the engine sump to the drain tank are to be submerged at their outlet ends.

M10.7 A warning notice is to be fitted either on the control stand or, preferably, on a crankcase door on each side of the engine. This warning notice is to specify that, whenever overheating is suspected within the crankcase, the crankcase doors or sight holes are not to be opened before a reasonable time, sufficient to permit adequate cooling after stopping the engine.

M10.8 Oil mist detection arrangements (or engine bearing temperature monitors or equivalent devices) are required:

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

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

Oil mist detection arrangements are to be of a type approved by classification societies and tested in accordance with UR M67 and comply with UR M10.9 to UR M10.20. Engine bearing temperature monitors or equivalent devices used as safety devices have to be of a type approved by classification societies for such purposes.

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

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

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

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

Note: For equivalent devices for high-speed engines, refer to UI SC 133.

M10.9 The oil mist detection system and arrangements are to be installed in accordance with the engine designer’s and oil mist manufacturer’s instructions/recommendations. The following particulars are to be included in the instructions:

- Schematic layout of engine oil mist detection and alarm system showing location of engine crankcase sample points and piping or cable arrangements together with pipe dimensions to detector.

- Evidence of study to justify the selected location of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry and the predicted crankcase atmosphere where oil mist can accumulate.

- The manufacturer’s maintenance and test manual.

- Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist detection equipment.

M10.10 A copy of the oil mist detection equipment maintenance and test manual required by UR M10.9 is to be provided on board ship.
M10.11 Oil mist detection and alarm information is to be capable of being read from a safe location away from the engine.

M10.12 Each engine is to be provided with its own independent oil mist detection arrangement and a dedicated alarm.

M10.13 Oil mist detection and alarm systems are to be capable of being tested on the test bed and board under engine at standstill and engine running at normal operating conditions in accordance with test procedures that are acceptable to the classification society.

M10.14 Alarms and shutdowns for the oil mist detection system are to be in accordance with UR M35 and UR M36 and the system arrangements are to comply with UR M29 and UR M30.

M10.15 The oil mist detection arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements.

M10.16 The oil mist detection system is to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

M10.17 Where oil mist detection equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with individual classification society requirements for such systems.

M10.18 Plans of showing details and arrangements of oil mist detection and alarm arrangements are to be submitted for approval in accordance with UR M44 under item 28.

M10.19 The equipment together with detectors is to be tested when installed on the test bed and on board ship to demonstrate that the detection and alarm system functionally operates. The testing arrangements are to be to the satisfaction of the classification society.

M10.20 Where sequential oil mist detection arrangements are provided the sampling frequency and time is to be as short as reasonably practicable.

M10.21 Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase details are to be submitted for consideration of individual classification societies. The following information is to be included in the details to be submitted for consideration:

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

M10.22 Where it is proposed to use the introduction of inert gas into the crankcase to minimise a potential crankcase explosion, details of the arrangements are to be submitted to the classification society for consideration.

End of Document
Protective devices for starting air mains

In order to protect starting air mains against explosion arising from improper functioning of starting valves, the following devices must be fitted:

(i) an isolation non-return valve or equivalent at the starting air supply connection to each engine

(ii) 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.

Devices under (ii) above may be omitted for engines having a bore not exceeding 230 mm.
Fire extinguishing systems for scavenge manifolds

For crosshead type engines, scavenge spaces in open connection to the cylinder must be connected to an approved fire extinguishing system, which is to be entirely separate from the fire extinguishing system of the engine room.
M13 Re-categorised as “Recommendation” No.28

(1973)
(Rev.1 1989)
Mass production of internal combustion engines: definition of mass production

Deleted Feb 2015, replaced by UR Z26.
Re-categorized as “recommendation”
No. 29

Device for emergency operation of propulsion steam turbines

In single screw ships fitted with cross compound steam turbines, the arrangements are to be such as to enable safe navigation when the steam supply to any one of the turbines is required to be isolated. For this emergency operation purpose the steam may be led directly to the L.P. turbine and either the H.P. or M.P. turbine can exhaust direct to the condenser. Adequate arrangements and controls are to be provided for these operating conditions so that the pressure and temperature of the steam will not exceed those which the turbines and condenser can safely withstand.

The necessary pipes and valves for these arrangements are to be readily available and properly marked. A fit up test of all combinations of pipes and valves is to be performed prior to the first sea trials.

The permissible power/speeds when operating without one of the turbines (all combinations) is to be specified and information provided on board.

The operation of the turbines under emergency conditions is to be assessed for the potential influence on shaft alignment and gear teeth loading conditions.

Deleted 1 July 1998
Parts of internal combustion engines for which material tests are required

Deleted Feb 2015, replaced by UR M72.
Parts of internal combustion engines for which nondestructive tests are required

Deleted Feb 2015, replaced by UR M72.
Periodical Survey of Machinery

Mass production of internal combustion engines: type test conditions

Deleted Feb 2015, replaced by UR M71.
Mass production of engines:
mass produced exhaust driven turboblowers

Deleted Feb 2015, replaced by UR M73.
Requirements concerning use of crude oil or slops as fuel for tanker boilers

M24.1 In tankers crude oil or slops may be used as fuel for main or auxiliary boilers according to the following requirements. For this purpose all arrangement drawings of a crude oil installation with pipeline layout and safety equipment are to be submitted for approval in each case.

M24.2 Crude oil or slops may be taken directly from cargo tanks or flow slop tanks or from other suitable tanks. These tanks are to be fitted in the cargo tank area and are to be separated from non-gas-dangerous areas by means of cofferdams with gas-tight bulkheads.

M24.3 The construction and workmanship of the boilers and burners are to be proved to be satisfactory in operation with crude oil.

The whole surface of the boilers shall be gas-tight separated from the engine room. The boilers themselves are to be tested for gas-tightness before being used. The whole system of pumps, strainers, separators and heaters, if any, shall be fitted in the cargo pump room or in another room, to be considered as dangerous, and separated from engine and boiler room by gas-tight bulkheads. When crude oil is heated by steam or hot water the outlet of the heating coils should be led to a separate observation tank installed together with above mentioned components. This closed tank is to be fitted with a venting pipe led to the atmosphere in a safe position according to the rules for tankers and with the outlet fitted with a suitable flame proof wire gauze of corrosion resistant material which is to be easily removable for cleaning.

M24.4 Electric, internal combustion and steam (when the steam temperature is higher than 220°C) prime movers of pumps, of separators (if any), etc., shall be fitted in the engine room or in another non-dangerous room.

Where drive shafts pass through pump room bulkhead or deck plating, gas-tight glands are to be fitted.

The glands are to be efficiently lubricated from outside the pump room.

M24.5 Pumps shall be fitted with a pressure relief bypass from delivery to suction side and it shall be possible to stop them by a remote control placed in a position near the boiler fronts or machinery control room and from outside the engine room.

M24.6 When it is necessary to preheat crude oil or slops, their temperature is to be automatically controlled and a high temperature alarm is to be fitted.

M24.7 The piping for crude oil or slops and the draining pipes for the tray defined in M24.9 are to have a thickness as follows:
M24

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<th>External diameter of pipes, $d_e$</th>
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<td>$t \geq 8$ mm</td>
</tr>
<tr>
<td>$152.4$ mm $\leq d_e$</td>
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</tbody>
</table>

Their connections (to be reduced to a minimum) are to be of the heavy flange type. Within the engine room and boiler room these pipes are to be fitted within a metal duct, which is to be gas-tight and tightly connected to the fore bulkhead separating the pump room and to the tray. This duct (and the enclosed piping) is to be fitted at a distance from the ship's side of at least 20% of the vessel's beam amidships and be at an inclination rising towards the boiler so that the oil naturally returns towards the pump room in the case of leakage or failure in delivery pressure. It is to be fitted with inspection openings with gas-tight doors in way of connections of pipes within it, with an automatic closing drain-trap placed on the pump room side, set in such a way as to discharge leakage of crude oil into the pump room.

In order to detect leakages, level position indicators with relevant alarms are to be fitted on the drainage tank defined in M24.9. Also a vent pipe is to be fitted at the highest part of the duct and is to be led to the open in a safe position. The outlet is to be fitted with a suitable flame proof wire gauze of corrosion-resistant material which is to be easily removable for cleaning.

The duct is to be permanently connected to an approved inert gas system or steam supply in order to make possible:

- injection of inert gas or steam in the duct in case of fire or leakage
- purging of the duct before carrying out work on the piping in case of leakage.

M24.8 In way of the bulkhead to which the duct defined in M24.7 is connected, delivery and return oil pipes are to be fitted on the pump room side, with shut-off valves remotely controlled from a position near the boiler fronts or from the machinery control room. The remote control valves should be interlocked with the hood exhaust fans (defined in M24.10) to ensure that whenever crude oil is circulating the fans are running.

M24.9 Boilers shall be fitted with a tray or gutterway of a height to the satisfaction of the Classification Society and be placed in such a way as to collect any possible oil leakage from burners, valves and connections.

Such a tray or gutterway shall be fitted with a suitable flame proof wire gauze, made of corrosion resistant material and easily dismountable for cleaning. Delivery and return oil pipes shall pass through the tray or gutterway by means of a tight penetration and shall then be connected to the oil supply manifolds.

A quick closing master valve is to be fitted on the oil supply to each boiler manifold. The tray or gutterway shall be fitted with a draining pipe discharging into a collecting tank in pump room. This tank is to be fitted with a venting pipe led to the open in a safe position and with the outlet fitted with wire gauze made of corrosion resistant material and easily dismountable for cleaning. The draining pipe is to be fitted with arrangements to prevent the return of gas to the boiler or engine room.
M24.10 Boilers shall be fitted with a suitable hood placed in such a way as to enclose as much as possible of the burners, valves and oil pipes, without preventing, on the other side, air inlet to burner register.

The hood, if necessary, is to be fitted with suitable doors placed in such a way as to enable inspection of and access to oil pipes and valves placed behind it. It is to be fitted with a duct leading to the open in a safe position, the outlet of which is to be fitted with a suitable flame wire gauze, easily dismountable for cleaning. At least two mechanically driven exhaust fans having spark proof impellers are to be fitted so that the pressure inside the hood is less than that in the boiler room. The exhaust fans are to be connected with automatic change over in case of stoppage or failure of the one in operation.

The exhaust fan prime movers shall be placed outside the duct and a gas-tight bulkhead penetration shall be arranged for the shaft.

Electrical equipment installed in gas dangerous areas or in areas which may become dangerous (i.e. in the hood or duct in which crude-oil piping is placed) is to be of certified safe type as required by Classification Societies.

M24.11 When using fuel oil for delivery to and return from boilers fuel oil burning units in accordance with Classification Societies' Rules shall be fitted in the boiler room. Fuel oil delivery to, and returns from, burners shall be effected by means of a suitable mechanical interlocking device so that running on fuel oil automatically excludes running on crude oil or vice versa.

M24.12 The boiler compartments are to be fitted with a mechanical ventilation plant and shall be designed in such a way as to avoid the formation of gas pockets. Ventilation is to be particularly efficient in way of electrical plants and machinery and other plants which may generate sparks. These plants shall be separated from those for service of other compartments and shall be in accordance with Classification Societies' requirements.

M24.13 A gas detector plant shall be fitted with intakes in the duct defined in M24.7, in the hood duct (downstream of the exhaust fans in way of the boilers) and in all zones where ventilation may be reduced. An optical warning device is to be installed near the boiler fronts and in the machinery control room. An acoustical alarm, audible in the machinery space and control room, is to be provided.

M24.14 Means are to be provided for the boiler to be automatically purged before firing.

M24.15 Independent of the fire extinguishing plant as required by Classification Societies' Rules, an additional fire extinguishing plant is to be fitted in the engine and boiler rooms in such a way that it is possible for an approved fire extinguishing medium to be directed on to the boiler fronts and on to the tray defined in M24.9. The emission of extinguishing medium should automatically stop the exhaust fan of the boiler hood (see M24.8).

M24.16 A warning notice must be fitted in an easily visible position near the boiler front. This notice must specify that when an explosive mixture is signalled by the gas detector plant defined in M24.13 the watchkeepers are to immediately shut off the remote controlled valves on the crude oil delivery and return pipes in the pump room, stop the relative pumps, inject inert gas into the duct defined in M24.7 and turn the boilers to normal running on fuel oil.

M24.17 One pilot burner in addition to the normal burning control is required.
M25 Astern power for main propulsion

M25.1 In order to maintain sufficient manoeuvrability and secure control of the ship in all normal circumstances, the main propulsion machinery is to be capable of reversing the direction of thrust so as to bring the ship to rest from the maximum service speed. The main propulsion machinery is to be capable of maintaining in free route astern at least 70% of the ahead revolutions.

M25.2 Where steam turbines are used for main propulsion, they are to be capable of maintaining in free route astern at least 70% of the ahead revolutions for a period of at least 15 minutes. The astern trial is to be limited to 30 minutes or in accordance with manufacturer’s recommendation to avoid overheating of the turbine due to the effects of “windage” and friction.

M25.3 For the main propulsion systems with reversing gears, controllable pitch propellers or electric propeller drive, running astern should not lead to the overload of propulsion machinery.

NOTES:

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

2. The reversing characteristics of the propulsion plant are to be demonstrated and recorded during trials.
Safety devices of steam turbines

M26 Governors and speed control

M26.1.1 All main and auxiliary turbines are to be provided with overspeed protective devices to prevent the design speed from being exceeded by more than 15%.

Where two or more turbines are coupled to the same gear wheel set, the Classification Society may agree that only one overspeed protective device be provided for all the turbines.

M26.1.2 Arrangement is to be provided for shutting off the steam to the main turbines by suitable hand trip gear situated at the manoeuvring stand and at the turbine itself.

Hand tripping for auxiliary turbines is to be arranged in the vicinity of the turbine overspeed protective device.

M26.1.3 Where the main turbine installation incorporates a reverse gear, electric transmission, controllable pitch propeller or other free-coupling arrangement, a separate speed governor in addition to the overspeed protective device is to be fitted and is to be capable of controlling the speed of the unloaded turbine without bringing the overspeed protective device into action.

M26.1.4 Where exhaust steam from auxiliary systems is led to the main turbine it is to be cut off at activation of the overspeed protective device.

M26.1.5 Auxiliary turbines driving electric generators are to have both:

- a speed governor which, with fixed setting, is to control the speed within the limit of 10% for momentary variation and 5% permanent variation when the full load is suddenly taken off, and
- an overspeed protective device which is to be independent of speed governor, and is to prevent the design speed from being exceeded by more than 15% when the full load is suddenly taken off (see M26.1.1).

M26.2 Miscellaneous safety arrangements

M26.2.1 Main ahead turbines are to be provided with a quick acting device which will automatically shut off the steam supply in the case of dangerous lowering of oil pressure in the bearing lubricating system. This device is to be so arranged as not to prevent the admission of steam to the astern turbine for braking purposes.

Where deemed necessary by the Classification Society appropriate means are to be provided to protect the turbines in case of:

- abnormal axial rotor displacement,
- excessive condenser pressure,
- high condensate level.

M26.2.2 Auxiliary turbines having governors operated other than hydraulically in which the lubricating oil is inherent in the system, are to be provided with an alarm device and a means of shutting off the steam supply in the case of lowering of oil pressure in the bearing lubricating oil system.

M26.2.3 Main turbines are to be provided with a satisfactory emergency supply of lubricating oil which will 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 are to be so arranged that their operation is not affected by failure of the power supply. Suitable arrangement for cooling the bearings after stopping may also be required.
M26.2.4 To provide a warning to personnel in the vicinity of the exhaust end steam turbines of excessive pressure, a sentinel valve or equivalent is to be provided at the exhaust end of all turbines. The valve discharge outlets are to 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 are to be provided.

M26.2.5 Non-return valves, or other approved means which will prevent steam and water returning to the turbines, are to be fitted in bled steam connections.

M26.2.6 Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines or alternatively at the inlets to manoeuvring valves.

NOTE
The hand trip gear is understood as any device which is operated manually irrespective of the way the action is performed, i.e. mechanically or by means of external power.

M27  Bilge level alarms for unattended machinery spaces

M27.1 All vessels are to be fitted with means for detecting a rise of water in the machinery space bilges or bilge wells. Bilge wells are to be large enough to accommodate normal drainage during the unattended period. The number and location of wells and detectors is to be such that accumulation of liquids may be detected at all normal angles of heel and trim.

M27.2 Where the bilge pumps start automatically, means shall be provided to indicate if the influx of liquid is greater than the pump capacity or if the pump is operating more frequently than would normally be expected. In this case, smaller bilge wells to cover a reasonable period of time may be permitted. Where automatically controlled bilge pumps are provided special attention shall be given to oil pollution prevention requirements.

M27.3 Alarms are to be given at the main control station, engineers’ accommodation area and at the bridge.

M28  Ambient reference conditions

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total barometric pressure</td>
<td>1000 mbar</td>
</tr>
<tr>
<td>Air temperature</td>
<td>+45°C</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>60%</td>
</tr>
<tr>
<td>Sea water temperature</td>
<td>32°C</td>
</tr>
<tr>
<td>(charge air coolant-inlet)</td>
<td></td>
</tr>
</tbody>
</table>

NOTE
The engine manufacturer shall not be expected to provide simulated ambient reference conditions at a test bed.
M29.1 Definition

The alarm system is intended to give warning of a condition in which deviation occurs outside the preset limits on selected variables. The arrangement of the alarm display should assist in identifying the particular fault condition and its location within the machinery space. Alarm systems, including those incorporating programmable electronic systems, are to satisfy the environmental requirements of IACS UR E10.

M29.2 General requirements

Where an alarm system is required by the Rules, the system is to comply with the conditions given in M29.2.1 - M29.2.10.

M29.2.1 The system is to be designed to function independently of control and safety systems so that a failure or malfunction in these systems will not prevent the alarm system from operating. Common sensors for alarms and automatic slowdown functions are acceptable as specified in M35 Table 1 and 2 as Gr 1.

M29.2.2 Machinery faults are to be indicated at the control locations for machinery.

M29.2.3 The system is to be so designed that the engineering personnel on duty are made aware that a machinery fault has occurred.

M29.2.4 If the bridge navigating officer of the watch is the sole watchkeeper then, in the event of a machinery fault being monitored at the control location for machinery, the alarm system is to be such that this watchkeeper is made aware when:

(i) a machinery fault has occurred,
(ii) the machinery fault is being attended to,
(iii) the machinery fault has been rectified. Alternative means of communication between the bridge area, the accommodation for engineering personnel and the machinery spaces may be used for this function.

M29.2.5 Group alarms may be arranged on the bridge to indicate machinery faults. Alarms associated with faults requiring speed reduction or the automatic shut down of propulsion machinery are to be separately identified.

M29.2.6 The alarm system should be designed with self monitoring properties. In so far as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

M29.2.7 The alarm system should be capable of being tested during normal machinery operation. Where practicable means are to be provided at convenient and accessible positions, to permit the sensors to be tested without affecting the operation of the machinery.

M29.2.8 Upon failure of normal power supply, the alarm system is to be powered by an independent standby power supply, e.g. a battery. Failure of either power supply to the alarm system is to be indicated as a separate alarm fault. Where an alarm system could be adversely affected by an interruption in power supply, change-over to the stand by power supply is to be achieved without a break.
M29.2.9

(a) Alarms are to be both audible and visual. If arrangements are fitted to silence audible alarms they are not to extinguish visible alarms.
(b) The local silencing of bridge or accommodation alarms is not to stop the audible machinery space alarm.
(c) Machinery alarms should be distinguishable from other audible alarms, i.e. fire, CO₂ flooding.
(d) The alarm system is to be so arranged that acknowledgement of visual alarms is clearly noticeable.

M29.2.10 If an alarm has been acknowledged and a second fault occurs before the first is rectified, then audible and visual alarms are to operate again.

Alarms due to temporary failures are to remain activated until acknowledged.

M30.1 Definition

The safety system is intended to operate automatically in case of faults endangering the plant so that:
(i) normal operating conditions are restored (by starting of standby units), or
(ii) the operation of the machinery is temporarily adjusted to the prevailing conditions (by reducing the output of machinery), or
(iii) machinery and boilers are protected from critical conditions by stopping the machinery and shutting off the fuel to the boilers respectively (shutdown).

M30.2 General requirements

M30.2.1 Where a safety system is required by the Rules, the system is to comply with M30.2.2 - M30.2.8.
M30.2.2 Operation of the safety system shall cause an alarm.
M30.2.3 The safety system intended for the functions listed under M30.1 (iii) is to be independent of all other control and alarm systems so that failure or malfunction in these systems will not prevent the safety system from operating. For the safety systems intended for functions listed under M30.1(i) and (ii), complete independence of other control and alarm systems is not required.
M30.2.4 In order to avoid undesirable interruption in the operation of machinery, the system is to intervene sequentially after the operation of alarm system by:
- Starting of standby units,
- load reduction or shutdown, such that the least drastic action is taken first.

M30.2.5 The system should be designed to 'fail safe'. The characteristics of 'fail safe' of a system is to be evaluated on the basis not only of the safety system itself and its associated machinery, but also on the inclusion of the whole machinery installation as well as the ship.
M30 cont’d

M30.2.6 Safety systems of different units of the machinery plant are to be independent. Failure in the safety system of one part of the plant is not to interfere with the operation of the safety system in another part of the plant.

M30.2.7 When the system has been activated, means are to be provided to trace the cause of the safety action.

M30.2.8 When the system has stopped a unit, the unit is not to be restarted automatically before a manual reset has been carried out.

M31 Continuity of electrical power supply for vessels with periodically unattended machinery spaces

M31.1 The continuity of electrical power on vessels with periodically unattended machinery spaces is to be assured in accordance with M31.2 and M31.3.

M31.2 For vessels having the electrical power requirements normally supplied by one ship’s service generator in case of loss of the generator in operation, there shall be adequate provisions for automatic starting and connecting to the main switchboard of a standby generator of sufficient capacity to permit propulsion and steering and to ensure the safety of the ship with automatic re-starting of the essential auxiliaries including, where necessary, sequential operations. This standby electric power is to be available automatically in not more than 45 seconds.

M31.3 For vessels having the electrical power requirements normally supplied by two or more ship’s service generating sets operating in parallel, arrangements are to be provided (by load shedding, for instance) to ensure that in case of loss of one of these generating sets, the remaining ones are kept in operation without overload to permit propulsion and steering and to ensure the safety of the ship.
M32 Definition of diesel engine type

(1979)

Deleted Feb 2015, replaced by UR M71.

End of Document
Scantlings of intermediate shafts

UR M33 was replaced by UR M68 in February 2005.
M34 Scantlings of coupling flanges

(1980)

M34.1 For intermediate, thrust and propeller shaft couplings having all fitted coupling bolts, the coupling bolt diameter is not less than that given by the following formula:

\[ d_b = 0.65 \sqrt{\frac{D (T + 160)}{iD_T}} \]

where

- \( d_b \) = diameter (mm) of fitted coupling bolt
- \( d = \) Rule diameter (mm), i.e., minimum required diameter of intermediate shaft made of material with tensile strength \( T \), taking into account ice strengthening requirements where applicable
- \( i = \) number of fitted coupling bolts
- \( D = \) pitch circle diameter (mm) of coupling bolts
- \( T = \) tensile strength (N/mm²) of the intermediate shaft material taken for calculation
- \( T_b = \) tensile strength (N/mm²) of the fitted coupling bolts material taken for calculation

while: \( T \leq T_b \leq 1.7T \), but not higher than 1000 N/mm².

M34.2 The design of coupling bolts in the shaftline other than that covered by M34.1 are to be considered and approved by the Classification Society individually.

M34.3 For intermediate shafts, thrust shafts and inboard end of propeller shafts the flange is to have a minimum thickness of 0.20 times the Rule diameter \( d \) of the intermediate shaft or the thickness of the coupling bolt diameter calculated for the material having the same tensile strength as the corresponding shaft, whichever is greater.

Special consideration will be given by the Classification Societies for flanges having non-parallel faces, but in no case is the thickness of the flange to be less than the coupling bolt diameter.

M34.4 Fillet radii at the base of the flange should in each case be not less than 0.08 times the actual shaft diameter.

Fillet radii are to have a smooth finish and should not be recessed in way of nuts and bolt heads.

The fillet may be formed of multiradii in such a way that the stress concentration factor will not be greater than that for a circular fillet with radius 0.08 times the actual shaft diameter.
Alarms, remote indications and safeguards for main reciprocating I.C. engines installed in unattended machinery spaces

35.1 General

Alarms, remote indications and safeguards listed in Table 1 and 2 are respectively referred to cross-head and trunk-piston reciprocating i.c. engines.

35.2 Alarms

A system of alarm displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment. This may be provided at a main control station or, alternatively, at subsidiary control stations. In the latter case, a master alarm display is to be provided at the main control station showing which of the subsidiary control stations is indicating a fault condition.

The detailed requirements covering communications of alarms from machinery spaces to the bridge area and accommodation for engineering personnel, are contained in M29.

35.3 Remote indications

Remote indications are required only for ships which are operated with machinery space unattended but under a continuous supervision from a position where control and monitoring devices are centralized, without the traditional watch service being done by personnel in machinery space.

35.4 Safeguards

35.4.1 Automatic start of standby pumps – slow down

A suitable alarm is to be activated at the starting of those pumps for which the automatic starting is required.

Note:

1. The requirements of M35 Rev.5 are to be uniformly implemented by IACS Societies for engines:
   i) when an application for certification of an engine is dated on or after 1 January 2010; or
   ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2010.

2. The requirements of M35 Rev.6 are to be uniformly implemented by IACS Societies for engines:
   i) when an application for certification of an engine is dated on or after 1 January 2015; or
   ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2015.

3. The requirements of M35 Rev.7 are to be uniformly implemented by IACS Societies for engines:
   i) when an application for certification of an engine is dated on or after 1 July 2017; or
   ii) which are installed in new ships for which the date of contract for construction is on or after 1 July 2017.

4. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.
35.4.2 Automatic reduction of power

If overriding devices of the required automatic reduction of power are provided, they are to be so arranged as to preclude their inadvertent operation, and a suitable alarm is to be activated by their operation.

35.4.3 Automatic stop – shut down

If overriding devices of the required automatic stops are provided, they are to be so arranged as to preclude their inadvertent operation, and a suitable alarm is to be operated by their activation. When the engine is stopped automatically, restarting after restoration of normal operating conditions is to be possible only after manual reset, e.g. by-passing the control lever through the ‘stop’ position.

Automatic restarting is not permissible (see M30.2.8).
Table 1  Cross-head diesel engines

<table>
<thead>
<tr>
<th>Monitored parameters for cross-head diesel engines</th>
<th>Remote Indication</th>
<th>Alarm activation</th>
<th>Slow down with alarm</th>
<th>Automatic start of standby pump with alarm</th>
<th>Shut down with alarm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0  Fuel oil system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel oil pressure after filter (engine inlet)</td>
<td>x</td>
<td>low</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel oil viscosity before injection pumps or</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel oil temp before injection pumps</td>
<td></td>
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<tr>
<td>Leakage from high pressure pipes</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level of fuel oil in daily service tank¹</td>
<td>low</td>
<td></td>
<td></td>
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<tr>
<td>Common rail fuel oil pressure</td>
<td>low</td>
<td></td>
<td></td>
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<tr>
<td>2.0  Lubricating oil system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lub oil to main bearing and thrust bearing, pressure</td>
<td>x</td>
<td>low</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Lub oil to crosshead bearing pressure²</td>
<td>x</td>
<td>low</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Lub oil to camshaft pressure²</td>
<td>low</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lub oil to camshaft temp²</td>
<td>high</td>
<td></td>
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<tr>
<td>Lub oil inlet temp</td>
<td>high</td>
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<tr>
<td>Thrust bearing pads temp or bearing outlet temp</td>
<td>high</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Main, crank, crosshead bearing, oil outlet temp or</td>
<td>high</td>
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<tr>
<td>Oil mist concentration in crankcase³</td>
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<tr>
<td>Flow rate cylinder lubricator. Each apparatus</td>
<td></td>
<td>low</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Level in lubricating oil tanks²</td>
<td>low</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Common rail servo oil pressure</td>
<td>low</td>
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<tr>
<td>3.0  Turbocharger system</td>
<td></td>
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<tr>
<td>Turbocharger lub oil inlet pressure⁵</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Turbocharger lub oil outlet temp each bearing⁶</td>
<td></td>
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<tr>
<td>Speed of turbocharger¹</td>
<td></td>
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<tr>
<td>4.0  Piston cooling system</td>
<td></td>
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<tr>
<td>Piston coolant inlet pressure³</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Piston coolant outlet temp each cylinder</td>
<td></td>
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<td></td>
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<tr>
<td>Piston coolant outlet flow each cylinder⁸</td>
<td></td>
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<td></td>
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<tr>
<td>Level of piston coolant in expansion tank</td>
<td></td>
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<tr>
<td>5.0  Sea water cooling system</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sea water pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

Gr 1  Common sensor for indication, alarm, slow down
Gr 2  Sensor for automatic start of standby pump with alarm
Gr 3  Sensor for shut down
<table>
<thead>
<tr>
<th>Table 1 (continued)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitored parameters for cross-head diesel engines</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>6.0 Cylinder fresh cooling water system</td>
</tr>
<tr>
<td>Cylinder water inlet pressure</td>
</tr>
<tr>
<td>Cylinder water outlet temp (from each cylinder) or Cylinder water outlet temp (general)</td>
</tr>
<tr>
<td>Oily contamination of engine cooling water system</td>
</tr>
<tr>
<td>Level of cylinder cooling water in expansion tank</td>
</tr>
<tr>
<td>7.0 Starting and control air systems</td>
</tr>
<tr>
<td>Starting air pressure before main shut-off valve</td>
</tr>
<tr>
<td>Control air pressure</td>
</tr>
<tr>
<td>Safety air pressure</td>
</tr>
<tr>
<td>8.0 Scavenge air system</td>
</tr>
<tr>
<td>Scavenge air receiver pressure</td>
</tr>
<tr>
<td>Scavenge air box temp (fire)</td>
</tr>
<tr>
<td>Scavenge air receiver water level</td>
</tr>
<tr>
<td>9.0 Exhaust gas system</td>
</tr>
<tr>
<td>Exhaust gas temp after each cylinder</td>
</tr>
<tr>
<td>Exhaust gas temp after each cylinder. Deviation from average.</td>
</tr>
<tr>
<td>Exhaust gas temp before each T/C</td>
</tr>
<tr>
<td>Exhaust gas temp after each T/C</td>
</tr>
<tr>
<td>10.0 Fuel valve coolant</td>
</tr>
<tr>
<td>Pressure of fuel valve coolant</td>
</tr>
<tr>
<td>Temperature of fuel valve coolant</td>
</tr>
<tr>
<td>Level of fuel valve coolant in expansion tank</td>
</tr>
<tr>
<td>11.0 Engine speed/direction of rotation.</td>
</tr>
<tr>
<td>Wrong way</td>
</tr>
<tr>
<td>12.0 Engine overspeed</td>
</tr>
<tr>
<td>13.0 Control-Safety-Alarm system power supply failure</td>
</tr>
</tbody>
</table>
1. High-level alarm is also required if no suitable overflow arrangement is provided.

2. If separate lub oil systems are installed.

3. When required by UR M10.8 or by SOLAS Reg. II-1/47.2.

4. Where separate lubricating oil systems are installed (e.g. camshaft, rocker arms, etc.), individual level alarms are required for the tanks.

5. The slow down is not required if the coolant is oil taken from the main cooling system of the engine.

6. Where one common cooling space without individual stop valves is employed for all cylinder jackets.

7. Where main engine cooling water is used in fuel and lubricating oil heat exchangers.

8. Where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted.

9. Unless provided with a self-contained lubricating oil system integrated with the turbocharger.

10. 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.

11. Only required for turbochargers of Categories B and C. (see M73.5)
### Table 2: Trunk-piston diesel engines

<table>
<thead>
<tr>
<th>Monitored parameters for trunk-piston diesel engines</th>
<th>Remote Indication</th>
<th>Alarm activation</th>
<th>Slow down with alarm</th>
<th>Automatic start of standby pump with alarm</th>
<th>Shut down with alarm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.0 Fuel oil system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel oil pressure after filter (engine inlet)</td>
<td>x</td>
<td>low</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Fuel oil viscosity before injection pumps or</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel oil temp before injection pumps (^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leakage from high pressure pipes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level of fuel oil in daily service tank (^2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common rail fuel oil pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2.0 Lubrication oil system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lub oil to main bearing and thrust bearing, pressure</td>
<td>x</td>
<td>low</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Lub oil filter differential pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lub oil temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lub oil filter differential pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lub oil inlet temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lub oil inlet temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil mist concentration in crankcase (^3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow rate cylinder lubricator. Each apparatus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common rail servo oil pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3.0 Turbocharger system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbocharger lub oil inlet pressure (^5)</td>
<td>x</td>
<td>low</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbocharger lub oil temperature each bearing (^8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed of turbocharger (^9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>4.0 Sea Water cooling system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sea Water pressure</td>
<td>x</td>
<td>low</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td><strong>5.0 Cylinder fresh cooling water system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylinder water inlet pressure or flow</td>
<td>x</td>
<td>low</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Cylinder water outlet temp (general) (^6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level of cylinder cooling water in expansion tank</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>6.0 Starting and control air systems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starting air pressure before main shut-off valve</td>
<td>x</td>
<td>low</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control air pressure</td>
<td>x</td>
<td>low</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Gr 1 Common sensor for indication, alarm, slow down
Gr 2 Sensor for automatic start of standby pump with alarm
Gr 3 Sensor for shut down
### Table 2 (continued)

<table>
<thead>
<tr>
<th>Monitored parameters for trunk-piston diesel engines</th>
<th>Gr 1</th>
<th>Gr 2</th>
<th>Gr 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Remote Indication</td>
<td>Alarm activation</td>
<td>Slow down with alarm</td>
</tr>
<tr>
<td>7.0 Scavenge air system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scavenge air receiver temp</td>
<td>high</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.0 Exhaust Gas system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exhaust gas temp after each cylinder</td>
<td>x</td>
<td>high</td>
<td>x</td>
</tr>
<tr>
<td>Exhaust gas temp after each cylinder. Deviation from average</td>
<td>high</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.0 Engine speed</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.0 Engine overspeed</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>11.0 Control-Safety-Alarm system power supply failure</td>
<td></td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

1. For heavy fuel oil burning engines only.

2. High-level alarm is also required if no suitable overflow arrangement is provided.

3. When required by UR M10.8 or by SOLAS Reg. II-1/47.2. One oil mist detector for each engine having two independent outputs for initiating the alarm and shut-down would satisfy the requirement for independence between alarm and shut-down system.

4. If necessary for the safe operation of the engine.

5. Unless provided with a self-contained lubricating oil system integrated with the turbocharger.

6. Two separate sensors are required for alarm and slow down.

7. For engine power > 500 kW/cyl.

8. 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.

9. Only required for turbochargers of Categories B and C. (see M73.5)
Alarms and safeguards for auxiliary reciprocating internal combustion engines driving generators in unattended machinery spaces

**M36.1 General**

This UR refers to trunk-piston reciprocating i. c. engines on fuel oil.

**M36.2 Alarms**

All monitored parameters for which alarms are required to identify machinery faults and associated safeguards are listed in Table 1.

All these alarms are to be indicated at the control location for machinery as individual alarms; where the alarm panel with individual alarms is installed on the engine or in the vicinity, common alarm in the control location for machinery is required.

For communication of alarms from machinery space to bridge area and accommodation for engineering personnel detailed requirements are contained in M29.

---

**Note:**

1. The requirements of M36 Rev.3 are to be uniformly implemented by IACS Societies for engines:
   i) when an application for certification of an engine is dated on or after 1 January 2010; or
   ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2010.

2. The requirements of M36 Rev.4 are to be uniformly implemented by IACS Societies for engines:
   i) when an application for certification of an engine is dated on or after 1 January 2015; or
   ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2015.

3. The requirements of M36 Rev.5 are to be uniformly implemented by IACS Societies for engines:
   i) when an application for certification of an engine is dated on or after 1 July 2017; or
   ii) which are installed in new ships for which the date of contract for construction is on or after 1 July 2017.

4. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and shipbuilder. For further details regarding the date of "contract for construction", refer to IACS Procedural Requirement (PR) No. 29.
Table 1

<table>
<thead>
<tr>
<th>Monitored parameters</th>
<th>Alarm</th>
<th>Shut down</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel oil leakage from high pressure pipes</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Lubricating oil temperature</td>
<td>high</td>
<td></td>
</tr>
<tr>
<td>Lubricating oil pressure</td>
<td>low</td>
<td>x</td>
</tr>
<tr>
<td>Oil mist concentration in crankcase¹</td>
<td>high</td>
<td>x</td>
</tr>
<tr>
<td>Pressure or flow of cooling water</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>Temperature of cooling water or cooling air</td>
<td>high</td>
<td></td>
</tr>
<tr>
<td>Level in cooling water expansion tank, if not connected to main system</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>Level in fuel oil daily service tank</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>Starting air pressure</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>Overspeed activated</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Fuel oil viscosity before injection pumps or fuel oil temp before injection pumps¹</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Exhaust gas temperature after each cylinder²</td>
<td>high</td>
<td></td>
</tr>
<tr>
<td>Common rail fuel oil pressure</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>Common rail servo oil pressure</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>Speed of turbocharger⁴</td>
<td>high</td>
<td></td>
</tr>
</tbody>
</table>

Notes:

1. For heavy fuel oil burning engines only.
2. For engine power above 500 kW/cyl.
3. When required by UR M10.8 or by SOLAS Reg. II-1/47.2, one oil mist detector for each engine having two independent outputs for initiating the alarm and shut-down system would satisfy the requirement for independence between alarm and shut-down system.
4. Only required for turbochargers of Categories B and C. (see M73.5)
M37  Scantlings of propeller shafts
(1981)

UR M37 was replaced by UR M68 in February 2005.

END
M38  k-factors for different shaft design features (intermediate shafts) - see M33

UR M38 was replaced by UR M68 in February 2005.
k-factors for different shaft design features (propeller shafts) - see M37

UR M39 was replaced by UR M68 in February 2005.
M40 Ambient conditions – Temperatures

M40.1 The ambient conditions specified under M40.2 are to be applied to the layout, selection and arrangement of all shipboard machinery, equipment and appliances as to ensure proper operation.

M40.2 Temperatures

<table>
<thead>
<tr>
<th>Installations, components</th>
<th>Location, arrangement</th>
<th>Temperature range (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In enclosed spaces</td>
<td>0 to +45°C</td>
</tr>
<tr>
<td>Machinery and electrical</td>
<td>On machinery compo-</td>
<td>According to specific</td>
</tr>
<tr>
<td>installations 1</td>
<td>nents, boilers,</td>
<td>local conditions</td>
</tr>
<tr>
<td></td>
<td>In spaces subject</td>
<td></td>
</tr>
<tr>
<td></td>
<td>to higher and lower</td>
<td></td>
</tr>
<tr>
<td></td>
<td>temperatures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>On the open deck</td>
<td>−25 to +45°C</td>
</tr>
</tbody>
</table>

Water

<table>
<thead>
<tr>
<th>Coolant</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seawater</td>
<td>+32°C</td>
</tr>
<tr>
<td>Charge air coolant inlet</td>
<td>see UR M28</td>
</tr>
<tr>
<td>to charge air cooler</td>
<td></td>
</tr>
</tbody>
</table>

NOTES

1. Electronic appliances are to be suitable for proper operation even with an air temperature of +55°C.
2. The Classification Society may approve other temperatures in the case of ships not intended for unrestricted service.
M41  Automation - type testing conditions for control and instrumentation equipment

UR E10 superseded UR M41 (1991)
Steering Gear

Preamble

In addition to the requirements contained in the Amendments to the 1974 SOLAS Convention, Chapter II–I Reg. 29 and 30, and related Guidelines (see Annex 2 of IMCO document MSC XLV/4) the following requirements apply to new ocean-going vessels of 500 GRT and upwards. These requirements may be applied to other vessels at the discretion of the Classification Society.

1. Plans and specifications

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

2. Definitions

The definitions relating to steering gear are given in Appendix 1.

3. Power piping arrangements

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

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

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

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

3.5 Piping, joints, valves, flanges and other fittings are to comply with Classification Society requirements for Class 1 components. The design pressure is to be in accordance with paragraph M42.6.8.

4. Rudder angle limiters

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

Note:

1. This revision of UR M42 applies to ships contracted for construction (as defined in IACS PR29) on or after 1 July 2012.

2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.
5. **Materials**

Ram cylinders; pressure housings of rotary vane type actuators; hydraulic power piping valves, flanges and fittings; and all steering gear components transmitting mechanical forces to the rudder stock (such as tillers, quadrants or similar components) should be of steel or other approved ductile material, duly tested in accordance with the requirements of the Classification Society. In general, such material should not have an elongation of less than 12 per cent nor a tensile strength in excess of 650 N/mm².

Grey cast iron may be accepted for redundant parts with low stress level, excluding cylinders, upon special consideration.

6. **Design**

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

6.2 **Welds**

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

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

6.3 **Oil seals**

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

b) Oil seals between moving parts, forming part of the external pressure boundary, should be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted at the discretion of the Administration.

6.4 All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

6.5 For piping, joints, valves, flanges and other fittings see paragraph M42.3.4.

6.6 Rudder actuators other than those covered by Regulation 29.17 and relating Guidelines should be designed in accordance with Class 1 pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

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

\[
\frac{\sigma_B}{A} \quad \text{or} \quad \frac{\sigma_y}{B}
\]

where:

\(\sigma_B\) = specified minimum tensile strength of material at ambient temperature

\(\sigma_y\) = specified minimum yield stress or 2 per cent proof stress of the material, at ambient temperature
A and B are given by the Table 1.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Steel</th>
<th>Cast Steel</th>
<th>Nodular Cast Iron</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>B</td>
<td>1.7</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

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

(i) 1.25 times the maximum working pressure,

(ii) the relief valve setting.

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

7. Dynamic loads for fatigue and fracture mechanic analysis

The dynamic loading to be assumed in the fatigue and fracture mechanics analysis considering Regulation 29.2.2 and 29.17.1 and relating Guidelines, will be established at the discretion of the Classification Society.

Both the case of high cycle and cumulative fatigue are to be considered.

8. Hoses

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

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

8.3 Burst pressure of hoses should not be less than four times the design pressure.

9. Relief valves

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

(1) The setting pressure should not be less than 1.25 times the maximum working pressure.

(2) The minimum discharge capacity of the relief valve(s) should not be less than the total capacity of the pumps, which can deliver through it (them), increased by 10 per cent.

Under such conditions the rise in pressure should not exceed 10 per cent of the setting pressure. In this regard, due consideration should be given to extreme foreseen ambient conditions in respect of oil viscosity.
The Classification Society may require, for the relief valves, discharge capacity tests and/or shock tests.

10. **Electrical installations**

Electrical installations should comply with the requirements of the Classification Society.

11. **Alternative source of power**

Where the alternative power source required by Regulation 29.14 is a generator, or an engine driven pump, automatic starting arrangements are to comply with the requirements relating to the automatic starting arrangements of emergency generators.

12. **Monitoring and alarm systems**

12.1 Monitoring and alarm systems, including the rudder angle indicators, should be designed, built and tested to the satisfaction of the Classification Society.

12.2 Where hydraulic locking, caused by a single failure, may lead to loss of steering, an audible and visual alarm, which identifies the failed system, shall be provided on the navigating bridge.

**NOTE:**
This alarm should be activated whenever:

- position of the variable displacement pump control system does not correspond with given order; or
- incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.

13. **Operating instructions**

Where applicable, following standard signboard should be fitted at a suitable place on steering control post on the bridge or incorporated into operating instruction on board:

**CAUTION**

IN SOME CIRCUMSTANCES WHEN 2 POWER UNITS ARE RUNNING SIMULTANEOUSLY THE RUDDER MAY NOT RESPOND TO HELM. IF THIS HAPPENS STOP EACH PUMP IN TURN UNTIL CONTROL IS REGAINED.

The above signboard is related to steering gears provided with 2 identical power units intended for simultaneous operation, and normally provided with either their own control systems or two separate (partly or mutually) control systems which are/may be operated simultaneously.

Note: Existing vessels according to SOLAS 1986 shall have minimum the above signboard, when applicable.

14. **Testing**

14.1 The requirements of the Classification Society relating to the testing of Class 1 pressure vessels, piping and relating fittings including hydraulic testing apply.
14.2 A power unit pump is to be subjected to a type test. The type test shall be for a duration of not less than 100 hours, the test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should occur at least as quickly as on board. During the whole test no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the pump should be disassembled and inspected. Type tests may be waived for a power unit which has been proven to be reliable in marine service.

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

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

15. Trials

The steering gear should be tried out on the trial trip in order to demonstrate to the Surveyor's satisfaction that the requirements of the Rules have been met. The trial is to include the operation of the following:

(i) the steering gear, including demonstration of the performances required by Regulation 29.3.2 and 29.4.2. For controllable pitch propellers, the propeller pitch is to be at the maximum design pitch approved for the maximum continuous ahead R.P.M. at the main steering gear trial. If the vessel cannot be tested at the deepest draught, steering gear trials shall be conducted at a displacement as close as reasonably possible to full-load displacement as required by Section 6.1.2 of ISO 19019:2005 on the conditions that either the rudder is fully submerged (zero speed waterline) and the vessel is in an acceptable trim condition, or the rudder load and torque at the specified trial loading condition have been predicted and extrapolated to the full load condition. In any case for the main steering gear trial, the speed of ship corresponding to the number of maximum continuous revolution of main engine and maximum design pitch applies.

(ii) the steering gear power units, including transfer between steering gear power units.

(iii) the isolation of one power actuating system, checking the time for regaining steering capability.

(iv) the hydraulic fluid recharging system.

(v) the emergency power supply required by Regulation 29.14.

(vi) the steering gear controls, including transfer of control and local control.

(vii) the means of communication between the wheelhouse, engine room, and the steering gear compartment.

(viii) the alarms and indicators required by regulations 29, 30 and M42.12, these tests may be effected at dockside.

(ix) where steering gear is designed to avoid hydraulic locking this feature shall be demonstrated.
Appendix 1

Definitions relating to steering gear

1. Steering gear control system means the equipment by which orders are transmitted from the navigating bridge to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

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

3. Steering gear power unit means:

(a) in the case of electric steering gear, and electric motor and its associated electrical equipment,

(b) in the case of electrohydraulic steering gear, an electric motor and its associated electrical equipment and connected pump,

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

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

5. Power actuating system means the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e. tiller, quadrant and rudder stock, or components serving the same purpose.

6. Maximum ahead service speed means the greatest speed which the ship is designed to maintain in service at sea at her deepest sea going draught at maximum propeller RPM and corresponding engine MCR.

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

8. Maximum working pressure means the maximum expected pressure in the system when the steering gear is operated to comply with 29.3.2.
M43 Bridge control of propulsion machinery for unattended machinery spaces

M43.1 Under all sailing conditions, including manœuvreuring, the speed, direction of thrust and, if applicable, pitch of the propeller shall be fully controllable from the navigating bridge.

M43.2 In principle the remote control mentioned under M43.1 is to be performed by a single control device for each independent propeller, with automatic performance of all associated services including, where necessary, means of preventing overload and prolonged running in critical speed ranges of the propelling machinery.

M43.3 The bridge control system is to be independent from the other transmission system; however, one control lever for both system may be accepted.

M43.4 Operations following any setting of the bridge control device including reversing from the maximum ahead service speed in case of emergency are to take place in an automatic sequence and with time intervals acceptable to the machinery.

M43.5 The main propulsion machinery shall be provided with an emergency stopping device on the navigating bridge and independent from the bridge control system.

M43.6 Remote starting of the propulsion machinery is to be automatically inhibited if conditions exist which may hazard the machinery, e.g. shaft turning gear engaged, drop of lubricating oil pressure.

M43.7 For steam turbines a slow-turning device should be provided which operates automatically if the turbine is stopped longer than admissible. Discontinuation of this automatic turning from the bridge must be possible.

M43.8 The design of the bridge control system shall be such that in case of its failure an alarm is given. In this case the speed and direction of the propeller thrust is to be maintained until local control is in operation, unless this is considered impracticable. In particular, lack of power (electric, pneumatic, hydraulic) should not lead to major and sudden change in propulsion power or direction of propeller rotation.

M43.9 The number of automatic consecutive attempts which fail to produce a start shall be limited to maintain sufficient starting air pressure. An alarm shall be provided at an air pressure level, which still permits main engine starting operation.

M43.10 It shall be possible for the propulsion machinery to be controlled from a local position even in the case of failure in any part of the automatic or remote control systems.

M43.11 Remote control of the propulsion machinery shall be possible only from one control location at one time; at such locations interconnected control positions are permitted.

M43.12 The control system shall include means to prevent the propelling thrust from altering significantly when transferring control from one control to another.

M43.13 Each control location is to be provided with means to indicate which of them is in control. Propulsion machinery orders from the navigating bridge shall be indicated in the engine control room or at the manœuvreuring platform, as appropriate.

M43.14 The transfer of control between the navigating bridge and machinery spaces shall be possible only in the main machinery space or the main machinery control room.
Documents for the approval of diesel engines

1. Scope

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

2. Definitions

Definitions relating to approval of diesel engines are given in Appendix 1.

3. Overview

3.1 Approval process

3.1.1 Type approval certificate

For each type of engine that is required to be approved, a type approval certificate is to be obtained by the engine designer. The process details for obtaining a type approval certificate are in Section 4. This process consists of the engine designer obtaining:

- drawing and specification approval,
- conformity of production,
- approval of type testing programme,
- type testing of engines,
- review of the obtained type testing results, and

Notes:

1. The requirements of M44 Rev.8 and Rev.9 are to be uniformly implemented by IACS Societies for engines for which the date of an application for type approval certification is dated on or after 1 July 2016.

2. The “date of application for type approval” is the date of documents accepted by the Classification Society as request for type approval certification of a new engine type or of an engine type that has undergone substantive modifications in respect of the one previously type approved, or for renewal of an expired type approval certificate.

3. Engines with an existing type approval on 1 July 2016 are not required to be re-type approved in accordance with this UR until the current Type Approval becomes invalid. For the purpose of certification of these engines, the current type approval and related submitted documentation will be accepted in place of that required by this UR until the current type approval expires or the engine type has undergone substantive modifications.
- evaluation of the manufacturing arrangements,
- issue of a type approval certificate upon satisfactorily meeting the Rule requirements.

3.1.2 Engine certificate

Each diesel engine manufactured for a shipboard application is to have an engine certificate. The certification process details for obtaining the engine certificate are in Section 5. This process consists of the engine builder/licensee obtaining design approval of the engine application specific documents, submitting a comparison list of the production drawings to the previously approved engine design drawings referenced in 3.1.1, forwarding the relevant production drawings and comparison list for the use of the Surveyors at the manufacturing plant and shipyard if necessary, engine testing and upon satisfactorily meeting the Rule requirements, the issuance of an engine certificate.

3.2 Document flow for diesel engines

3.2.1 Document flow for obtaining a type approval certificate

3.2.1.1 For the initial engine type, the engine designer prepares the documentation in accordance with requirements in Tables 1 and 2 and forwards to the Classification Society according to the agreed procedure for review.

3.2.1.2 Upon review and approval of the submitted documentation (evidence of approval), it is returned to the engine designer.

3.2.1.3 The engine designer arranges for a Surveyor to attend an engine type test and upon satisfactory testing the Classification Society issues a type approval certificate.

3.2.1.4 A representative document flow process for obtaining a type approval certificate is shown in Appendix 2, Figure 1.

3.2.2 Document flow for engine certificate

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

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

3.2.2.3 The engine builder/licensee develops a comparison list of the production documentation to the documentation listed in Tables 1 and 2. An example comparison list is provided in Appendix 4. If there are differences in the technical content on the licensee’s production drawings/documents compared to the corresponding licensor’s drawings, the licensee must obtain agreement to such differences from the licensor using the template in Appendix 5.

If the designer acceptance is not confirmed, the engine is to be regarded as a different engine type and is to be subjected to the complete type approval process by the licensee.
### 3.2.2.4 The engine builder/licensee submits the comparison list and the production documentation to the Classification Society according to the agreed procedure for review/approval.

### 3.2.2.5 The Classification Society returns documentation to the engine builder/licensee with confirmation that the design has been approved. This documentation is intended to be used by the engine builder/licensee and their subcontractors and attending Surveyors. As the attending Surveyors may request the engine builder/licensee or their subcontractors to provide the actual documents indicated in the list, the documents are necessary to be prepared and available for the Surveyors.

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

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

### 3.2.2.8 A representative document flow process for obtaining an engine certificate is shown in Appendix 2, Figure 2.

### 3.3 Approval of diesel engine components

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

### 3.4 Submission format of documentation

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

### 4. Type approval process

The type approval process consists of the steps in 4.1 to 4.4. The document flow for this process is shown in Appendix 2, Figure 1.

The documentation, as far as applicable to the type of engine, to be submitted by the engine designer/licensor to the Classification Society is listed in Tables 1 and 2.

### 4.1 Documents for information Table 1

Table 1 lists basic descriptive information to provide the Classification Society an overview of the engine’s design, engine characteristics and performance. Additionally, there are requirements related to auxiliary systems for the engine’s design including installation arrangements, list of capacities, technical specifications and requirements, along with information needed for maintenance and operation of the engine.
4.2 Documents for approval or recalculation Table 2

Table 2 lists the documents and drawings, which are to be approved by the Classification Society.

4.3 Design approval/appraisal (DA)

DA’s are valid as long as no substantial modifications have been implemented. Where substantial modifications have been made the validity of the DA’s may be renewed based on evidence that the design is in conformance with all current Rules and statutory regulations (e.g. SOLAS, MARPOL). See also 4.6.

4.4 Type approval test

A type approval test is to be carried out in accordance with IACS UR M71 and is to be witnessed by the Classification Society.

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

4.5 Type approval certificate

After the requirements in M44.4.1 through M44.4.4 have been satisfactorily completed the Classification Society issues a type approval certificate (TAC).

4.6 Design modifications

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

4.7 Type approval certificate renewals

A renewal of type approval certificates will be granted upon:

4.7.1 Submission of information in either 4.7.1.1 or 4.7.1.2.

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

4.7.1.2 A declaration that no substantial modifications have been applied since the last DA issued.

4.8 Validity of type approval certificate

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

4.9 Document review and approval

4.9.1 The assignment of documents to Table 1 for information does not preclude possible comments by the individual Classification Society.
4.9.2 Where considered necessary, the Classification Society may request further documents to be submitted. This may include details or evidence of existing type approval or proposals for a type testing programme in accordance with UR M71.

5. Certification process

The certification process consists of the steps in 5.1 to 5.5. This process is illustrated in Appendix 2, Figure 2 showing the document flows between the:

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

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

The documents listed in Table 3 may be submitted by:

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

5.1 Document development for production

Prior to the start of the engine certification process, a design approval is to be obtained per 4.1 through 4.3 for each type of engine. Each type of engine is to be provided with a type approval certificate obtained by the engine designer/licensor prior to the engine builder/licensee beginning production manufacturing. For the first engine of a type, the type approval process and the certification process may be performed simultaneously.

The engine designer/licensor reviews the documents listed in Tables 1 and 2 for the application and develops, if necessary, application specific documentation for the use of the engine builder/licensee in developing engine specific production documents.

If substantive changes have been made, the affected documents are to be resubmitted to the Classification Society as per 4.6.

5.2 Documents to be submitted for inspection and testing

Table 3 lists the production documents, which are to be submitted by the engine builder/licensee to the Classification Society following acceptance by the engine designer/licensor. The Surveyor uses the information for inspection purposes during manufacture and testing of the engine and its components. See 3.2.2.3 through 3.2.2.6.

5.3 Alternative execution

If there are differences in the technical content on the licensee’s production drawings/documents compared to the corresponding licensor’s drawings, the licensee must
provide to the Classification Society approval centre a “Confirmation of the licensor’s acceptance of licensee’s modifications” approved by the licensor and signed by licensee and licensor. Modifications applied by the licensee are to be provided with appropriate quality requirements. See Appendix 5 for a sample format.

5.4 Manufacturer approval

The Classification Society assesses conformity of production with the Classification Society’s requirements for production facilities comprising manufacturing facilities and processes, machining tools, quality assurance, testing facilities, etc. See IACS UR M72. Satisfactory conformance results in the issue of a class approval document.

5.5 Document availability

In addition to the documents listed in Table 3, the engine builder/licensee is to be able to provide to the Surveyor performing the inspection upon request the relevant detail drawings, production quality control specifications and acceptance criteria. These documents are for supplemental purposes to the survey only.

5.6 Engine assembly and testing

Each engine assembly and testing procedure required according to relevant IACS URs are to be witnessed by the Classification Society unless an Alternative Certification Scheme meeting the requirements of UR Z26 is agreed between manufacturer and the Society.
Table 1  Documentation to be submitted for information, as applicable

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Engine particulars (e.g. Data sheet with general engine information (see Appendix 3), Project Guide, Marine Installation Manual)</td>
</tr>
<tr>
<td>2</td>
<td>Engine cross section</td>
</tr>
<tr>
<td>3</td>
<td>Engine longitudinal section</td>
</tr>
<tr>
<td>4</td>
<td>Bedplate and crankcase of cast design</td>
</tr>
<tr>
<td>5</td>
<td>Thrust bearing assembly(^{1})</td>
</tr>
<tr>
<td>6</td>
<td>Frame/framebox/gearbox of cast design(^{2})</td>
</tr>
<tr>
<td>7</td>
<td>Tie rod</td>
</tr>
<tr>
<td>8</td>
<td>Connecting rod</td>
</tr>
<tr>
<td>9</td>
<td>Connecting rod, assembly(^{3})</td>
</tr>
<tr>
<td>10</td>
<td>Crosshead, assembly(^{3})</td>
</tr>
<tr>
<td>11</td>
<td>Piston rod, assembly(^{3})</td>
</tr>
<tr>
<td>12</td>
<td>Piston, assembly(^{3})</td>
</tr>
<tr>
<td>13</td>
<td>Cylinder jacket/ block of cast design(^{2})</td>
</tr>
<tr>
<td>14</td>
<td>Cylinder cover, assembly(^{3})</td>
</tr>
<tr>
<td>15</td>
<td>Cylinder liner</td>
</tr>
<tr>
<td>16</td>
<td>Counterweights (if not integral with crankshaft), including fastening</td>
</tr>
<tr>
<td>17</td>
<td>Camshaft drive, assembly(^{3})</td>
</tr>
<tr>
<td>18</td>
<td>Flywheel</td>
</tr>
<tr>
<td>19</td>
<td>Fuel oil injection pump</td>
</tr>
<tr>
<td>20</td>
<td>Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly</td>
</tr>
</tbody>
</table>

For electronically controlled engines, construction and arrangement of:

| 21  | Control valves                                                      |
| 22  | High-pressure pumps                                                 |
| 23  | Drive for high pressure pumps                                       |
| 24  | Operation and service manuals\(^{4}\)                               |
| 25  | FMEA (for engine control system)\(^{5}\)                            |
| 26  | Production specifications for castings and welding (sequence)       |
| 27  | Evidence of quality control system for engine design and in service maintenance |
| 28  | Quality requirements for engine production                          |
| 29  | Type approval certification for environmental tests, control components\(^{6}\) |

FOOTNOTES:

1. If integral with engine and not integrated in the bedplate.
2. Only for one cylinder or one cylinder configuration.
3. Including identification (e.g. drawing number) of components.
4. Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.
5. Where engines rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves, a failure mode and effects analysis (FMEA) is to be submitted to demonstrate that failure of the control system will not result in the operation of the engine being degraded beyond acceptable performance criteria for the engine. The FMEA reports required will not be explicitly approved by the Classification Society.
6. Tests are to demonstrate the ability of the control, protection and safety equipment to function as intended under the specified testing conditions per UR E10.
### Table 2  Documentation to be submitted for approval, as applicable

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bedplate and crankcase of welded design, with welding details and welding instructions¹,²</td>
</tr>
<tr>
<td>2</td>
<td>Thrust bearing bedplate of welded design, with welding details and welding instructions¹</td>
</tr>
<tr>
<td>3</td>
<td>Bedplate/oil sump welding drawings¹</td>
</tr>
<tr>
<td>4</td>
<td>Frame/framebox/gearbox of welded design, with welding details and instructions¹,²</td>
</tr>
<tr>
<td>5</td>
<td>Engine frames, welding drawings¹,²</td>
</tr>
<tr>
<td>6</td>
<td>Crankshaft, details, each cylinder No.</td>
</tr>
<tr>
<td>7</td>
<td>Crankshaft, assembly, each cylinder No.</td>
</tr>
<tr>
<td>8</td>
<td>Crankshaft calculations (for each cylinder configuration) according to the attached data sheet and UR M53</td>
</tr>
<tr>
<td>9</td>
<td>Thrust shaft or intermediate shaft (if integral with engine)</td>
</tr>
<tr>
<td>10</td>
<td>Shaft coupling bolts</td>
</tr>
<tr>
<td>11</td>
<td>Material specifications of main parts with information on non-destructive material tests and pressure tests³</td>
</tr>
<tr>
<td>12</td>
<td>Schematic layout or other equivalent documents on the engine of:</td>
</tr>
<tr>
<td>13</td>
<td>Starting air system</td>
</tr>
<tr>
<td>14</td>
<td>Fuel oil system</td>
</tr>
<tr>
<td>15</td>
<td>Lubricating oil system</td>
</tr>
<tr>
<td>16</td>
<td>Cooling water system</td>
</tr>
<tr>
<td>17</td>
<td>Hydraulic system</td>
</tr>
<tr>
<td>18</td>
<td>Hydraulic system (for valve lift)</td>
</tr>
<tr>
<td>19</td>
<td>Engine control and safety system</td>
</tr>
<tr>
<td>20</td>
<td>Shielding of high pressure fuel pipes, assembly⁴</td>
</tr>
<tr>
<td>21</td>
<td>Construction of accumulators (for electronically controlled engine)</td>
</tr>
<tr>
<td>22</td>
<td>Construction of common accumulators (for electronically controlled engine)</td>
</tr>
<tr>
<td>23</td>
<td>Arrangement and details of the crankcase explosion relief valve (see UR M9)⁵</td>
</tr>
<tr>
<td>24</td>
<td>Calculation results for crankcase explosion relief valves (see UR M9)</td>
</tr>
<tr>
<td>25</td>
<td>Details of the type test program and the type test report⁷</td>
</tr>
<tr>
<td>26</td>
<td>High pressure parts for fuel oil injection system⁶</td>
</tr>
<tr>
<td>27</td>
<td>Oil mist detection and/or alternative alarm arrangements (see UR M10)</td>
</tr>
<tr>
<td>28</td>
<td>Details of mechanical joints of piping systems (see UR P2)</td>
</tr>
<tr>
<td>29</td>
<td>Documentation verifying compliance with inclination limits (see UR M46)</td>
</tr>
</tbody>
</table>

**FOOTNOTES:**

1. For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.
2. For each cylinder for which dimensions and details differ.
3. For comparison with Society requirements for material, NDT and pressure testing as applicable.
4. All engines.
5. Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m³ or more.
6. The documentation to contain specifications for pressures, pipe dimensions and materials.
7. The type test report may be submitted shortly after the conclusion of the type test.
Table 3  Documentation for the inspection of components and systems

- Special consideration will be given to engines of identical design and application
- For engine applications refer to UR M72

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Engine particulars as per data sheet in Appendix 3</td>
</tr>
<tr>
<td>2</td>
<td>Material specifications of main parts with information on non-destructive material tests and pressure tests¹</td>
</tr>
<tr>
<td>3</td>
<td>Bedplate and crankcase of welded design, with welding details and welding instructions²</td>
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<tr>
<td>4</td>
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<tr>
<td>5</td>
<td>Frame/framebox/gearbox of welded design, with welding details and instructions²</td>
</tr>
<tr>
<td>6</td>
<td>Crankshaft, assembly and details</td>
</tr>
<tr>
<td>7</td>
<td>Thrust shaft or intermediate shaft (if integral with engine)</td>
</tr>
<tr>
<td>8</td>
<td>Shaft coupling bolts</td>
</tr>
<tr>
<td>9</td>
<td>Bolts and studs for main bearings</td>
</tr>
<tr>
<td>10</td>
<td>Bolts and studs for cylinder heads and exhaust valve (two stroke design)</td>
</tr>
<tr>
<td>11</td>
<td>Bolts and studs for connecting rods</td>
</tr>
<tr>
<td>12</td>
<td>Tie rods</td>
</tr>
<tr>
<td>13</td>
<td>Schematic layout or other equivalent documents on the engine of:³</td>
</tr>
<tr>
<td>14</td>
<td>Starting air system</td>
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<tr>
<td>15</td>
<td>Fuel oil system</td>
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<td>Hydraulic system (for valve lift)</td>
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<td>Engine control and safety system</td>
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<td>23</td>
<td>High pressure parts for fuel oil injection system⁵</td>
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<td>Oil mist detection and/or alternative alarm arrangements (see UR M10)</td>
</tr>
<tr>
<td>26</td>
<td>Cylinder head</td>
</tr>
<tr>
<td>27</td>
<td>Cylinder block, engine block</td>
</tr>
<tr>
<td>28</td>
<td>Cylinder liner</td>
</tr>
<tr>
<td>29</td>
<td>Counterweights (if not integral with crankshaft), including fastening</td>
</tr>
<tr>
<td>30</td>
<td>Connecting rod with cap</td>
</tr>
<tr>
<td>31</td>
<td>Crosshead</td>
</tr>
<tr>
<td>32</td>
<td>Piston rod</td>
</tr>
<tr>
<td>33</td>
<td>Piston, assembly²</td>
</tr>
<tr>
<td>34</td>
<td>Piston head</td>
</tr>
<tr>
<td>35</td>
<td>Camshaft drive, assembly²</td>
</tr>
<tr>
<td>36</td>
<td>Flywheel</td>
</tr>
<tr>
<td>37</td>
<td>Arrangement of foundation (for main engines only)</td>
</tr>
<tr>
<td>38</td>
<td>Fuel oil injection pump</td>
</tr>
<tr>
<td>39</td>
<td>Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly</td>
</tr>
<tr>
<td>40</td>
<td>Construction and arrangement of dampers</td>
</tr>
<tr>
<td></td>
<td>For electronically controlled engines, assembly drawings or arrangements of:</td>
</tr>
<tr>
<td></td>
<td>Control valves</td>
</tr>
<tr>
<td>No.</td>
<td>Item</td>
</tr>
<tr>
<td>-----</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>41</td>
<td>High-pressure pumps</td>
</tr>
<tr>
<td>42</td>
<td>Drive for high pressure pumps</td>
</tr>
<tr>
<td>43</td>
<td>Valve bodies, if applicable</td>
</tr>
<tr>
<td>44</td>
<td>Operation and service manuals⁸⁸</td>
</tr>
<tr>
<td>45</td>
<td>Test program resulting from FMEA (for engine control system)⁹⁹</td>
</tr>
<tr>
<td>46</td>
<td>Production specifications for castings and welding (sequence)</td>
</tr>
<tr>
<td>47</td>
<td>Type approval certification for environmental tests, control components¹⁰</td>
</tr>
<tr>
<td>48</td>
<td>Quality requirements for engine production</td>
</tr>
</tbody>
</table>

**FOOTNOTES:**

1. For comparison with Society requirements for material, NDT and pressure testing as applicable.
2. For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.
3. Details of the system so far as supplied by the engine manufacturer such as: main dimensions, operating media and maximum working pressures.
4. All engines.
5. The documentation to contain specifications for pressures, pipe dimensions and materials.
6. Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m³ or more.
7. Including identification (e.g. drawing number) of components.
8. Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.
9. Required for engines that rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves.
10. Documents modified for a specific application are to be submitted to the Classification Society for information or approval, as applicable. See 3.2.2.2, Appendix 4 and Appendix 5.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance criteria</td>
<td>A set of values or criteria which a design, product, service or process is required to conform with, in order to be considered in compliance</td>
</tr>
<tr>
<td>Accepted</td>
<td>Status of a design, product, service or process, which has been found to conform to specific acceptance criteria</td>
</tr>
<tr>
<td>Alternative Certification Scheme (ACS)</td>
<td>A system, by which a society evaluates a manufacturer's quality assurance and quality control arrangements for compliance with Rule requirements, then authorizes a manufacturer to undertake and witness testing normally required to be done in the presence of a Surveyor. The Alternative Certification Scheme as presently administered by the Member Societies is generally known as:</td>
</tr>
<tr>
<td></td>
<td>ABS: Product Quality Assurance</td>
</tr>
<tr>
<td></td>
<td>BV: Alternative Survey Scheme</td>
</tr>
<tr>
<td></td>
<td>CCS: Type Approval-A</td>
</tr>
<tr>
<td></td>
<td>CRS: Examination of the manufacturing process and quality assurance system</td>
</tr>
<tr>
<td></td>
<td>DNV-GL: Manufacturing Survey Arrangement</td>
</tr>
<tr>
<td></td>
<td>IRS: IRS Quality Assurance Scheme</td>
</tr>
<tr>
<td></td>
<td>KR: Quality Assurance System</td>
</tr>
<tr>
<td></td>
<td>LR: LR Quality Schemes</td>
</tr>
<tr>
<td></td>
<td>NK: Approval of Manufacturers</td>
</tr>
<tr>
<td></td>
<td>PRS: Alternative Certification Scheme</td>
</tr>
<tr>
<td></td>
<td>RINA: Alternative Survey Scheme</td>
</tr>
<tr>
<td></td>
<td>RS: Agreement on Survey</td>
</tr>
<tr>
<td>Appraisal</td>
<td>Evaluation by a competent body</td>
</tr>
<tr>
<td>Approval</td>
<td>The granting of permission for a design, product, service or process to be used for a stated purpose under specific conditions based upon a satisfactory appraisal</td>
</tr>
<tr>
<td>Assembly</td>
<td>Equipment or a system made up of components or parts</td>
</tr>
<tr>
<td>Assess</td>
<td>Determine the degree of conformity of a design, product, service, process, system or organization with identified specifications, Rules, standards or other normative documents</td>
</tr>
<tr>
<td>Audit</td>
<td>Planned systematic and independent examination to determine whether the activities are documented, the documented activities are implemented, and the results meet the stated objectives</td>
</tr>
<tr>
<td>Auditor</td>
<td>Individual who has the qualifications and experience to perform audits</td>
</tr>
<tr>
<td>Certificate</td>
<td>A formal document attesting to the compliance of a design, product, service or process with acceptance criteria</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Certification</td>
<td>A procedure whereby a design, product, service or process is approved in accordance with acceptance criteria</td>
</tr>
<tr>
<td>Class</td>
<td>Short for Classification Society</td>
</tr>
<tr>
<td>Class approval</td>
<td>Approved by a Classification Society</td>
</tr>
<tr>
<td>Classification</td>
<td>Specific type of certification, which relates to the Rules of the relevant Classification Society</td>
</tr>
<tr>
<td>Competent body</td>
<td>Organization recognized as having appropriate knowledge and expertise in a specific area</td>
</tr>
<tr>
<td>Component</td>
<td>Part, member of equipment or system</td>
</tr>
<tr>
<td>Conformity</td>
<td>Where a design, product, process or service demonstrates compliance with its specific requirements</td>
</tr>
<tr>
<td>Contract</td>
<td>Agreement between two or more parties relating to the scope of service</td>
</tr>
<tr>
<td>Contractor</td>
<td>see Supplier</td>
</tr>
<tr>
<td>Customer</td>
<td>Party who purchases or receives goods or services from another</td>
</tr>
<tr>
<td>Design</td>
<td>All relevant plans, documents, calculations described in the performance, installation and manufacturing of a product</td>
</tr>
<tr>
<td>Design analysis</td>
<td>Investigative methodology selectively used to assess the design</td>
</tr>
<tr>
<td>Design appraisal</td>
<td>Evaluation of all relevant plans, calculations and documents related to the design</td>
</tr>
<tr>
<td>Design review</td>
<td>Part of the appraisal process to evaluate specific aspects of the design</td>
</tr>
<tr>
<td>Drawings approval/ plan approval</td>
<td>Part of the design approval process which relates to the evaluation of drawings and plans</td>
</tr>
<tr>
<td>Equipment</td>
<td>Part of a system assembled from components</td>
</tr>
<tr>
<td>Equivalent</td>
<td>An acceptable, no less effective alternative to specified criteria</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Systematic examination of the extent to which a design, product, service or process satisfies specific criteria</td>
</tr>
<tr>
<td>Examination</td>
<td>Assessment by a competent person to determine compliance with requirements</td>
</tr>
<tr>
<td>Inspection</td>
<td>Examination of a design, product service or process by an Inspector</td>
</tr>
<tr>
<td>Inspection plan</td>
<td>List of tasks of inspection to be performed by the Inspector</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Installation</td>
<td>The assembling and final placement of components, equipment and subsystems to permit operation of the system</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Party responsible for the manufacturing and quality of the product</td>
</tr>
<tr>
<td>Manufacturing process</td>
<td>Systematic series of actions directed towards manufacturing a product</td>
</tr>
<tr>
<td>Manufacturing process approval</td>
<td>Approval of the manufacturing process adopted by the manufacturer during production of a specific product</td>
</tr>
<tr>
<td>Material</td>
<td>Goods supplied by one manufacturer to another manufacturer that will require further forming or manufacturing before becoming a new product</td>
</tr>
<tr>
<td>Modification</td>
<td>A limited change that does not affect the current approval</td>
</tr>
<tr>
<td>Modification notice</td>
<td>Information about a design modification with new modification index or new drawing number replacing the earlier drawing</td>
</tr>
<tr>
<td>Performance test</td>
<td>Technical operation where a specific performance characteristic is determined</td>
</tr>
<tr>
<td>Producer</td>
<td>See manufacturer</td>
</tr>
<tr>
<td>Product</td>
<td>Result of the manufacturing process</td>
</tr>
<tr>
<td>Prototype test</td>
<td>Investigations on the first or one of the first new engines with regard to optimization, fine tuning of engine parameters and verification of the expected running behaviour</td>
</tr>
<tr>
<td>Quality assurance</td>
<td>All the planned and systematic activities implemented within the quality system, and demonstrated as needed to provide adequate confidence that an entity will fulfil requirements for quality. Refer to ISO 9000 series</td>
</tr>
<tr>
<td>Regulation</td>
<td>Rule or order issued by an executive authority or regulatory agency of a government and having the force of law</td>
</tr>
<tr>
<td>Repair</td>
<td>Restore to original or near original condition from the results of wear and tear or damages for a product or system in service</td>
</tr>
<tr>
<td>Requirement</td>
<td>Specified characteristics used for evaluation purposes</td>
</tr>
<tr>
<td>Information</td>
<td>Additional technical data or details supplementing the drawings requiring approval</td>
</tr>
<tr>
<td>Revision</td>
<td>Means to record changes in one or more particulars of design drawings or specifications</td>
</tr>
<tr>
<td>Specification</td>
<td>Technical data or particulars which are used to establish the suitability of materials, products, components or systems for their intended use</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>Substantive modifications or major modifications or major changes</td>
<td>Design modifications, which lead to alterations in the stress levels, operational behaviour, fatigue life or an effect on other components or characteristics of importance such as emissions</td>
</tr>
<tr>
<td>Subsupplier/subcontractor</td>
<td>One who contracts to supply material to another supplier</td>
</tr>
<tr>
<td>Supplier</td>
<td>One who contracts to furnish materials or design, products, service or components to a customer or user</td>
</tr>
<tr>
<td>Test</td>
<td>A technical operation that consists of the determination of one or more characteristics or performance of a given product, material, equipment, organism, physical phenomenon, process or service according to a specified procedure. A technical operation to determine if one or more characteristic(s) or performance of a product, process or service satisfies specific requirements</td>
</tr>
<tr>
<td>Traceability</td>
<td>Ability to follow back through the design and manufacturing process to the origin</td>
</tr>
<tr>
<td>Type approval</td>
<td>The establishment of the acceptability of a product through the systematic: 1. Evaluation of a design to determine conformance with specifications 2. Witnessing manufacture and testing of a type of product to determine compliance with the specification 3. Evaluation of the manufacturing arrangements to confirm that the product can be consistently produced in accordance with the specification</td>
</tr>
<tr>
<td>Type approval test</td>
<td>Last step of the type approval procedure. Test program in accordance with UR M71</td>
</tr>
<tr>
<td>Witness</td>
<td>Individual physically present at a test and being able to record and give evidence about its outcome</td>
</tr>
</tbody>
</table>
The document flow diagrams in this appendix are provided as an aid to all parties involved in the engine certification process as to their roles and responsibilities. Variations in the document flow may vary in response to unique issues with regard to various factors related to location, availability of components and surveys. In any case, the text in the UR takes precedence over these flow diagrams.

* May also be produced by licensee

Figure 1 Type approval document flow
UR M44 Document Flow, FAT

- Engine Designer (ED) / Licensor
  - Obtains TA based on documents in Tables 1 and 2
  - Develops documents for specific engine 3.2.2.2

- Engine Builder (EB) / Licensee (L)
  - Develops/modifies engine specific documents for production 2)
  - Based on Table 3
  - Develops:
    - Comparison list, as per Appendix 4
    - Documents as per Appendix 5 if required 3.2.2.3

- Checks alternative execution and issues acceptance 3.2.2.3

- Component Manufacturer
  - Reviews/approves documents, App. 4 and App. 5 docs as applicable
  - Reviews/approves documents, App. 4 and App. 5 as applicable

- Class Approval Centre
  - Reviews/approves documents, App. 4 and App. 5 as applicable

- Class Site Office 1)
  - Reviews/approves documents, App. 4 and App. 5 as applicable
  - EB Site Office: Files list of marked documents for use in FAT survey

- Production based on marked documents

1) Class Site office with responsibility for engine builder and/or component manufacturers in different locations

2) For alternative execution, see 5.3

Figure 2 Engine certificate document flow
UR M44 Document Flow, FAT (Continued)

Figure 2 Engine certificate document flow (continued)
### General Data

<table>
<thead>
<tr>
<th>Engine Designer:</th>
<th>Contact Person:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Address:</th>
<th>Engine Manufacturer(s), Licensee(s) and/or Manufacturing Sites Name Country</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 1. Document purpose (select options from either 1a or 1b)

#### 1a. Type Approval Application

- [ ] New Type Approval
- [ ] Renew Type Approval
- [ ] Amend Type Approval
- [ ] Design Evaluation
- [ ] Update TA Supplement
- [ ] Other

**Required activities**

- **DA, TT, CoP**
- **CoP, if design change then amended or new certificate process to be followed**
- **DA & CoP, Further TT if previously approved engine has been substantively modified (as required by UR M71)**
- **DA, TT, applicable where designer does not have production facilities, Type Approval to be granted to specific production facility once associated CoP has been completed**
- **Update to Supplement, only for minor changes not affecting the Type Approval Certificate**
- **e.g. National/Statutory Administration requirements i.e. MSC.81(70) for emergency engines**

**For TA Cert amendments or Supplement updates, details of what is to be changed:**

**For 'Other', Details of the requirements to be considered:**

#### 1b. Addendum for Individual Engine FAT and Certification

Individual engine requiring FAT and Certification, only where the performance data for the engine being certified differs from the details provided on the original Type Approval Application.

Only section 3b requires completion. Where changes to other sections are necessary, a new Type Approval Application may be required.

**Reference number of Internal Combustion Engine Approval Application Form previously submitted and reference number of the Type Approval Certificate.**

(Copy of original application form to be attached to this document)

### 2. Existing documentation

<table>
<thead>
<tr>
<th>Previous Class Type Approval Certificate No. or related Design Approval No. (if applicable)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Formerly issued documentation for engine (E.g. previous type test reports, in-service experience justification reports, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issuing Body:</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Existing Certification (E.g. Manufacturer’s quality certification ISO 9001 etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issuing Body:</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

### 3. Design (mark all that apply)

#### 3a. Engine Particulars:

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Number of delivered marine engines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Application</th>
<th>Direct drive Propulsion</th>
<th>Emergency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Single engine / Multi-engine installation)</td>
<td>(Aux. Services / Electric Propulsion)</td>
</tr>
<tr>
<td>2-stroke</td>
<td>4-stroke</td>
<td>In-line</td>
</tr>
<tr>
<td>Cross-head</td>
<td>Trunk-piston</td>
<td>Reversible</td>
</tr>
<tr>
<td>Cylinder bore(mm)</td>
<td>Length of piston stroke (mm)</td>
<td></td>
</tr>
<tr>
<td>Without supercharging</td>
<td>With supercharging</td>
<td></td>
</tr>
<tr>
<td>Without charge air cooling</td>
<td>With charge air cooling</td>
<td></td>
</tr>
<tr>
<td>Constant-pressure charging system</td>
<td>Pulsating pressure charging system</td>
<td></td>
</tr>
</tbody>
</table>

**Valve operation**

- [ ] Cam control
- [ ] Electronic control

**Fuel Injection**

- [ ] Direct injection
- [ ] Indirect injection
- [ ] Cam controlled injection
- [ ] Electronically controlled injection
### M44 (cont)

#### Fuel Types

*Classification according to ISO 8216*

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

#### 3b. Performance Data

*(Related to: Barometric pressure 1,000 mbar; Air temperature 45°C; Relative humidity 60%; Seawater temperature 32°C)*

<table>
<thead>
<tr>
<th>Model reference No. (if applicable)</th>
<th>Max. continuous rating kW/cyl</th>
<th>Rated speed 1/min</th>
<th>Mean indicated pressure MPa</th>
<th>Mean effective pressure MPa</th>
<th>Max. firing pressure MPa</th>
<th>Charge air pressure MPa</th>
<th>Compression ratio -</th>
<th>Mean piston speed m/s</th>
</tr>
</thead>
</table>

#### 3c. Crankshaft

- Design: Solid, Semi-built, Built
- Method of Manufacture: Cast, Forged, Slab forged, Approved die forged, Continuous grain flow process

<table>
<thead>
<tr>
<th>Is the crankshaft hardened by an approved process which includes the fillet radii of crankpins and journals?</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>If yes, state process:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Crankshaft material specification:
  - U.T.S. (N/mm²) | Yield strength (N/mm²)
  - Hardness value (Brinell/Vickers) | Elongation (%)

#### Dimensional Data

<table>
<thead>
<tr>
<th>If shrunk on webs, state shrinkage allowance (mm)</th>
<th>Yield strength of crankweb material (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centre of gravity of connecting rod from large end centre (mm)</td>
<td>Radius of gyration of connecting rod (mm)</td>
</tr>
<tr>
<td>Mass of each crankweb (kg)</td>
<td>Centre of gravity of web from journal axis (mm)</td>
</tr>
<tr>
<td>Mass of each counterweight (kg)</td>
<td>Centre of gravity of each counterweight from journal axis (mm)</td>
</tr>
<tr>
<td>Axial length of main bearing (mm)</td>
<td>Main bearing working clearance (mm)</td>
</tr>
<tr>
<td>Mass of flywheel at driving end (kg)</td>
<td>Mass of flywheel at opposite end (kg)</td>
</tr>
<tr>
<td>Nominal alternating torsional stress in crankpin (N/mm²)</td>
<td>Nominal alternating torsional stress in crank journal (N/mm²)</td>
</tr>
<tr>
<td>Length between centres (Total length)(mm)</td>
<td></td>
</tr>
</tbody>
</table>

#### 3d. Firing order

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

<table>
<thead>
<tr>
<th>Number of cylinders</th>
<th>Clockwise firing order</th>
<th>Counter-clockwise firing order</th>
</tr>
</thead>
</table>

---

4. Engine Ancillary Systems

4a. Turbochargers

<table>
<thead>
<tr>
<th>Turbocharger oil supply by:</th>
<th>Engine lub. oil system</th>
<th>TC internal lub. oil sys</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>No. of cylinders</th>
<th>No. of aux blowers</th>
<th>No. of charge air coolers</th>
<th>No. of TC</th>
<th>TC manufacturer &amp; type</th>
<th>TC type approval certificate No.</th>
</tr>
</thead>
</table>

4b. Speed governor

<table>
<thead>
<tr>
<th>Engine application (Main/Aux/Emergency)</th>
<th>Manufacturer / type</th>
<th>Mode of operation</th>
<th>Type approval cert. No. (if electric / electronic gov.)</th>
</tr>
</thead>
</table>

4c. Overspeed protection

<table>
<thead>
<tr>
<th>Independent overspeed protection available</th>
<th>Yes</th>
<th>No</th>
<th>Mode of operation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer / type, if electronic:</td>
<td>/</td>
<td></td>
<td>Type approval certificate No.</td>
</tr>
</tbody>
</table>

4d. Electronic systems

<table>
<thead>
<tr>
<th>Engine control and management system Note: use Remarks section to identify when a different engine control system will be used for Type Test Hardware: Manufacturer &amp; Model:</th>
<th>/</th>
<th>Type approval certificate No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software: Name &amp; Version:</td>
<td>/</td>
<td>Software conformity certificate No.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional electronic system 1:</th>
<th>Manufacturer &amp; type:</th>
<th>System function:</th>
<th>Type approval certificate No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional electronic system 2:</td>
<td>Manufacturer &amp; type:</td>
<td>System function:</td>
<td>Type approval certificate No.</td>
</tr>
<tr>
<td>Additional electronic system 3:</td>
<td>Manufacturer &amp; type:</td>
<td>System function:</td>
<td>Type approval certificate No.</td>
</tr>
</tbody>
</table>

4e. Starting System

<table>
<thead>
<tr>
<th>Type:</th>
</tr>
</thead>
</table>

4f. Safety devices/functions

| A flame arrester or a bursting disk is installed before each starting valve | Yes | No |
| in the starting air manifold | Yes | No |

<table>
<thead>
<tr>
<th>Crankcase relief valves available</th>
<th>Yes</th>
<th>No</th>
<th>Manufacturer / type:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type approval certificate No.</td>
<td>/</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No. of cyl.</th>
<th>Total crankcase gross volume incl. attachments (m³)</th>
<th>Type &amp; size (mm) of relief valve</th>
<th>Relief area per relief valve (mm²)</th>
<th>No. of relief valves</th>
</tr>
</thead>
</table>

Method used for detection of potentially explosive crankcase condition:

<table>
<thead>
<tr>
<th>Oil mist detector: Manufacturer / type:</th>
<th>/</th>
<th>Type approval certificate No.</th>
</tr>
</thead>
</table>

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

<table>
<thead>
<tr>
<th>Engine driven pumps:</th>
<th>Sea cooling water pump</th>
<th>LT-fresh cooling water pump</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main lubricating oil pump</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HT-fresh cooling water pump</td>
<td>Fuel oil booster pump</td>
<td>Hydraulic oil pump</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Engine attached motor driven pumps:</th>
<th>Cooling fresh water pump</th>
<th>Fuel oil booster pump</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lubricating oil pump</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydraulic oil pump</td>
<td>Other ( )</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cylinder overpressure warning device available</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type: Opening pressure (bar):</td>
<td>/</td>
<td></td>
</tr>
</tbody>
</table>
### Engine attached cooler or heater:
- [ ] Lubricating oil cooler
- [ ] Lubricating oil heater
- [ ] Fuel oil valve cooler
- [ ] Hydraulic oil cooler
- [ ] Cooling fresh water cooler

### Engine attached filter:
- Lubricating oil filter: [ ] Single [ ] Duplex [ ] Automatic
- Fuel oil filter: [ ] Single [ ] Duplex [ ] Automatic

### 5. Inclination limits

<table>
<thead>
<tr>
<th></th>
<th>Athwartships</th>
<th>Fore-and- aft</th>
</tr>
</thead>
<tbody>
<tr>
<td>(engine operation is safeguarded under the following limits)</td>
<td>Static</td>
<td>Dynamic</td>
</tr>
<tr>
<td>Main &amp; Auxiliary machinery</td>
<td>15.0°</td>
<td>22.5°</td>
</tr>
<tr>
<td>Emergency machinery</td>
<td>22.5°</td>
<td>22.5°</td>
</tr>
<tr>
<td>Emergency machinery on ships for the carriage of liquefied gas and liquid chemicals</td>
<td>30.0°</td>
<td>30.0°</td>
</tr>
</tbody>
</table>

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

### 7. References: Additional Information Attached to Application

<table>
<thead>
<tr>
<th>Document Name/Number</th>
<th>Summary of information contained in document</th>
</tr>
</thead>
</table>

### 8. Further Remarks:
- * All parties that affect the final complete engine (e.g. manufacture, modify, adjust) are to be listed. All sites where such work is carried out may be required to complete CoP assessment.
- † DA = Design Appraisal, TT = Type Test, CoP = Assessment of Conformity of Production. See ‘Definitions’ at the end of this application form for more information.
- ‡ Only in case of TA Extension.
- § See ‘Definitions’ at the end of this application form for more information.
### Definitions:

**Design Appraisal**: Evaluation of all relevant plans, calculations and documents related to the design to determine compliance with the IACS and individual Societies’ technical requirements. This includes requirements for all associated ancillary equipment and systems essential for the safe operation of the engine i.e. the Complete Engine. The Design Appraisal is recorded on a Supplement to the Type Approval Certificate.

**Type Testing** requires satisfactory completion of testing of the Complete Engine against the requirements of the Classification Societies’ applicable engine Type Testing programme (based on minimum requirements of IACS Unified Requirement M71). Type testing is only applicable to the first in series; all engines are to complete factory acceptance and shipboard trials as defined by IACS Unified Requirement M51 and Society requirements.

**Design Evaluation Certification** may be granted upon satisfactory completion of Design Appraisal and Type Testing.

**Assessment of Conformity of Production** means the assessment of quality assurance, manufacturing facilities and processes and testing facilities, to confirm the manufacturer’s capability to repeatedly produce the complete engine in accordance with the approved and type tested design.

**Type Approval Certification** will be granted upon satisfactory completion of Design Appraisal, Type Testing and assessment of Conformity of Production of the complete engine. The Type Approval Certificate will incorporate outputs from the Design Appraisal, the Type Test and the Assessment of Conformity of Production.

**Complete Engine** includes the control system and all ancillary systems and equipment referred to in the Rules that are used for safe operation of the engine and for which there are rule requirements, this includes systems allowing the use of different fuel types. The exact list of components/items that will need to be tested in together with the bare engine will depend on the specific design of the engine, its control system and the fuel(s) used but may include, but are not limited to, the following:

(a) Turbocharger(s)  
(b) Crankcase explosion relief devices  
(c) Oil mist detection and alarm devices  
(d) Piping  
(e) Electronic monitoring and control system(s) – software and hardware  
(f) Fuel management system (where dual fuel arrangements are fitted)  
(g) Engine driven pumps  
(h) Engine mounted filters

**Fuel Types**: All fuels that the engine is designed to operate with are to be identified on the application form as this may have impact on the requirements that are applicable for Design Appraisal and the scope of the tests required for Type Testing. Where the engine is to operate in a Dual Fuel mode, the combinations of fuel types are to be detailed. E.g. Natural Gas + DMA, Natural Gas + Marine Residual Fuel, the specific details of each fuel are to be provided as indicated in the relevant rows of the Fuel Types part of section 3a of this form.
UR M44 - APPENDIX 4 - Tabular Listing of Licensor's and Licensee's Drawing and Data

Licensee: ________________________________  Licensor: ________________________________
Licensee Engine No.: ______________________________  Engine type: ______________________________

<table>
<thead>
<tr>
<th>No.</th>
<th>Components or System</th>
<th>Licensor</th>
<th>Licensee</th>
<th>Has Design been modified by Licensee?</th>
<th>If Yes, indicate following information</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dwg. No. &amp; Title</td>
<td>Rev. No.</td>
<td>Date of Class Approval or Review</td>
<td>Dwg. No.</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
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<td>3</td>
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<td>4</td>
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<td>5</td>
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<td>6</td>
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<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I attest the above information to be correct and accurate.

Person in Charge (Licensee): ________________________________
Printed Name ________________________________
Signature ________________________________

Date: ________________________________
# UR M44 - APPENDIX 5 SAMPLE TEMPLATE FOR CONFIRMATION OF THE LICENSOR’S ACCEPTANCE OF LICENSEE’S MODIFICATIONS

## Engine Licensee Proposed Alternative to Licensor’s Design

### Licensee information

<table>
<thead>
<tr>
<th>Licensee:</th>
<th>Ref No.:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>Info No.:</td>
</tr>
<tr>
<td>Engine type:</td>
<td>Main Section:</td>
</tr>
<tr>
<td>Engine No.:</td>
<td>Plant Id.:</td>
</tr>
</tbody>
</table>

### Design Spec:
- [ ] General
- [ ] Specific Nos:

### Licensor design:
- State relevant part or drawing numbers. Insert drawing clips or pictures.
- Add any relevant information

<table>
<thead>
<tr>
<th>Licensor design:</th>
<th>Licensee Proposed Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>For example:</td>
<td></td>
</tr>
<tr>
<td>- Differences in geometry</td>
<td></td>
</tr>
<tr>
<td>- Differences in the functionality</td>
<td></td>
</tr>
<tr>
<td>- Material</td>
<td></td>
</tr>
<tr>
<td>- Hardness</td>
<td></td>
</tr>
<tr>
<td>- Surface condition</td>
<td></td>
</tr>
<tr>
<td>- Alternative standard</td>
<td></td>
</tr>
<tr>
<td>- Licensor production information introduced on the drawing</td>
<td></td>
</tr>
<tr>
<td>- Weldings or castings</td>
<td></td>
</tr>
<tr>
<td>- etc.</td>
<td></td>
</tr>
</tbody>
</table>

### Reason:
- [ ] Licensee’s production
- [ ] Sub-supplier’s production
- [ ] Cost down
- [ ] Tools

<table>
<thead>
<tr>
<th>Interchangeability w. licensor design</th>
<th>Non-conformity Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ] Yes</td>
<td>[ ] NCR</td>
</tr>
<tr>
<td>[ ] No</td>
<td>[ ] RAE</td>
</tr>
</tbody>
</table>

### Licensor comments

<table>
<thead>
<tr>
<th>LoAE:</th>
<th>NCR:</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ] Accepted as alternative execution</td>
<td>[ ] Approved</td>
</tr>
<tr>
<td>[ ] No objection</td>
<td>[ ] Conditionally approved</td>
</tr>
<tr>
<td>[ ] Not acceptable</td>
<td>[ ] Rejected</td>
</tr>
</tbody>
</table>

Certified by licensor:
- Initials:
- Date:

<table>
<thead>
<tr>
<th>Non-conformity Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research, Assessment, Evaluation</td>
</tr>
</tbody>
</table>

Certified by licensee:
- Initials:
- Date:

### End of Document
Ventilation of Machinery Spaces

The ventilation of machinery spaces shall be according to the principles laid down in SOLAS Regulation II-1/35 and supplied through suitably protected openings arranged in such a way that they can be used in all weather conditions, taking into account Reg.17(3) and Reg.19 of the 1966 Load Line Convention as amended by the Protocol of 1988.

The machinery spaces are those defined in SOLAS Regulation II-1/3.16.

Note:

1. Rev.2 of this UR is to be uniformly implemented by IACS Societies for ships contracted for construction on or after 1 January 2012.

2. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to IACS Procedural Requirement (PR) No. 29.
**Ambient conditions - Inclinations**

M46.1 The ambient conditions specified under M46.2 are to be applied to the layout, selection and arrangement of all shipboard machinery, equipment and appliances to ensure proper operation.

M46.2 Inclinations

<table>
<thead>
<tr>
<th>Installations, components</th>
<th>Angle of inclination [°]$^2$</th>
<th>Athwartships</th>
<th>Fore-and-aft</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>static</td>
<td>dynamic</td>
<td>static</td>
</tr>
<tr>
<td>Main and auxiliary machinery</td>
<td>15</td>
<td>22,5</td>
<td>5$^4$</td>
</tr>
<tr>
<td>Safety equipment, e.g. emergency power installations, emergency fire pump and their devices</td>
<td>$^{22,5^3}$</td>
<td>$^{22,5^3}$</td>
<td>10</td>
</tr>
<tr>
<td>Switch gear, electrical and electronic appliances$^1$ and remote control systems</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTES:

1. Up to an angle of inclination of 45° no undesired switching operations or operational changes may occur.

2. Athwartships and fore-end-aft inclinations may occur simultaneously.

3. In ships for the carriage of liquefied gases and of chemicals the emergency power supply must also remain operable with the ship flooded to a final athwartships inclination up to maximum of 30°.

4. Where the length of the ship exceeds 100m, the fore-and-aft static angle of inclination may be taken as $500/L$ degrees where $L =$ length of the ship, in metres, as defined in UR S2.

The Society may consider deviations from these angles of inclination taking into consideration the type, size and service conditions of the ship.
Bridge control of propulsion machinery for attended machinery spaces

Installations shall comply with the requirements of M43. If the slow-turning device referred to in M43.7 is arranged to be operated manually, automatic operation will not be required.

Permissible limits of stresses due to torsional vibrations for intermediate, thrust and propeller shafts

UR M48 was replaced by UR M68 in February 2005.
Availability of Machinery

Deleted in Dec 2003

(E8 has been merged with UR M49 to form a new UR M61 (Dec 2003))
Programme for type testing of non-mass produced I.C. engines

Deleted Feb 2015, replaced by UR M71.
Factory Acceptance Test and Shipboard Trials of I.C. Engines

1. Safety precautions

1.1 Before any test run is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer / shipyard and is to be operational.

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

1.3 The overspeed protective device is to be set to a value, which is not higher than the overspeed value that was demonstrated during the type test for that engine. This set point shall be verified by the surveyor.

2. General

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

2.2 Adequate test bed facilities for loads as required in UR M51.3.3 shall be provided. All fluids used for testing purposes such as fuel, lubrication oil and cooling water are to be suitable for the purpose intended, e.g. they are to be clean, preheated if necessary and cause no harm to engine parts. This applies to all fluids used temporarily or repeatedly for testing purposes only.

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

Notes:

1. The requirements in M51 Rev.3 are to be uniformly implemented by IACS Societies for engines; when an application for certification for an engine is dated on or after 1 January 2009.

2. The “date of application for certification of the engine” is the date of whatever document the Classification Society requires/accepts as an application or request for certification of an individual engine.

3. The requirements of UR M51 Rev. 4 – except for UR M51.4 – are to be uniformly implemented by IACS Societies to engines with an application for certification dated on or after 1 July 2016.

The requirement of UR M51.4 are to be uniformly implemented by IACS Societies to engines:

   i) with an application for certification dated on or after 1 July 2016; or

   ii) installed on ships contracted for construction on or after 1 July 2016.

4. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No.29.
2.4 Engines are to be inspected for:

- Jacketing of high-pressure fuel oil lines including the system used for the detection of leakage.
- Screening of pipe connections in piping containing flammable liquids.
- Insulation of hot surfaces by taking random temperature readings that are to be compared with corresponding readings obtained during the type test. This shall be done while running at the rated power of engine. Use of contact thermometers may be accepted at the discretion of the attending Surveyor. If the insulation is modified subsequently to the Type Approval Test, the Society may request temperature measurements as required by UR M71.8.9.

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

3. Works trials (Factory Acceptance Test)

3.1 Objectives

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

3.2 Records

3.2.1 The following environmental test conditions are to be recorded:

- Ambient air temperature
- Ambient air pressure
- Atmospheric humidity

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

- Power and speed
- Fuel index (or equivalent reading)
- Maximum combustion pressures (only when the cylinder heads installed are designed for such measurement).
- Exhaust gas temperature before turbine and from each cylinder (to the extent that monitoring is required in M73 and M35/36)
- Charge air temperature
- Charge air pressure
- Turbocharger speed (to the extent that monitoring is required in M73)
3.2.3 Calibration records for the instrumentation are, upon request, to be presented to the attending Surveyor.

3.2.4 For all stages at which the engine is to be tested, the pertaining operational values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer. This also includes crankshaft deflections if considered necessary by the engine designer.

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

3.3 Test loads

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

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

3.3.2 Propulsion engines driving propeller or impeller only.

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

B) 110% power at engine speed \( 1.032n_0 \): Records to be taken after 15 minutes or after steady conditions have been reached, whichever is shorter.

Note:
Only required once for each different engine/turbocharger configuration.

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

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

E) Reversing manoeuvres (if applicable).

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

3.3.3 Engines driving generators for electric propulsion.

A) 100% power (MCR) at corresponding speed \( n_0 \): at least 60 min.
B) 110% power at engine speed $n_0$: 15 min. - after having reached steady conditions.

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

D) 75%, 50% and 25% power and idle, the sequence to be selected by the engine manufacturer.

Note:
After running on the test bed, the fuel delivery system is to be adjusted so that full power plus a 10% margin for transient regulation can be given in service after installation onboard. The transient overload capability is required so that the required transient governing characteristics are achieved also at 100% loading of the engine, and also so that the protection system utilised in the electric distribution system can be activated before the engine stalls.

3.3.4 Engines driving generators for auxiliary purposes.
Tests to be performed as in UR M51.3.3.2.

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

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

B) 110% power at engine speed $n_0$: 15 min. - after having reached steady conditions.

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

D) 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve or at constant speed $n_0$, the sequence to be selected by the engine manufacturer.

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

3.3.6 Engines driving auxiliaries.

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

B) 110% power at engine speed $n_0$: 15 min. - after having reached steady conditions.

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

D) For variable speed engines, 75%, 50% and 25% power in accordance with the nominal power consumption curve, the sequence to be selected by the engine manufacturer.
Note:
After running on the test bed, the fuel delivery system is normally to be so adjusted that overload power cannot be delivered in service, unless intermittent overload power is approved. In that case, the fuel delivery system is to be blocked to that power.

3.4 Turbocharger matching with engine

3.4.1 Compressor chart

Turbochargers shall have a compressor characteristic that allows the engine, for which it is intended, to operate without surging during all operating conditions and also after extended periods in operation.
For abnormal, but permissible, operation conditions, such as misfiring and sudden load reduction, no continuous surging shall occur.
In this section, surging and continuous surging are defined as follows:
Surging means the phenomenon, which results in a high pitch vibration of an audible level or explosion-like noise from the scavenger area of the engine.
Continuous surging means that surging happens repeatedly and not only once.

3.4.2 Surge margin verification

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

For 4-stroke engines:
The following shall be performed without indication of surging:

- With maximum continuous power and speed (=100%), the speed shall be reduced with constant torque (fuel index) down to 90% power.

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

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

1. The engine working characteristic established at workshop testing of the engine shall be plotted into the compressor chart of the turbocharger (established in a test rig). There shall be at least 10% surge margin in the full load range, i.e. working flow shall be 10% above the theoretical (mass) flow at surge limit (at no pressure fluctuations).

2. Sudden fuel cut-off to at least one cylinder shall not result in continuous surging and the turbocharger shall be stabilised at the new load within 20 seconds. For applications with more than one turbocharger the fuel shall be cut-off to the cylinders closest upstream to each turbocharger.

This test shall be performed at two different engine loads:

- The maximum power permitted for one cylinder misfiring.
- The engine load corresponding to a charge air pressure of about 0.6 bar (but without auxiliary blowers running).

3. No continuous surging and the turbocharger shall be stabilised at the new load within 20 seconds when the power is abruptly reduced from 100% to 50% of the maximum continuous power.

3.5 Integration tests

For electronically controlled engines, integration tests are to be made to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes and the tests considered as a system are to be carried out at the works. If such tests are technically unfeasible at the works, however, these tests may be conducted during sea trial. The scope of these tests is to be agreed with the Society for selected cases based on the FMEA required in UR M44.

3.6 Component inspections

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

4. Shipboard trials

4.1 Objectives

The purpose of the shipboard testing is to verify compatibility with power transmission and driven machinery in the system, control systems and auxiliary systems necessary for the engine and integration of engine / shipboard control systems, as well as other items that had not been dealt with in the FAT (Factory Acceptance Testing).

4.2 Starting capacity

Starting manoeuvres are to be carried out in order to verify that the capacity of the starting media satisfies the required number of start attempts.

4.3 Monitoring and alarm system

The monitoring and alarm systems are to be checked to the full extent for all engines, except items already verified during the works trials.

4.4 Test loads

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

4.4.2 The suitability of the engine to operate on fuels intended for use is to be demonstrated.

Note:
Tests other than those listed below may be required by statutory instruments (e.g. EEDI verification).
4.4.3 Propulsion engines driving fixed pitch propeller or impeller.

A) At rated engine speed \( n_0 \): at least 4 hours.

B) At engine speed 1.032\( n_0 \) (if engine adjustment permits, see 3.3.1): 30 min.

C) At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.

D) Minimum engine speed to be determined.

E) The ability of reversible engines to be operated in reverse direction is to be demonstrated.

Note:
During stopping tests according to Resolution MSC.137 (76), see 4.5.1 for additional requirements in the case of a barred speed range.

4.4.4 Propulsion engines driving controllable pitch propellers.

A) At rated engine speed \( n_0 \) with a propeller pitch leading to rated engine power (or to the maximum achievable power if 100% cannot be reached): at least 4 hours.

B) At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.

C) With reverse pitch suitable for manoeuvring, see UR M51.4.5.1 for additional requirements in the case of a barred speed range.

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

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

B) At 110% power (rated electrical power of generator): at least 10 min.

Note:
Each engine is to be tested 100% electrical power for at least 60 min and 110% of rated electrical power of the generator for at least 10 min. This may, if possible, be done during the electrical propulsion plant test, which is required to be tested with 100% propulsion power (i.e. total electric motor capacity for propulsion) by distributing the power on as few generators as possible. The duration of this test is to be sufficient to reach stable operating temperatures of all rotating machines or for at least 4 hours. When some of the gen. set(s) cannot be tested due to insufficient time during the propulsion system test mentioned above, those required tests are to be carried out separately.

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

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

A) 100% engine power (MCR) at corresponding speed \( n_0 \): at least 4 hours.
B) 100% propeller branch power at engine speed \( n_0 \) (unless already covered in A): 2 hours.

C) 100% PTO branch power at engine speed \( n_0 \): at least 1 hour.

4.4.7 Engines driving auxiliaries.

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

B) Approved intermittent overload: testing for duration as approved.

4.5 Torsional vibrations

4.5.1 Barred speed range

Where a barred speed range (bsr) is required, passages through this bsr, both accelerating and decelerating, are to be demonstrated. The times taken are to be recorded and are to be equal to or below those times stipulated in the approved documentation, if any. This also includes when passing through the bsr in reverse rotational direction, especially during the stopping test.

Note:
Applies both for manual and automatic passing-through systems.

The ship’s draft and speed during all these demonstrations is to be recorded. In the case of a controllable pitch propeller, the pitch is also to be recorded.

The engine is to be checked for stable running (steady fuel index) at both upper and lower borders of the bsr. Steady fuel index means an oscillation range less than 5% of the effective stroke (idle to full index).
Length of aft stern bush bearing

M52.1 Oil lubricated bearings of white metal

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

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

M52.2 Oil lubricated bearings of synthetic rubber, reinforced resin or plastic materials

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

2.2 The length of bearing may be less provided the nominal bearing pressure is not more than 6 bar as determined by static bearing reaction calculation taking into account shaft and propeller weight which is deemed to be exerted solely on the aft bearing divided by the projected area of the shaft. However, the minimum length is to be not less than 1,5 times the actual diameter.

Where the material has proven satisfactory testing and operating experience, consideration may be given to an increased bearing pressure.

M52.3 Water lubricated bearings of lignum vitae

Where the bearing comprises staves of wood (known as lignum vitae), the length of the bearing is to be not less than 4,0 times the rule diameter of the shaft in way of the bearing.

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

M52.4 Water lubricated bearings of synthetic material

4.1 Where the bearing is constructed of synthetic materials which are approved for use as water lubricated stern bush bearings such as rubber or plastics the length of the bearing is to be not less than 4,0 times the rule diameter of the shaft in way of the bearing.

4.2 For a bearing design substantiated by experiments to the satisfaction of the Society consideration may be given to a bearing length not less than 2,0 times the rule diameter of the shaft in way of the bearing.

End of Document
Calculation of Crankshafts for I.C. Engines

TABLE OF CONTENTS

M 53.1 GENERAL

1.1 Scope
1.2 Field of application
1.3 Principles of calculation
1.4 Drawings and particulars to be submitted

M 53.2 CALCULATION OF STRESSES

2.1 Calculation of alternating stresses due to bending moments and radial forces

2.1.1 Assumptions
   2.1.1.1 Bending moments and radial forces acting in web
   2.1.1.2 Bending acting in outlet of crankpin oil bore

2.1.2 Calculation of nominal alternating bending and compressive stresses in web
   2.1.2.1 Nominal alternating bending and compressive stresses in web cross section
   2.1.2.2 Nominal alternating bending stress in outlet of crankpin oil bore

2.1.3 Calculation of alternating bending stresses in fillets

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

2.2 Calculation of alternating torsional stresses

   2.2.1 General

   2.2.2 Calculation of nominal alternating torsional stresses

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

M 53.3 EVALUATION OF STRESS CONCENTRATION FACTORS

3.1 General

3.2 Crankpin fillet

Note: Rev.1 is to be applied to crankshafts whose application for design approval is dated on or after 1 January 2007.

Note: Rev.2 is to be applied to crankshafts whose application for design approval is dated on or after 1 January 2012.
3.3 Journal fillet (not applicable to semi-built crankshaft)

3.4 Outlet of crankpin oil bore

M 53.4 ADDITIONAL BENDING STRESSES

M 53.5 CALCULATION OF EQUIVALENT ALTERNATING STRESS

5.1 General

5.2 Equivalent alternating stress

M 53.6 CALCULATION OF FATIGUE STRENGTH

M 53.7 ACCEPTABILITY CRITERIA

M 53.8 CALCULATION OF SHRINK-FITS OF SEMI-BUILT CRANKSHAFTS

8.1 General

8.2 Maximum permissible hole in the journal pin

8.3 Necessary minimum oversize of shrink-fit

8.4 Maximum permissible oversize of shrink-fit

Appendix I Definition of Stress Concentration Factors in crankshaft fillets

Appendix II Stress Concentration Factors and stress distribution at the edge of oil drillings

Appendix III Alternative method for calculation of Stress Concentration Factors in the web fillet radii of crankshafts by utilizing Finite Element Method
M53.1 GENERAL

1.1 Scope

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

Where a crankshaft design involves the use of surface treated fillets, or when fatigue parameter influences are tested, or when working stresses are measured, the relevant documents with calculations/analysis are to be submitted to Classification Societies in order to demonstrate equivalence to the Rules.

1.2 Field of application

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

1.3 Principles of calculation

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

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

- fillet transitions between the crankpin and web as well as between the journal and web,
- outlets of crankpin oil bores.

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

Calculation of crankshaft strength consists initially in determining the nominal alternating bending (see § M53.2.1) and nominal alternating torsional stresses (see § M53.2.2) which, multiplied by the appropriate stress concentration factors (see § M53.3), result in an equivalent alternating stress (uni-axial stress) (see § M53.5). This equivalent alternating stress is then compared with the fatigue strength of the selected crankshaft material (see § M53.6). This comparison will show whether or not the crankshaft concerned is dimensioned adequately (see § M53.7).

1.4 Drawings and particulars to be submitted

For the calculation of crankshafts, the documents and particulars listed below are to be submitted:

- crankshaft drawing
  (which must contain all data in respect of the geometrical configurations of the crankshaft)
- type designation and kind of engine
  (in-line engine or V-type engine with adjacent connecting-rods, forked connecting-rod or articulated-type connecting-rod)
- operating and combustion method
  (2-stroke or 4-stroke cycle/direct injection, precombustion chamber, etc.)
- number of cylinders
- rated power [kW]
- rated engine speed [r/min]
- direction of rotation (see fig. 1)
- firing order with the respective ignition intervals and, where necessary,
- V-angle $\alpha_v$ [°] (see fig. 1)

Fig. 1 – Designation of the cylinders

- cylinder diameter [mm]
- stroke [mm]
- maximum net cylinder pressure $P_{\text{max}}$ [bar]
- charge air pressure [bar]
  (before inlet valves or scavenge ports, whichever applies)
- connecting-rod length $L_H$ [mm]
- all individual reciprocating masses acting on one crank [kg]
- digitized gas pressure curve presented at equidistant intervals [bar versus Crank Angle] (at least every 5° CA)
- for engines with articulated-type connecting-rod (see fig. 2)
  - distance to link point $L_A$ [mm]
  - link angle $\alpha_N$ [°]
- connecting-rod length $L_N$ [mm]
Fig. 2 – articulated-type connecting-rod

- details of crankshaft material
  - material designation
    (according to ISO, EN, DIN, AISI, etc.)
  - mechanical properties of material
    (minimum values obtained from longitudinal test specimens)
    - tensile strength [N/mm²]
    - yield strength [N/mm²]
    - reduction in area at break [%]
    - elongation A₅ [%]
    - impact energy – KV [J]
  - type of forging
    (free form forged, continuous grain flow forged, drop-forged, etc… ; with description of the forging process)
- Every surface treatment affecting fillets or oil holes shall be subject to special consideration
- Particulars of alternating torsional stress calculations, see item M 53.2.2.
Connecting-rod acting component forces \((F_R \text{ or } F_T)\)

Radial shear force diagrams \((Q_R)\)

Bending moment diagrams \((M_{BR} \text{ or } M_{BT})\)

Fig. 3 Crankthrow for in line engine

Fig. 4 Crankthrow for Vee engine with 2 adjacent connecting-rods

\[ L_1 = \text{Distance between main journal centre line and crankweb centre} \]
\[
\text{(see also Fig 5 for crankshaft without overlap)}
\]
\[ L_2 = \text{Distance between main journal centre line and connecting-rod centre} \]
\[ L_3 = \text{Distance between two adjacent main journal centre lines} \]
M 53.2 CALCULATION OF STRESSES

2.1 Calculation of alternating stresses due to bending moments and radial forces

2.1.1 Assumptions

The calculation is based on a statically determined system, composed of a single crankthrow supported in the centre of adjacent main journals and subject to gas and inertia forces. The bending length is taken as the length between the two main bearing midpoints (distance $L_3$, see fig. 3 and 4).

The bending moments $M_{BR}$, $M_{BT}$ are calculated in the relevant section based on triangular bending moment diagrams due to the radial component $F_R$ and tangential component $F_T$ of the connecting-rod force, respectively (see fig. 3).

For crankthrows with two connecting-rods acting upon one crankpin the relevant bending moments are obtained by superposition of the two triangular bending moment diagrams according to phase (see fig. 4).

2.1.1.1 Bending moments and radial forces acting in web

The bending moment $M_{BRF}$ and the radial force $Q_{RF}$ are taken as acting in the centre of the solid web (distance $L_1$) and are derived from the radial component of the connecting-rod force.

The alternating bending and compressive stresses due to bending moments and radial forces are to be related to the cross-section of the crank web. This reference section results from the web thickness $W$ and the web width $B$ (see fig. 5).

Mean stresses are neglected.
Overlapped crankshaft

Crankshaft without overlap

Fig. 5 – Reference area of crankweb cross section
2.1.1.2 Bending acting in outlet of crankpin oil bore

The two relevant bending moments are taken in the crankpin cross-section through the oil bore.

\[ MB_{RO} \text{ is the bending moment of the radial component of the connecting-rod force} \]

\[ MB_{TO} \text{ is the bending moment of the tangential component of the connecting-rod force} \]

Fig. 6 – Crankpin section through the oil bore

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

Mean bending stresses are neglected.

2.1.2 Calculation of nominal alternating bending and compressive stresses in web

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

Using the forces calculated over one working cycle and taking into account of the distance from the main bearing midpoint, the time curve of the bending moments \( M_{BRF}, M_{BRO}, M_{BTO} \) and radial forces \( Q_{RF} \) - as defined in M53 2.1.1.1 and 2.1.1.2 - will then be calculated.

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

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

The decisive alternating values will then be calculated according to:

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

where:

- \( X_N \) is considered as alternating force, moment or stress
- \( X_{\text{max}} \) is maximum value within one working cycle
- \( X_{\text{min}} \) is minimum value within one working cycle
2.1.2.1 Nominal alternating bending and compressive stresses in web cross section

The calculation of the nominal alternating bending and compressive stresses is as follows:

\[
\sigma_{BFN} = \pm \frac{M_{BRFN}}{W_{eqw}} \cdot 10^3 \cdot Ke
\]

\[
\sigma_{QFN} = \pm \frac{Q_{RFN}}{F} \cdot Ke
\]

where:

- \(\sigma_{BFN} \) [N/mm²] nominal alternating bending stress related to the web
- \(M_{BRFN} \) [Nm] alternating bending moment related to the centre of the web (see fig. 3 and 4)
  \[M_{BRFN} = \pm \frac{1}{2} \left[ M_{BRF_{max}} - M_{BRF_{min}} \right]\]
- \(W_{eqw} \) [mm³] section modulus related to cross-section of web
  \[W_{eqw} = \frac{B \cdot W^2}{6}\]
- \(Ke\) empirical factor considering to some extent the influence of adjacent crank and bearing restraint
  with: \( Ke = 0.8 \) for 2-stroke engines
  \( Ke = 1.0 \) for 4-stroke engines
- \(\sigma_{QFN} \) [N/mm²] nominal alternating compressive stress due to radial force related to the web
- \(Q_{RFN} \) [N] alternating radial force related to the web (see fig. 3 and 4)
  \[Q_{RFN} = \pm \frac{1}{2} \left[ Q_{RF_{max}} - Q_{RF_{min}} \right]\]
- \(F\) [mm²] area related to cross-section of web
  \[F = B \cdot W\]

2.1.2.2 Nominal alternating bending stress in outlet of crankpin oil bore

The calculation of nominal alternating bending stress is as follows:

\[
\sigma_{BON} = \pm \frac{M_{BON}}{W_e} \cdot 10^3
\]
where:

$\sigma_{BON} \text{ [N/mm}^2\text{]}$ nominal alternating bending stress related to the crank pin diameter

$M_{BON} \text{ [Nm]}$ alternating bending moment calculated at the outlet of crankpin oil bore

$$M_{BON} = \pm \frac{1}{2} \left[ M_{BO_{\text{max}}} - M_{BO_{\text{min}}} \right]$$

with

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

and $\psi \text{ [-]}$ angular position (see fig. 6)

$W_e \text{ [mm}^3\text{]}$ section modulus related to cross-section of axially bored crankpin

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

2.1.3 Calculation of alternating bending stresses in fillets

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

For the crankpin fillet:

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

where:

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

$\alpha_B \text{ [-]}$ stress concentration factor for bending in crankpin fillet (determination - see item M53.3)

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

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

where:

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

$\beta_B \text{ [-]}$ stress concentration factor for bending in journal fillet (determination - see item M53.3)

$\beta_Q \text{ [-]}$ stress concentration factor for compression due to radial force in journal fillet (determination - see item M53.3)
2.1.4 Calculation of alternating bending stresses in outlet of crankpin oil bore

\[
\sigma_{BO} = \pm \gamma_B \cdot \sigma_{BON}
\]

where:

- \( \sigma_{BO} \) [N/mm²] alternating bending stress in outlet of crankpin oil bore
- \( \gamma_B \) [-] stress concentration factor for bending in crankpin oil bore (determination - see item M53.3)

2.2 Calculation of alternating torsional stresses

2.2.1 General

The calculation for nominal alternating torsional stresses is to be undertaken by the engine manufacturer according to the information contained in item M 53.2.2.2. The manufacturer shall specify the maximum nominal alternating torsional stress.

2.2.2 Calculation of nominal alternating torsional stresses

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

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

The values received from such calculation are to be submitted to Classification Society.

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

\[
\tau_N = \pm \frac{M_{TN} \cdot 10^3}{W_p}
\]

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

\[
W_p = \frac{\pi}{16} \left( \frac{D^4 - D_{BH}^4}{D} \right) \quad \text{or} \quad W_p = \frac{\pi}{16} \left( \frac{D_G^4 - D_{BG}^4}{D_G} \right)
\]

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

- \( \tau_N \) [N/mm²] nominal alternating torsional stress referred to crankpin or journal
- \( M_{TN} \) [Nm] maximum alternating torque
- \( W_p \) [mm³] polar section modulus related to cross-section of axially bored crankpin or bored journal
- \( M_{T\text{max}} \) [Nm] maximum value of the torque
- \( M_{T\text{min}} \) [Nm] minimum value of the torque

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

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

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

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

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

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

For the crankpin fillet:

\[
\tau_H = \pm (\alpha_T \cdot \tau_N)
\]

where:

- \( \tau_H \) [N/mm²] alternating torsional stress in crankpin fillet
- \( \alpha_T \) [-] stress concentration factor for torsion in crankpin fillet (determination - see item M53.3)
- \( \tau_N \) [N/mm²] nominal alternating torsional stress related to crankpin diameter

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

\[
\tau_G = \pm (\beta_T \cdot \tau_N)
\]
where:

\[ \tau_G [\text{N/mm}^2] \] alternating torsional stress in journal fillet

\[ \beta_T [-] \] stress concentration factor for torsion in journal fillet (determination - see item M53.3)

\[ \tau_N [\text{N/mm}^2] \] nominal alternating torsional stress related to journal diameter

For the outlet of crankpin oil bore:

\[ \sigma_{TO} = \pm (\gamma_T \cdot \tau_N) \]

where:

\[ \sigma_{TO} [\text{N/mm}^2] \] alternating stress in outlet of crankpin oil bore due to torsion

\[ \gamma_T [-] \] stress concentration factor for torsion in outlet of crankpin oil bore (determination- see item M53.3)

\[ \tau_N [\text{N/mm}^2] \] nominal alternating torsional stress related to crankpin diameter
3.1 General

The stress concentration factors are evaluated by means of the formulae according to items M53.3.2, M53.3.3 and M53.3.4 applicable to the fillets and crankpin oil bore of solid forged web-type crankshafts and to the crankpin fillets of semi-built crankshafts only. It must be noticed that stress concentration factor formulae concerning the oil bore are only applicable to a radially drilled oil hole. All formulae are based on investigations of FVV (Forschungsvereinigung Verbrennungskraftmaschinen) for fillets and on investigations of ESDU (Engineering Science Data Unit) for oil holes.

Where the geometry of the crankshaft is outside the boundaries of the analytical stress concentration factors (SCF) the calculation method detailed in Appendix III may be undertaken.

All crank dimensions necessary for the calculation of stress concentration factors are shown in figure 7.

The stress concentration factor for bending ($\alpha_B$, $\beta_B$) is defined as the ratio of the maximum equivalent stress (VON MISES) – occurring in the fillets under bending load – to the nominal bending stress related to the web cross-section (see Appendix I).

The stress concentration factor for compression ($\beta_Q$) in the journal fillet is defined as the ratio of the maximum equivalent stress (VON MISES) – occurring in the fillet due to the radial force – to the nominal compressive stress related to the web cross-section.

The stress concentration factor for torsion ($\alpha_T$, $\beta_T$) is defined as the ratio of the maximum equivalent shear stress – occurring in the fillets under torsional load – to the nominal torsional stress related to the axially bored crankpin or journal cross-section (see Appendix I).

The stress concentration factors for bending ($\gamma_B$) and torsion ($\gamma_T$) are defined as the ratio of the maximum principal stress – occurring at the outlet of the crankpin oil-hole under bending and torsional loads – to the corresponding nominal stress related to the axially bored crankpin cross section (see Appendix II).

When reliable measurements and/or calculations are available, which can allow direct assessment of stress concentration factors, the relevant documents and their analysis method have to be submitted to Classification Societies in order to demonstrate their equivalence to present rules evaluation.
Fig. 7 – Crank dimensions

Actual dimensions:

- **D** [mm] crankpin diameter
- **D_{BH}** [mm] diameter of axial bore in crankpin
- **D_o** [mm] diameter of oil bore in crankpin
- **R_H** [mm] fillet radius of crankpin
- **T_H** [mm] recess of crankpin fillet
- **D_G** [mm] journal diameter
- **D_{BG}** [mm] diameter of axial bore in journal
- **R_G** [mm] fillet radius of journal
- **T_G** [mm] recess of journal fillet
- **E** [mm] pin eccentricity
- **S** [mm] pin overlap
  \[ S = \frac{D + D_o}{2} - E \]
- **W (*)** [mm] web thickness
- **B (*)** [mm] web width

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

- when **T_H > R_H**, the web thickness must be considered as equal to:
  \[ W_{red} = W - (T_H - R_H) \] [refer to fig. 5]

- web width **B** must be taken in way of crankpin fillet radius centre according to fig. 5

The following related dimensions will be applied for the calculation of stress concentration factors in:
Stress concentration factors are valid for the ranges of related dimensions for which the investigations have been carried out. Ranges are as follows:

\begin{align*}
  s & \leq 0.5 \\
  0.2 & \leq w \leq 0.8 \\
  1.1 & \leq b \leq 2.2 \\
  0.03 & \leq r \leq 0.13 \\
  0 & \leq d_G \leq 0.8 \\
  0 & \leq d_H \leq 0.8 \\
  0 & \leq d_O \leq 0.2
\end{align*}

Low range of \( s \) can be extended down to large negative values provided that:

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

### 3.2 Crankpin fillet

The stress concentration factor for bending (\( \alpha_B \)) is:

\[
\alpha_B = 2.6914 \cdot f(s,w) \cdot f(w) \cdot f(b) \cdot f(r) \cdot f(d_G) \cdot f(d_H) \cdot f(\text{recess})
\]

where:

\[
\begin{align*}
  f(s,w) &= -4.1883 + 29.2004 \cdot w - 77.5925 \cdot w^2 + 91.9454 \cdot w^3 - 40.0416 \cdot w^4 \\
           &\quad + (1-s) \cdot (9.5440 - 58.3480 \cdot w + 159.3415 \cdot w^2 - 192.5846 \cdot w^3 \\
           &\quad + 85.2916 \cdot w^4) + (1-s)^2 \cdot (-3.8399 + 25.0444 \cdot w - 70.5571 \cdot w^2 \\
           &\quad + 87.0328 \cdot w^3 - 39.1832 \cdot w^4) \\
  f(w) &= 2.1790 \cdot w^{0.7171} \\
  f(b) &= 0.6840 - 0.0077 \cdot b + 0.1473 \cdot b^2
\end{align*}
\]
\[ f(r) = 0.2081 \cdot r^{-0.5231} \]

\[ f(d_o) = 0.9993 + 0.27 \cdot d_o - 1.0211 \cdot d_o^2 + 0.5306 \cdot d_o^3 \]

\[ f(d_h) = 0.9978 + 0.3145 \cdot d_h - 1.5241 \cdot d_h^2 + 2.4147 \cdot d_h^3 \]

\[ f(\text{recess}) = 1 + (t_h + t_g) \cdot (1.8 + 3.2 \cdot s) \]

The stress concentration factor for torsion \((\alpha_T)\) is:

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

where:

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

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

\[ f(w) = w^{(-0.145)} \]

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

The stress concentration factor for bending \((\beta_B)\) is:

\[ \beta_B = 2.7146 \cdot f_B(s,w) \cdot f_B(w) \cdot f_B(b) \cdot f_B(r) \cdot f_B(d_o) \cdot f_B(d_h) \cdot f(\text{recess}) \]

where:

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

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

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

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

\[ f_B(d_o) = 1.0012 - 0.6441 \cdot d_o + 1.2265 \cdot d_o^2 \]

\[ f_B(d_h) = 1.0022 - 0.1903 \cdot d_h + 0.0073 \cdot d_h^2 \]

\[ f(\text{recess}) = 1 + (t_h + t_g) \cdot (1.8 + 3.2 \cdot s) \]

The stress concentration factor for compression \((\beta_Q)\) due to the radial force is:

\[ \beta_Q = 3.0128 \cdot f_Q(s) \cdot f_Q(w) \cdot f_Q(b) \cdot f_Q(r) \cdot f_Q(d_h) \cdot f(\text{recess}) \]

where:

\[ f_Q(s) = 0.4368 + 2.1630 \cdot (1-s) - 1.5212 \cdot (1-s)^2 \]
The stress concentration factor for torsion ($\beta_T$) is:

$$\beta_T = \alpha_T$$

if the diameters and fillet radii of crankpin and journal are the same.

If crankpin and journal diameters and/or radii are of different sizes

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

where:

$f(r,s)$, $f(b)$ and $f(w)$ are to be determined in accordance with item M 53.3.2. (see calculation of $\alpha_T$), however, the radius of the journal fillet is to be related to the journal diameter:

$$r = \frac{R_g}{D_g}$$

### 3.4 Outlet of crankpin oil bore

The stress concentration factor for bending ($\gamma_B$) is:

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

The stress concentration factor for torsion ($\gamma_T$) is:

$$\gamma_T = 4 - 6 \cdot d_o + 30 \cdot d_o^2$$
M 53.4 ADDITIONAL BENDING STRESSES

In addition to the alternating bending stresses in fillets (see item M 53.2.1.3) further bending stresses due to misalignment and bedplate deformation as well as due to axial and bending vibrations are to be considered by applying $\sigma_{\text{add}}$ as given by table:

<table>
<thead>
<tr>
<th>Type of engine</th>
<th>$\sigma_{\text{add}}$ [N/mm²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crosshead engines</td>
<td>$\pm 30$ (*)</td>
</tr>
<tr>
<td>Trunk piston engines</td>
<td>$\pm 10$</td>
</tr>
</tbody>
</table>

(*) The additional stress of $\pm 30$ N/mm² is composed of two components
1) an additional stress of $\pm 20$ N/mm² resulting from axial vibration
2) an additional stress of $\pm 10$ N/mm² resulting from misalignment / bedplate deformation

It is recommended that a value of $\pm 20$ N/mm² be used for the axial vibration component for assessment purposes where axial vibration calculation results of the complete dynamic system (engine/shafting/gearing/propeller) are not available. Where axial vibration calculation results of the complete dynamic system are available, the calculated figures may be used instead.

M 53.5 CALCULATION OF EQUIVALENT ALTERNATING STRESS

5.1 General

In the fillets, bending and torsion lead to two different biaxial stress fields which can be represented by a Von Mises equivalent stress with the additional assumptions that bending and torsion stresses are time phased and the corresponding peak values occur at the same location (see Appendix I).

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

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

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

5.2 Equivalent alternating stress

The equivalent alternating stress is calculated in accordance with the formulae given.

For the crankpin fillet:

$$ \sigma_v = \pm \sqrt{(\sigma_{BH} + \sigma_{\text{add}})^2 + 3 \cdot \tau_H^2} $$
For the journal fillet:

\[
\sigma_v = \pm \sqrt{\left(\sigma_{BG} + \sigma_{add}\right)^2 + 3 \tau_{BDW}^2}
\]

For the outlet of crankpin oil bore:

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

where:

\(\sigma_v\) [N/mm²] equivalent alternating stress

for other parameters see items M53.2.1.3, M53.2.2.3 and M53.4.

**M 53.6  CALCULATION OF FATIGUE STRENGTH**

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

Related to the crankpin diameter:

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

with:

\(R_X = R_H\) in the fillet area

\(R_X = D_y/2\) in the oil bore area

Related to the journal diameter:

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

where:

\(\sigma_{DW}\) [N/mm²] allowable fatigue strength of crankshaft

\(K\) [-] factor for different types of crankshafts without surface treatment. Values greater than 1 are only applicable to fatigue strength in fillet area.

\(= 1.05\) for continuous grain flow forged or drop-forged crankshafts

\(= 1.0\) for free form forged crankshafts (without continuous grain flow)

\(= 0.93\) for cast steel crankshafts with cold rolling treatment in fillet area

\(= 0.93\) for cast steel crankshafts manufactured by companies using a classification society approved cold rolling process
σ_B [N/mm²] minimum tensile strength of crankshaft material

For other parameters see item M53.3.3.

When a surface treatment process is applied, it must be approved by Classification Society.

These formulae are subject to the following conditions:

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

As an alternative the fatigue strength of the crankshaft can be determined by experiment based either on full size crankthrow (or crankshaft) or on specimens taken from a full size crankthrow.

In any case the experimental procedure for fatigue evaluation of specimens and fatigue strength of crankshaft assessment have to be submitted for approval to Classification Society (method, type of specimens, number of specimens (or crankthrows), number of tests, survival probability, confidence number,...).

M 53.7 ACCEPTABILITY CRITERIA

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

\[ Q = \frac{\sigma_{DW}}{\sigma_v} \]

where:

Q [-] acceptability factor

Adequate dimensioning of the crankshaft is ensured if the smallest of all acceptability factors satisfies the criteria:

\[ Q \geq 1.15 \]

M 53.8 CALCULATION OF SHRINK-FITS OF SEMI-BUILT CRANKSHAFT

8.1 General

All crank dimensions necessary for the calculation of the shrink-fit are shown in figure 8.
Fig. 8 – Crankthrow of semi-built crankshaft

where:

\( D_A \) [mm] outside diameter of web

or
twice the minimum distance \( x \) between centre-line of journals and outer contour of web, whichever is less

\( D_S \) [mm] shrink diameter

\( D_G \) [mm] journal diameter

\( D_{BG} \) [mm] diameter of axial bore in journal

\( L_S \) [mm] length of shrink-fit

\( R_G \) [mm] fillet radius of journal

\( y \) [mm] distance between the adjacent generating lines of journal and pin

\[ y \geq 0.05 \times D_S \]

Where \( y \) is less than 0.1 \( D_S \) special consideration is to be given to the effect of the stress due to the shrink-fit on the fatigue strength at the crankpin fillet.
Respecting the radius of the transition from the journal to the shrink diameter, the following should be complied with:

\[
R_G \geq 0.015 \cdot D_G
\]

and

\[
R_G \geq 0.5 \cdot (D_S - D_G)
\]

where the greater value is to be considered.

The actual oversize Z of the shrink-fit must be within the limits Z_{\text{min}} and Z_{\text{max}} calculated in accordance with items M53.8.3 and 8.4.

In the case where 8.2 condition cannot be fulfilled then 8.3 and 8.4 calculation methods of Z_{\text{min}} and Z_{\text{max}} are not applicable due to multizone-plasticity problems.

In such case Z_{\text{min}} and Z_{\text{max}} have to be established based on FEM calculations.

### 8.2 Maximum permissible hole in the journal pin

The maximum permissible hole diameter in the journal pin is calculated in accordance with the following formula:

\[
D_{BG} = D_S \cdot \sqrt{1 - \frac{4000 \cdot S_R \cdot M_{\text{max}}}{\mu \cdot \pi \cdot D_S^2 \cdot L_S \cdot \sigma_{SP}}}
\]

where:

- **S_R [-]** safety factor against slipping, however a value not less than 2 is to be taken unless documented by experiments.
- **M_{\text{max}} [Nm]** absolute maximum value of the torque M_{T\text{max}} in accordance with M 53 2.2.2
- **\mu [-]** coefficient for static friction, however a value not greater than 0.2 is to be taken unless documented by experiments.
- **\sigma_{SP} [N/mm^2]** minimum yield strength of material for journal pin

This condition serves to avoid plasticity in the hole of the journal pin.
8.3 Necessary minimum oversize of shrink-fit

The necessary minimum oversize is determined by the greater value calculated according to:

\[ Z_{\text{min}} \geq \frac{\sigma_{SW} \cdot D_S}{E_m} \]

and

\[ Z_{\text{min}} \geq \frac{4000}{\mu \cdot \pi} \cdot \frac{S_{B} \cdot M_{\text{max}}}{E_m \cdot D_S \cdot L_S} \cdot \frac{1 - Q_A^2 \cdot Q_S^2}{(1 - Q_A^2) \cdot (1 - Q_S^2)} \]

where:

- \( Z_{\text{min}} \) [mm] minimum oversize
- \( E_m \) [N/mm²] Young’s modulus
- \( \sigma_{SW} \) [N/mm²] minimum yield strength of material for crank web
- \( Q_A \) [-] web ratio, \( Q_A = \frac{D_S}{D_A} \)
- \( Q_S \) [-] shaft ratio, \( Q_S = \frac{D_{BG}}{D_S} \)

8.4 Maximum permissible oversize of shrink-fit

The maximum permissible oversize is calculated according to:

\[ Z_{\text{max}} \leq D_S \cdot \left( \frac{\sigma_{SW}}{E_m} + \frac{0.8}{1000} \right) \]

This condition serves to restrict the shrinkage induced mean stress in the fillet.
### Definition of Stress Concentration Factors in crankshaft fillets

| Stress | Max \(|\sigma_3|\) | Max \(\sigma_1\) | Typical principal stress system |
|--------|----------------|----------------|--------------------------------|
| Location of maximal stresses | A | C | B |
| Torsional loading | | |
| Mohr's circle diagram with \(\sigma_2 = 0\) | \(|\sigma_3| > \sigma_1\) | \(\sigma_1 > |\sigma_3|\) | \(\sigma_1 \approx |\sigma_3|\) |
| Equivalent stress and S.C.F. | | |
| | \(\tau_{\text{equiv}} = \frac{\sigma_1 - \sigma_3}{2}\) | | |
| | S.C.F. = \(\frac{\tau_{\text{equiv}}}{\tau_n}\) for \(\alpha_T, \beta_T\) | | |
| Location of maximal stresses | B | B | B |
| Bending loading | | | |
| Typical principal stress system | | | |
| Mohr's circle diagram with \(\sigma_3 = 0\) | \(\sigma_2 \neq 0\) | | |
| Equivalent stress and S.C.F. | | | |
| | \(\sigma_{\text{equiv}} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \cdot \sigma_2}\) | | |
| | S.C.F. = \(\frac{\sigma_{\text{equiv}}}{\sigma_n}\) for \(\alpha_B, \beta_B, \beta_Q\) | | |
Stress Concentration Factors and stress distribution at the edge of oil drillings

### Appendix II

#### Stress type | Nominal stress tensor | Uniaxial stress distribution around the edge | Mohr’s circle diagram
--- | --- | --- | ---
Tension | \[ \begin{bmatrix} \sigma_n & 0 \\ 0 & 0 \end{bmatrix} \] | \[ \sigma_n = \sigma_n \gamma_B / 3 [1 + 2 \cos (2 \alpha)] \] | [Mohr's circle diagram for tension](#) |
Shear | \[ \begin{bmatrix} 0 & m \\ m & 0 \end{bmatrix} \] | \[ \sigma_n = \gamma_T \tau_n \sin (2\alpha) \] | [Mohr's circle diagram for shear](#) |
Tension + shear | \[ \begin{bmatrix} \sigma_n & m \\ m & 0 \end{bmatrix} \] | \[ \sigma_n = \frac{\gamma_B}{3} \sigma_n \left[ 1 + 2 \left[ \cos (2\alpha) + \frac{3}{2} \frac{\gamma_T \tau_n}{\gamma_B \sigma_n} \sin (2\alpha) \right] \right] \] | [Mohr's circle diagram for tension + shear](#) |

\[ \gamma_B = \frac{\sigma_{max}}{\sigma_n} \text{ for } \alpha = k\pi \]

\[ \gamma_T = \frac{\sigma_{max}}{\tau_n} \text{ for } \alpha = \frac{\pi}{4} + k\frac{\pi}{2} \]

\[ \sigma_{max} = \frac{\gamma_B}{3} \sigma_n \left[ 1 + 2 \left[ 1 + \frac{9}{4} \left( \frac{\gamma_T \tau_n}{\gamma_B \sigma_n} \right)^2 \right] \right] \]

for \[ \alpha = \frac{1}{2} \tan^{-1} \left( \frac{3\gamma_T \tau_n}{2\gamma_B \sigma_n} \right) \]

\(d = \text{hole diameter}\)
Appendix III

Alternative method for calculation of Stress Concentration Factors in the web fillet radii of crankshafts by utilizing Finite Element Method

Contents

1. General
2. Model requirements
   2.1. Element mesh recommendations
   2.2. Material
   2.3. Element mesh quality criteria
      2.3.1. Principal stresses criterion
      2.3.2. Averaged/unaveraged stresses criterion
3. Load cases
   3.1. Torsion
   3.2. Pure bending (4 point bending)
   3.3. Bending with shear force (3 point bending)
      3.3.1. Method 1
      3.3.2. Method 2
1. General

The objective of the analysis is to develop Finite Element Method (FEM) calculated figures as an alternative to the analytically calculated Stress Concentration Factors (SCF) at the crankshaft fillets. The analytical method is based on empirical formulae developed from strain gauge measurements of various crank geometries and accordingly the application of these formulae is limited to those geometries.

The SCF’s calculated according to the rules of this document are defined as the ratio of stresses calculated by FEM to nominal stresses in both journal and pin fillets. When used in connection with the present method in M53 or the alternative methods, von Mises stresses shall be calculated for bending and principal stresses for torsion.

The procedure as well as evaluation guidelines are valid for both solid cranks and semibuilt cranks (except journal fillets).

The analysis is to be conducted as linear elastic FE analysis, and unit loads of appropriate magnitude are to be applied for all load cases.

The calculation of SCF at the oil bores is not covered by this document.

It is advised to check the element accuracy of the FE solver in use, e.g. by modeling a simple geometry and comparing the stresses obtained by FEM with the analytical solution for pure bending and torsion.

Boundary Element Method (BEM) may be used instead of FEM.

2. Model requirements

The basic recommendations and perceptions for building the FE-model are presented in 2.1. It is obligatory for the final FE-model to fulfill the requirement in 2.3.

2.1. Element mesh recommendations

In order to fulfil the mesh quality criteria it is advised to construct the FE model for the evaluation of Stress Concentration Factors according to the following recommendations:

- The model consists of one complete crank, from the main bearing centerline to the opposite side main bearing centerline.
- Element types used in the vicinity of the fillets:
  - 10 node tetrahedral elements
  - 8 node hexahedral elements
  - 20 node hexahedral elements
- Mesh properties in fillet radii. The following applies to ±90 degrees in circumferential direction from the crank plane:
  - Maximum element size $a=r/4$ through the entire fillet as well as in the circumferential direction. When using 20 node hexahedral elements, the element size in the circumferential direction may be extended up to 5a. In the case of multi-radii fillet r is the local fillet radius. (If 8 node hexahedral elements are used even smaller element size is required to meet the quality criteria.)
  - Recommended manner for element size in fillet depth direction
    - First layer thickness equal to element size of a
    - Second layer thickness equal to element size of 2a
    - Third layer thickness equal to element size of 3a
- Minimum 6 elements across web thickness.
Generally the rest of the crank should be suitable for numeric stability of the solver.
Counterweights only have to be modeled only when influencing the global stiffness of the crank significantly.
Modeling of oil drillings is not necessary as long as the influence on global stiffness is negligible and the proximity to the fillet is more than 2r, see figure 2.1.
Drillings and holes for weight reduction have to be modeled.
Sub-modeling may be used as far as the software requirements are fulfilled.

Figure 2.1. Oil bore proximity to fillet.

2.2. Material

UR M53 does not consider material properties such as Young’s Modulus (E) and Poisson’s ratio (ν). In FE analysis those material parameters are required, as strain is primarily calculated and stress is derived from strain using the Young's Modulus and Poisson’s ratio. Reliable values for material parameters have to be used, either as quoted in literature or as measured on representative material samples.

For steel the following is advised: $E = 2.05 \cdot 10^5$ MPa and $\nu = 0.3$.

2.3. Element mesh quality criteria

If the actual element mesh does not fulfil any of the following criteria at the examined area for SCF evaluation, then a second calculation with a refined mesh is to be performed.

2.3.1. Principal stresses criterion

The quality of the mesh should be assured by checking the stress component normal to the surface of the fillet radius. Ideally, this stress should be zero. With principal stresses $\sigma_1$, $\sigma_2$ and $\sigma_3$, the following criterion is required:

$$\min(\sigma_1, \sigma_2, \sigma_3) < 0.03 \cdot \max(\sigma_1, \sigma_2, \sigma_3)$$

2.3.2. Averaged/unaveraged stresses criterion

The criterion is based on observing the discontinuity of stress results over elements at the fillet for the calculation of SCF:
Unaveraged nodal stress results calculated from each element connected to a node should differ less than by 5% from the 100% averaged nodal stress results at this node at the examined location.

3. Load cases

To substitute the analytically determined SCF in UR M53 the following load cases have to be calculated.

3.1. Torsion

In analogy to the testing apparatus used for the investigations made by FVV the structure is loaded pure torsion. In the model surface warp at the end faces is suppressed.

Torque is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is connected rigidly to all nodes of the end face.

Boundary and load conditions are valid for both in-line and V-type engines.

![Figure 3.1 Boundary and load conditions for the torsion load case.](image)

For all nodes in both the journal and crank pin fillet principal stresses are extracted and the equivalent torsional stress is calculated:

$$\tau_{\text{equiv}} = \max\left(\frac{|\sigma_1 - \sigma_2|}{2}, \frac{|\sigma_2 - \sigma_3|}{2}, \frac{|\sigma_1 - \sigma_3|}{2}\right)$$

The maximum value taken for the subsequent calculation of the SCF:
\[ \alpha_T = \frac{\tau_{\text{equiv},a}}{\tau_N} \]
\[ \beta_T = \frac{\tau_{\text{equiv},\beta}}{\tau_N} \]

where \( \tau_N \) is nominal torsional stress referred to the crankpin and respectively journal as per UR M53 2.2.2 with the torsional torque \( T \):
\[ \tau_N = \frac{T}{W_P} \]

3.2. Pure bending (4 point bending)

In analogy to the testing apparatus used for the investigations made by FVV the structure is loaded in pure bending. In the model surface warp at the end faces is suppressed.

The bending moment is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is connected rigidly to all nodes of the end face.

Boundary and load conditions are valid for both in-line- and V- type engines.
For all nodes in both the journal and pin fillet von Mises equivalent stresses $\sigma_{\text{equiv}}$ are extracted. The maximum value is used to calculate the SCF according to:

$$\alpha_B = \frac{\sigma_{\text{equiv},a}}{\sigma_N}$$

$$\beta_B = \frac{\sigma_{\text{equiv},f}}{\sigma_N}$$

Nominal stress $\sigma_N$ is calculated as per UR M53 2.1.2.1 with the bending moment $M$:

$$\sigma_N = \frac{M}{W_{eqw}}$$

3.3. Bending with shear force (3-point bending)

This load case is calculated to determine the SCF for pure transverse force (radial force, $\beta_Q$) for the journal fillet.

In analogy to the testing apparatus used for the investigations made by FVV, the structure is loaded in 3-point bending. In the model, surface warp at the both end faces is suppressed. All
nodes are connected rigidly to the centre node; boundary conditions are applied to the centre nodes. These nodes act as master nodes with 6 degrees of freedom.

The force is applied to the central node located at the pin centre-line of the connecting rod. This node is connected to all nodes of the pin cross sectional area. Warping of the sectional area is not suppressed.

Boundary and load conditions are valid for in-line and V-type engines. V-type engines can be modeled with one connecting rod force only. Using two connecting rod forces will make no significant change in the SCF.

Figure 3.3. Boundary and load conditions for the 3-point bending load case of an inline engine.
The maximum equivalent von Mises stress $\sigma_{3p}$ in the journal fillet is evaluated. The SCF in the journal fillet can be determined in two ways as shown below.

### 3.3.1. Method 1

This method is analogue to the FVV investigation. The results from 3-point and 4-point bending are combined as follows:

$$\sigma_{3p} = \sigma_{N3p} \cdot \beta_b + \sigma_{Q3p} \cdot \beta_Q$$

where:

- $\sigma_{3p}$ as found by the FE calculation.
- $\sigma_{N3p}$ Nominal bending stress in the web centre due to the force $F_{3p}$ [N] applied to the centre-line of the actual connecting rod, see figure 3.4.
- $\beta_b$ as determined in paragraph 3.2.
- $\sigma_{Q3p} = Q_{3p} \cdot (B \cdot W)$ where $Q_{3p}$ is the radial (shear) force in the web due to the force $F_{3p}$ [N] applied to the centre-line of the actual connecting rod, see also figures 3 and 4 in M53.

### 3.3.2. Method 2

This method is not analogous to the FVV investigation. In a statically determined system with one crank throw supported by two bearings, the bending moment and radial (shear) force are proportional. Therefore the journal fillet SCF can be found directly by the 3-point bending FE calculation.

The SCF is then calculated according to

$$\beta_{Q3} = \frac{\sigma_{3p}}{\sigma_{N3p}}$$

For symbols see 3.3.1.
When using this method the radial force and stress determination in M53 becomes superfluous. The alternating bending stress in the journal fillet as per UR M53 2.1.3 is then evaluated:

\[ \sigma_{BG} = \pm \beta_{BG} \sigma_{BFX} \]

Note that the use of this method does not apply to the crankpin fillet and that this SCF must not be used in connection with calculation methods other than those assuming a statically determined system as in M53.
M54  Deleted
(1986)  
(Rev 1  
1997)

M55  Planned maintenance scheme (PMS) for machinery  
Deleted in May 2001

(1988)
Marine gears – load capacity of involute parallel axis spur and helical gears

M56.1 Basic principles - introduction and general influence factors

M56.1.1 Introduction

The following definitions are mainly based on the ISO 6336 standard (hereinafter called “reference standard”) for the calculation of load capacity of spur and helical gears.

M56.1.2 Scope and field of application

These requirements apply to enclosed gears, both intended for main propulsion and for essential auxiliary services, which accumulate a large number of load cycles (several millions), whose gear set is intended to transmit a maximum continuous power equal to, or greater than:

- 220 kW for gears intended for main propulsion
- 110 kW for gears intended for essential auxiliary services

These requirements, however, may be applied to the enclosed gears, whose gear set is intended to transmit a maximum continuous power less than those specified above at the request of the individual society.

The following definitions deal with the determination of load capacity of external and internal involute spur and helical gears, having parallel axis, with regard to surface durability (pitting) and tooth root bending strength and to this purpose the relevant basic equations are provided in Parts 2 and 3.

The influence factors common to said equations are described in the present Part 1.

The others, introduced in connection with each basic equation, are described in the following Parts 2 and 3.

Notes:

1. The requirements of UR M56 Rev.2 are to be uniformly implemented from 1 January 2015 by all IACS Societies to any marine gear subject to approval and to any Type Approved marine gear from the date of the first renewal after 1 January 2015. For a marine gear approved prior to 1 January 2015 where no failure has occurred, and no changes in design / scantlings of the gear meshes or materials or declared load capacity data has taken place the requirements of UR M56 Rev.2 may be waived.

2. The requirements of UR M56 Rev.3 are to be uniformly implemented from 1 January 2017 by all IACS Societies to any marine gear subject to approval and to any Type Approved marine gear from the date of the first renewal after 1 January 2017. For a marine gear approved prior to 1 January 2017 where no failure has occurred, and no changes in design / scantlings of the gear meshes or materials or declared load capacity data has taken place the requirements of UR M56 Rev.3 may be waived.
All influence factors are defined regarding their physical interpretation. Some of the influence factors are determined by the gear geometry or have been established by conventions. These factors are to be calculated in accordance with the equations provided. Other factors, which are approximations, can be calculated according to methods acceptable to the Society.

**M56.1.3 Symbols and units**

The main symbols used are listed below.

Other symbols introduced in connection with the definition of influence factors are described in the appropriate sections.

SI units have been adopted.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>centre distance</td>
<td>mm</td>
</tr>
<tr>
<td>b</td>
<td>common face width</td>
<td>mm</td>
</tr>
<tr>
<td>b₁,₂</td>
<td>face width of pinion, wheel</td>
<td>mm</td>
</tr>
<tr>
<td>d</td>
<td>reference diameter</td>
<td>mm</td>
</tr>
<tr>
<td>d₁,₂</td>
<td>reference diameter of pinion, wheel</td>
<td>mm</td>
</tr>
<tr>
<td>dₜ₁,₂</td>
<td>tip diameter of pinion, wheel</td>
<td>mm</td>
</tr>
<tr>
<td>dₒ₁,₂</td>
<td>base diameter of pinion, wheel</td>
<td>mm</td>
</tr>
<tr>
<td>dᵣ₁,₂</td>
<td>root diameter of pinion, wheel</td>
<td>mm</td>
</tr>
<tr>
<td>dₚ₁,₂</td>
<td>working diameter of pinion, wheel</td>
<td>mm</td>
</tr>
<tr>
<td>Fₙ</td>
<td>nominal tangential load</td>
<td>N</td>
</tr>
<tr>
<td>Fₙᵣ</td>
<td>nominal tangential load on base cylinder in the transverse section</td>
<td>N</td>
</tr>
<tr>
<td>h</td>
<td>tooth depth</td>
<td>mm</td>
</tr>
<tr>
<td>mₙ</td>
<td>normal module</td>
<td>mm</td>
</tr>
<tr>
<td>mₜ</td>
<td>transverse module</td>
<td>mm</td>
</tr>
<tr>
<td>n₁,₂</td>
<td>rotational speed of pinion, wheel</td>
<td>revs/min (rpm)</td>
</tr>
<tr>
<td>P</td>
<td>maximum continuous power transmitted by the gear set</td>
<td>kW</td>
</tr>
<tr>
<td>T₁,₂</td>
<td>torque in way of pinion, wheel</td>
<td>Nm</td>
</tr>
<tr>
<td>u</td>
<td>gear ratio</td>
<td></td>
</tr>
<tr>
<td>v</td>
<td>linear velocity at pitch diameter</td>
<td>m/s</td>
</tr>
<tr>
<td>x₁,₂</td>
<td>addendum modification coefficient of pinion, wheel</td>
<td></td>
</tr>
<tr>
<td>z</td>
<td>number of teeth</td>
<td></td>
</tr>
<tr>
<td>z₁,₂</td>
<td>number of teeth of pinion, wheel</td>
<td></td>
</tr>
<tr>
<td>zᵣ</td>
<td>virtual number of teeth</td>
<td></td>
</tr>
<tr>
<td>aₙ</td>
<td>normal pressure angle at reference cylinder</td>
<td>°</td>
</tr>
<tr>
<td>aᵣ</td>
<td>transverse pressure angle at ref. cylinder</td>
<td>°</td>
</tr>
<tr>
<td>aₚᵣ</td>
<td>transverse pressure angle at working pitch cylinder</td>
<td>°</td>
</tr>
</tbody>
</table>
**M56 (cont)**

- $\beta$: helix angle at reference cylinder °
- $\beta_b$: helix angle at base cylinder °
- $\varepsilon_a$: transverse contact ratio
- $\varepsilon_\beta$: overlap ratio
- $\varepsilon_\gamma$: total contact ratio
M56.1.4 Geometrical definitions

For internal gearing \( z_2, a, d_2, d_{a2}, d_{b2} \) and \( d_{w2} \) are negative. The pinion is defined as the gear with the smaller number of teeth, therefore the absolute value of the gear ratio, defined as follows, is always greater or equal to the unity:

\[
u = \frac{z_2}{z_1} = \frac{d_{w2}}{d_{w1}} = \frac{d_2}{d_1}\]

For external gears \( u \) is positive, for internal gears \( u \) is negative.

In the equation of surface durability \( b \) is the common face width on the pitch diameter.

In the equation of tooth root bending stress \( b_1 \) or \( b_2 \) are the face widths at the respective tooth roots. In any case, \( b_1 \) and \( b_2 \) are not to be taken as greater than \( b \) by more than one module \( (m_n) \) on either side.

The common face width \( b \) may be used also in the equation of teeth root bending stress if significant crowning or end relief have been adopted.

\[
tan \alpha_i = \frac{tan \alpha}{\cos \beta}\]

\[
tan \beta_b = tan \beta \cdot \cos \alpha_i\]

\[
d_{i,2} = \frac{z_{i,2}m_n}{\cos \beta}\]

\[
d_{h1,2} = d_{i,2} \cos \alpha_i\]

\[
d_{w1} = \frac{2a}{\frac{u+1}{u+1}} \text{ where } a = 0.5(d_{w1} + d_{w2})\]

\[
d_{w2} = \frac{2au}{\frac{u+1}{u+1}}\]

\[
z_{a1,2} = \frac{z_{1,2}}{\cos^2 \beta \cdot \cos \beta}\]

\[
m_t = \frac{m_n}{\cos \beta}\]

\[
inv \alpha = \tan \alpha - \frac{\pi \alpha}{180}; \quad \alpha [\degree]\]

\[
inv \alpha_{tw} = inv \alpha_i + 2 \tan \alpha_i \frac{x_1 + x_2}{z_1 + z_2} \quad \text{or} \quad \cos \alpha_{tw} = \frac{m_t(z_i + z_2)}{2a} \cos \alpha_i\]

\[
e_a = \frac{0.5\sqrt{d_{a1}^2 - d_{b1}^2} \pm 0.5\sqrt{d_{a2}^2 - d_{b2}^2} - a \cdot \sin \alpha_{tw}}{\frac{\pi}{m_t} \cdot \cos \alpha_i}\]

the positive sign is used for external gears, the negative sign for internal gears
\[ \varepsilon_\beta = \frac{b \cdot \sin \beta}{\pi \cdot m_s} \]

for double helix, \( b \) is to be taken as the width of one helix

\[ \varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta \]

\[ \nu = \pi \cdot d_{12} n_{12} / 60 \cdot 10^3 \]

**M56.1.5 Nominal tangential load, \( F_t \)**

The nominal tangential load, \( F_t \), tangential to the reference cylinder and perpendicular to the relevant axial plane, is calculated directly from the maximum continuous power transmitted by the gear set by means of the following equations:

\[ T_{12} = \frac{30 \cdot 10^3 P}{\pi \cdot n_{12}} \]

\[ F_t = 2000 \cdot T_{12} / d_{12} \]

**M56.1.6 General influence factors**

**M56.1.6.1 Application factor, \( K_A \)**

The application factor, \( K_A \), accounts for dynamic overloads from sources external to the gearing.

\( K_A \), for gears designed for infinite life is defined as the ratio between the maximum repetitive cyclic torque applied to the gear set and the nominal rated torque.

The nominal rated torque is defined by the rated power and speed and is the torque used in the rating calculations.

The factor mainly depends on:
- characteristics of driving and driven machines;
- ratio of masses;
- type of couplings;
- operating conditions (overspeeds, changes in propeller load conditions, ...).

When operating near a critical speed of the drive system, a careful analysis of conditions must be made.

The application factor, \( K_A \), should be determined by measurements or by system analysis acceptable to the Society. Where a value determined in such a way cannot be supplied, the following values can be considered.

a) Main propulsion
- diesel engine with hydraulic or electromagnetic slip coupling : 1.00
- diesel engine with high elasticity coupling : 1.30
- diesel engine with other couplings : 1.50

---

1) Where the vessel, on which the reduction gear is being used, is receiving an Ice Class notation, the Application Factor or the Nominal Tangential Force should be adjusted to reflect the ice load associated with the requested Ice Class, i.e. applying the design approach in UR I3 when applicable.
b) Auxiliary gears
- electric motor, diesel engine with hydraulic or electromagnetic slip coupling : 1.00
- diesel engine with high elasticity coupling : 1.20
- diesel engine with other couplings : 1.40

M56.1.6.2 Load sharing factor, $K_\gamma$

The load sharing factor, $K_\gamma$, accounts for the maldistribution of load in multiple path transmissions (dual tandem, epicyclic, double helix, etc.)

$K_\gamma$ is defined as the ratio between the maximum load through an actual path and the evenly shared load. The factor mainly depends on accuracy and flexibility of the branches.

The load sharing factor, $K_\gamma$, should be determined by measurements or by system analysis. Where a value determined in such a way cannot be supplied, the following values can be considered for epicyclic gears:

- up to 3 planetary gears : 1.00
- 4 planetary gears : 1.20
- 5 planetary gears : 1.30
- 6 planetary gears and over : 1.40

M56.1.6.3 Internal dynamic factor, $K_v$

The internal dynamic factor, $K_v$, accounts for internally generated dynamic loads due to vibrations of pinion and wheel against each other.

$K_v$ is defined as the ratio between the maximum load which dynamically acts on the tooth flanks and the maximum externally applied load ($F_t K_a K_\gamma$).

The factor mainly depends on:
- transmission errors (depending on pitch and profile errors);
- masses of pinion and wheel;
- gear mesh stiffness variation as the gear teeth pass through the meshing cycle;
- transmitted load including application factor;
- pitch line velocity;
- dynamic unbalance of gears and shaft;
- shaft and bearing stiffnesses;
- damping characteristics of the gear system.

The dynamic factor, $K_v$, is to be calculated as follows:

This method may be applied only to cases where all the following conditions are satisfied:

- running velocity in the subcritical range, i.e.:
  \[
  \frac{\nu z_1}{100 \sqrt{1+u^2}} < 10 \text{ m/s}
  \]
- spur gears ($\beta = 0^\circ$) and helical gears with $\beta \leq 30^\circ$
- pinion with relatively low number of teeth, $z_1 < 50$
- solid disc wheels or heavy steel gear rim
This method may be applied to all types of gears if \( \frac{v_{z1}}{100} \sqrt[2]{\frac{u^2}{1+u^2}} < 3 \text{ m/s} \), as well as to helical gears where \( \beta > 30^\circ \).

For gears other than the above, reference is to be made to Method B outlined in the reference standard ISO 6336-1.

**(a)** For spur gears and for helical gears with overlap ratio \( \varepsilon \beta \geq 1 \)

\[
K_v = 1 + \left( \frac{K_1}{K_2} + K_2 \right) \frac{v_{z1}}{100} K_4 \sqrt[2]{\frac{u^2}{1+u^2}}
\]

If \( K_4 F/v \) is less than 100 N/mm, this value is assumed to be equal to 100 N/mm.

Numerical values for the factor \( K_1 \) are to be as specified in the Table 1.1

<table>
<thead>
<tr>
<th>ISO accuracy grades 2)</th>
<th>K₁</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
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<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>spur gears</td>
<td>2.1</td>
</tr>
<tr>
<td>helical gears</td>
<td>1.9</td>
</tr>
</tbody>
</table>

**Table 1.1 Values of the factor \( K_1 \) for the calculation of \( K_v \)**

For all accuracy grades the factor \( K_2 \) is to be in accordance with the following:
- for spur gears, \( K_2 = 0.0193 \)
- for helical gears, \( K_2 = 0.0087 \)

Factor \( K_3 \) is to be in accordance with the following:

If \( \frac{v_{z1}}{100} \sqrt[2]{\frac{u^2}{1+u^2}} \leq 0.2 \) then \( K_3 = 2.0 \)

If \( \frac{v_{z1}}{100} \sqrt[2]{\frac{u^2}{1+u^2}} > 0.2 \) then \( K_3 = 2.071 - 0.357 \cdot \frac{v_{z1}}{1+u^2} \)

**(b)** For helical gears with overlap ratio \( \varepsilon \beta < 1 \) the value \( K_v \) is determined by linear interpolation between values determined for spur gears \( (K_{v\alpha}) \) and helical gears \( (K_{v\beta}) \) in accordance with:

\[
K_v = K_{v\alpha} - \varepsilon \beta (K_{v\alpha} - K_{v\beta})
\]

Where:

- \( K_{v\alpha} \) is the \( K_v \) value for spur gears, in accordance with a);
- \( K_{v\beta} \) is the \( K_v \) value for helical gears, in accordance with a).

2) ISO accuracy grades according to ISO 1328. In case of mating gears with different accuracy grades, the grade corresponding to the lower accuracy should be used.
M56.1.6.4 Face load distribution factors, $K_{H\beta}$ and $K_{F\beta}$

The face load distribution factors, $K_{H\beta}$ for contact stress, $K_{F\beta}$ for tooth root bending stress, account for the effects of non-uniform distribution of load across the face width.

$K_{H\beta}$ is defined as follows:

$$K_{H\beta} = \frac{\text{maximum load per unit face width}}{\text{mean load per unit face width}}$$

$K_{F\beta}$ is defined as follows:

$$K_{F\beta} = \frac{\text{maximum bending stress at tooth root per unit face width}}{\text{mean bending stress at tooth root per unit face width}}$$

The mean bending stress at tooth root relates to the considered face width $b_1$ resp. $b_2$.

$K_{F\beta}$ can be expressed as a function of the factor $K_{H\beta}$.

The factors $K_{H\beta}$ and $K_{F\beta}$ mainly depend on:
- gear tooth manufacturing accuracy;
- errors in mounting due to bore errors;
- bearing clearances;
- wheel and pinion shaft alignment errors;
- elastic deflections of gear elements, shafts, bearings, housing and foundations which support the gear elements;
- thermal expansion and distortion due to operating temperature;
- compensating design elements (tooth crowning, end relief, etc.).

The face load distribution factors, $K_{H\beta}$ for contact stress, and $K_{F\beta}$ for tooth root bending stress, are to be determined according to the Method C outlined in the reference standard ISO 6336-1.

Alternative methods acceptable to the Society may be applied.

a) In case the hardest contact is at the end of the face width $K_{F\beta}$ is given by the following equations:

$$K_{F\beta} = K_{H\beta}^{u_l}$$

$$N = \frac{(b/h)^2}{1 + (b/h) + (b/h)^2}$$

$(b/h) = \text{face width/tooth height ratio, the minimum of } b_1/h_1 \text{ or } b_2/h_2.$

For double helical gears, the face width of only one helix is to be used.
When $b/h<3$ the value $b/h=3$ is to be used.

b) In case of gears where the ends of the face width are lightly loaded or unloaded (end relief or crowning):

$$K_{F\beta} = K_{H\beta}$$
M56.1.6.5 Transverse load distribution factors, $K_{H\alpha}$ and $K_{F\alpha}$

The transverse load distribution factors, $K_{H\alpha}$ for contact stress and $K_{F\alpha}$ for tooth root bending stress, account for the effects of pitch and profile errors on the transversal load distribution between two or more pairs of teeth in mesh.

The factors $K_{H\alpha}$ and $K_{F\alpha}$ mainly depend on:
- total mesh stiffness;
- total tangential load $F_t$, $K_A$, $K_{\gamma}$, $K_v$, $K_{H\beta}$;
- base pitch error;
- tip relief;
- running-in allowances.

The transverse load distribution factors, $K_{H\alpha}$ for contact stress and $K_{F\alpha}$ for tooth root bending stress, are to be determined according to Method B outlined in the reference standard ISO 6336-1.

M56.2 Surface durability (pitting)

M56.2.1 Scope and general remarks

The criterion for surface durability is based on the Hertz pressure on the operating pitch point or at the inner point of single pair contact. The contact stress $\sigma_H$ must be equal to or less than the permissible contact stress $\sigma_{HP}$.

M56.2.2 Basic equations

M56.2.2.1 Contact stress

$$\sigma_H = \sigma_{H0} \sqrt{K_A \cdot K_{\gamma} \cdot K_v \cdot K_{H\alpha} \cdot K_{H\beta}} \leq \sigma_{HP}$$

where:

- $\sigma_{H0}$ = basic value of contact stress for pinion and wheel

$$\sigma_{H0} = Z_B \cdot Z_H \cdot Z_E \cdot Z_z \cdot Z_{\beta} \frac{F_i \cdot (u + 1)}{d_1 \cdot b \cdot u}$$

for pinion

$$\sigma_{H0} = Z_D \cdot Z_H \cdot Z_E \cdot Z_z \cdot Z_{\beta} \frac{F_i \cdot (u + 1)}{d_1 \cdot b \cdot u}$$

for wheel

where:

- $Z_B$ = single pair tooth contact factor for pinion (see clause 2.3)
- $Z_D$ = single pair tooth contact factor for wheel (see clause 2.3)
- $Z_H$ = zone factor (see clause 2.4)
- $Z_E$ = elasticity factor (see clause 2.5)
\[ Z_\varepsilon = \text{contact ratio factor} \]  
(see clause 2.6) 
\[ Z_\beta = \text{helix angle factor} \]  
(see clause 2.7) 
\[ F_t = \text{nominal tangential load at reference cylinder in the transverse section} \]  
(see Part 1) 
\[ b = \text{common face width} \] 
\[ d_1 = \text{reference diameter of pinion} \] 
\[ u = \text{gear ratio} \]  
(for external gears \( u \) is positive, for internal gears \( u \) is negative) 

Regarding factors \( K_A, K_V, K_{\bar{H}} \) and \( K_{H \beta} \), see Part 1.

**M56.2.2.2 Permissible contact stress**

The permissible contact stress \( \sigma_{HP} \) is to be evaluated separately for pinion and wheel:

\[
\sigma_{HP} = \frac{\sigma_{H \text{lim}} \cdot Z_N \cdot Z_L \cdot Z_v \cdot Z_R \cdot Z_W \cdot Z_X}{S_H}
\]

where:

\[ \sigma_{H \text{lim}} = \text{endurance limit for contact stress} \]  
(see clause 2.8) 
\[ Z_N = \text{life factor for contact stress} \]  
(see clause 2.9) 
\[ Z_L = \text{lubrication factor} \]  
(see clause 2.10) 
\[ Z_v = \text{velocity factor} \]  
(see clause 2.10) 
\[ Z_R = \text{roughness factor} \]  
(see clause 2.10) 
\[ Z_W = \text{hardness ratio factor} \]  
(see clause 2.11) 
\[ Z_X = \text{size factor for contact stress} \]  
(see clause 2.12) 
\[ S_H = \text{safety factor for contact stress} \]  
(see clause 2.13)

**M56.2.3 Single pair tooth contact factors, \( Z_B \) and \( Z_D \)**

The single pair tooth contact factors, \( Z_B \) for pinion and \( Z_D \) for wheel, account for the influence of the tooth flank curvature on contact stresses at the inner point of single pair contact in relation to \( Z_H \).

The factors transform the contact stresses determined at the pitch point to contact stresses considering the flank curvature at the inner point of single pair contact.

The single pair tooth contact factors, \( Z_B \) for pinions and \( Z_D \) for wheels, are to be determined as follows:
For spur gears, $\varepsilon_B = 0$

$$Z_B = M_1 \text{ or } 1 \text{ whichever is the larger value}$$

$$Z_D = M_2 \text{ or } 1 \text{ whichever is the larger value}$$

$$M_1 = \frac{\tan \alpha_{nw}}{\sqrt{\left(\frac{d_{a1}^2}{d_{b1}^2} - 1\right) - \frac{2\pi}{z_1} \left(\frac{d_{a1}^2}{d_{b1}^2} - 1 \cdot \frac{M_1 - 1}{z_1}\right)}}$$

$$M_2 = \frac{\tan \alpha_{nw}}{\sqrt{\left(\frac{d_{a2}^2}{d_{b2}^2} - 1\right) - \frac{2\pi}{z_2} \left(\frac{d_{a2}^2}{d_{b2}^2} - 1 \cdot \frac{M_2 - 1}{z_2}\right)}}$$

For helical gears when $\varepsilon_B \geq 1$

$$Z_B = 1$$

$$Z_D = 1$$

For helical gears when $\varepsilon_B < 1$ the values of $Z_B$ and $Z_D$ are determined by linear interpolation between $Z_B$ and $Z_D$ for spur gears and $Z_B$ and $Z_D$ for helical gears having $\varepsilon_B \geq 1$.

Thus:

$$Z_B = M_1 - \varepsilon_B (M_1 - 1) \text{ and } Z_B \geq 1$$

$$Z_D = M_2 - \varepsilon_B (M_2 - 1) \text{ and } Z_D \geq 1$$

For internal gears, $Z_D$ shall be taken as equal to 1.

**M56.2.4 Zone factor, $Z_H$**

The zone factor, $Z_H$, accounts for the influence on the Hertzian pressure of tooth flank curvature at pitch point and transforms the tangential load at the reference cylinder to the normal load at the pitch cylinder.

The zone factor, $Z_H$, is to be calculated as follows:

$$Z_H = \sqrt{\frac{2\cos \beta_s}{\cos^2 \alpha_i \tan \alpha_{nw}}}$$
M56.2.5 Elasticity factor, $Z_E$

The elasticity factor, $Z_E$, accounts for the influence of the material properties $E$ (modulus of elasticity) and $\nu$ (Poisson's ratio) on the contact stress.

The elasticity factor, $Z_E$, for steel gears ($E= 206 000$ N/mm$^2$, $\nu= 0.3$) is equal to:

$$Z_E = 189.8 \sqrt{N/mm^2}$$

In other cases, reference is to be made to the reference standard ISO 6336-2.

M56.2.6 Contact ratio factor, $Z_c$

The contact ratio factor, $Z_c$, accounts for the influence of the transverse contact ratio and the overlap ratio on the specific surface load of gears.

The contact ratio factor, $Z_c$, is to be calculated as follows:

Spur gears:

$$Z_c = \sqrt{\frac{4 - \varepsilon_\alpha}{3}}$$

Helical gears:

- for $\varepsilon_\beta < 1$

$$Z_c = \sqrt{\frac{4 - \varepsilon_\alpha}{3} (1 - \varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}}$$

- for $\varepsilon_\beta \geq 1$

$$Z_c = \sqrt{\frac{1}{\varepsilon_\alpha}}$$

M56.2.7 Helix angle factor, $Z_\beta$

The helix angle factor, $Z_\beta$, accounts for the influence of helix angle on surface durability, allowing for such variables as the distribution of load along the lines of contact. $Z_\beta$ is dependent only on the helix angle.

The helix angle factor, $Z_\beta$, is to be calculated as follows:

$$Z_\beta = \sqrt{\frac{1}{\cos \beta}}$$

Where $\beta$ is the reference helix angle.
M56.2.8 Endurance limit for contact stress, $\sigma_{Hlim}$

For a given material, $\sigma_{Hlim}$ is the limit of repeated contact stress which can be permanently endured. The value of $\sigma_{Hlim}$ can be regarded as the level of contact stress which the material will endure without pitting for at least $5 \times 10^7$ load cycles.

For this purpose, pitting is defined by:

- for not surface hardened gears:
  - pitted area > 2% of total active flank area
- for surface hardened gears:
  - pitted area > 0.5% of total active flank area, or
  - > 4% of one particular tooth flank area.

The $\sigma_{Hlim}$ values are to correspond to a failure probability of 1% or less.

The endurance limit mainly depends on:
- material composition, cleanliness and defects;
- mechanical properties;
- residual stresses;
- hardening process, depth of hardened zone, hardness gradient;
- material structure (forged, rolled bar, cast).

The endurance limit for contact stress $\sigma_{Hlim}$ is to be determined, in general, making reference to values indicated in the standard ISO 6336-5, for material quality MQ.

M56.2.9 Life factor, $Z_N$

The life factor $Z_N$, accounts for the higher permissible contact stress in case a limited life (number of cycles) is required.

The factor mainly depends on:
- material and heat treatment;
- number of cycles;

The life factor, $Z_N$, is to be determined according to Method B outlined in the reference standard ISO 6336-2.

M56.2.10 Influence factors of lubrication film on contact stress, $Z_L$, $Z_v$ and $Z_R$

The lubricant factor, $Z_L$, accounts for the influence of the type of lubricant and its viscosity. The velocity factor, $Z_v$, accounts for the influence of the pitch line velocity. The roughness factor, $Z_R$, accounts for the influence of the surface roughness on the surface endurance capacity.

The factors may be determined for the softer material where gear pairs are of different hardness.

The factors mainly depend on:
- viscosity of lubricant in the contact zone;
- the sum of the instantaneous velocities of the tooth surfaces;
- load;
- relative radius of curvature at the pitch point;
- surface roughness of teeth flanks;
- hardness of pinion and gear.

The lubricant factor, $Z_L$, the velocity factor, $Z_v$, and the roughness factor $Z_R$ are to be calculated as follows:

a) Lubricant factor, $Z_L$

The factor, $Z_L$, is to be calculated from the following equation:

$$Z_L = C_{ZL} + \frac{4(1 - C_{ZL})}{\left(1.2 + \frac{134}{\nu_{40}}\right)^2}$$

In the range $850 \text{ N/mm}^2 \leq \sigma_{Hlim} \leq 1200 \text{ N/mm}^2$, $C_{ZL}$ is to be calculated as follows:

$$C_{ZL} = \left(0.08 \frac{\sigma_{Hlim} - 850}{350}\right) + 0.83$$

If $\sigma_{Hlim} < 850 \text{ N/mm}^2$, take $C_{ZL} = 0.83$

If $\sigma_{Hlim} > 1200 \text{ N/mm}^2$, take $C_{ZL} = 0.91$

Where:

$\nu_{40} =$ nominal kinematic viscosity of the oil at $40^\circ\text{C}$, mm$^2$/s

b) Velocity factor, $Z_v$

The velocity factor, $Z_v$, is to be calculated from the following equations:

$$Z_v = C_{ZV} + \frac{2(1 - C_{ZV})}{\sqrt{0.8 + \frac{32}{v}}}$$

In the range $850 \text{ N/mm}^2 \leq \sigma_{Hlim} \leq 1200 \text{ N/mm}^2$, $C_{ZV}$ is to be calculated as follows:

$$C_{ZV} = C_{ZL} + 0.02$$

c) Roughness factor, $Z_R$

The roughness factor, $Z_R$, is to be calculated from the following equations:

$$Z_R = \left(\frac{3}{R_{z10}}\right)^{C_{ZR}}$$

Where:

$$R_z = \frac{R_{z1} + R_{z2}}{2}$$
The peak-to-valley roughness determined for the pinion $R_{z1}$ and for the wheel $R_{z2}$ are mean values for the peak-to-valley roughness $R_z$ measured on several tooth flanks ($R_z$ as defined in the reference standard ISO 6336-2).

$$R_{z10} = R_{z2} \left( \frac{10}{\rho_{red}} \right)$$

relative radius of curvature:

$$\rho_{red} = \frac{\rho_1 \cdot \rho_2}{\rho_1 + \rho_2}$$

Wherein:

$$\rho_{12} = 0.5 \cdot d_{b12} \cdot \tan \alpha_{tw}$$

(also for internal gears, $d_b$ negative sign)

If the roughness stated is an arithmetic mean roughness, i.e. $R_a$ value (=CLA value) (=AA value) the following approximate relationship can be applied:

$$R_a = CLA = AA = R_z / 6$$

In the range $850 \, \text{N/mm}^2 \leq \sigma_{Hlim} \leq 1200 \, \text{N/mm}^2$, $C_{ZR}$ is to be calculated as follows:

$$C_{ZR} = 0.32 - 0.0002 \cdot \sigma_{Hlim}$$

If $\sigma_{Hlim} < 850 \, \text{N/mm}^2$, take $C_{ZR} = 0.150$

If $\sigma_{Hlim} > 1200 \, \text{N/mm}^2$, take $C_{ZR} = 0.080$

**M56.2.11 Hardness ratio factor, $Z_W$**

The hardness ratio factor, $Z_W$, accounts for the increase of surface durability of a soft steel gear meshing with a significantly harder gear with a smooth surface in the following cases:

a) Surface-hardened pinion with through-hardened wheel

If $HB < 130$

$$Z_W = 1.2 \cdot \left( \frac{3}{R_{zh}} \right)^{0.15}$$

If $130 \leq HB \leq 470$

$$Z_W = \left( 1.2 - \frac{HB - 130}{1700} \right) \cdot \left( \frac{3}{R_{zh}} \right)^{0.15}$$

If $HB > 470$

$$Z_W = \left( \frac{3}{R_{zh}} \right)^{0.15}$$

Where:

$$HB = \text{Brinell hardness of the tooth flanks of the softer gear of the pair}$$
\[ R_{sH} = \text{equivalent roughness, \( \mu m \)} \]
\[ R_{sH} = \frac{R_{s1} \cdot (10 / \rho_{rzd})^{0.33} \cdot (R_{s1} / R_{s2})^{0.66}}{(v \cdot v_{40} / 1500)^{0.33}} \]

\[ \rho_{rzd} = \text{relative radius of curvature (see clause 2.10 c)} \]

b) Through-hardened pinion and wheel

When the pinion is substantially harder than the wheel, the work hardening effect increases the load capacity of the wheel flanks. \( Z_W \) applies to the wheel only, not to the pinion.

If \( \frac{H_{B1}}{H_{B2}} < 1.2 \)
\[ Z_W = 1 \]
If \( 1.2 \leq \frac{H_{B1}}{H_{B2}} \leq 1.7 \)
\[ Z_W = 1 + \left( 0.00898 \frac{H_{B1}}{H_{B2}} - 0.00829 \right) \cdot (u - 1) \]
If \( \frac{H_{B1}}{H_{B2}} > 1.7 \)
\[ Z_W = 1 + 0.00698 \cdot (u - 1) \]

If gear ratio \( u > 20 \) then the value \( u = 20 \) is to be used.

In any case, if calculated \( Z_W < 1 \) then the value \( Z_W = 1.0 \) is to be used.

M56.2.12 Size factor, \( Z_X \)

The size factor, \( Z_X \), accounts for the influence of tooth dimensions on permissible contact stress and reflects the non-uniformity of material properties.

The factor mainly depends on:
- material and heat treatment;
- tooth and gear dimensions;
- ratio of case depth to tooth size;
- ratio of case depth to equivalent radius of curvature.

For through-hardened gears and for surface-hardened gears with adequate casedepth relative to tooth size and radius of relative curvature \( Z_X = 1 \). When the casedepth is relatively shallow then a smaller value of \( Z_X \) should be chosen.

M56.2.13 Safety factor for contact stress, \( S_H \)

The safety factor for contact stress, \( S_H \), can be assumed by the Society taking into account the type of application.

The following guidance values can be adopted:
- Main propulsion gears: 1.20 to 1.40
- Auxiliary gears: 1.15 to 1.20

For gearing of duplicated independent propulsion or auxiliary machinery, duplicated beyond that required for class, a reduced value can be assumed at the discretion of the Society.
M56.3  Tooth root bending strength

M56.3.1 Scope and general remarks

The criterion for tooth root bending strength is the permissible limit of local tensile strength in the root fillet. The root stress $\sigma_F$ and the permissible root stress $\sigma_{FP}$ shall be calculated separately for the pinion and the wheel.

$\sigma_F$ must not exceed $\sigma_{FP}$.

The following formulae and definitions apply to gears having rim thickness greater than $3.5m_n$.

The result of rating calculations made by following this method are acceptable for normal pressure angles up to 25° and reference helix angles up to 30°.

For larger pressure angles and large helix angles, the calculated results should be confirmed by experience as by Method A of the reference standard ISO 6336-3.

M56.3.2 Basic equations

M56.3.2.1  Tooth root bending stress for pinion and wheel

$$\sigma_F = \frac{F_r}{b m_n} Y_F Y_S Y_B Y_D T B K_A K_Y K_{Fa} K_{Fp} \leq \sigma_{FP}$$

where:

- $Y_F = $ tooth form factor (see clause 3.3)
- $Y_S = $ stress correction factor (see clause 3.4)
- $Y_B = $ helix angle factor (see clause 3.5)
- $Y_B = $ rim thickness factor (see clause 3.6)
- $Y_D T = $ deep tooth factor (see clause 3.7)
- $F_r, K_A, K_Y, K_{Fa}, K_{Fp}$ (see Part 1)
- $b$ (see Part 1, clause 1.4)
- $m_n$ (see Part 1, clause 1.3)

M56.3.2.2  Permissible tooth root bending stress for pinion and wheel

$$\sigma_{FP} = \frac{\sigma_{FE} Y_A Y_N}{S_F} Y_{relT} Y_{relT} Y_X$$

where:

- $\sigma_{FE} = $ bending endurance limit
- $Y_A = $ design factor
- $Y_N = $ life factor
- $Y_{relT} = $ relative notch sensitivity factor
- $Y_{relT} = $ relative surface factor
- $Y_X = $ size factor
- $S_F = $ safety factor for tooth root bending stress
M56.3.3 Tooth form factor, $Y_F$

The tooth form factor, $Y_F$, represents the influence on nominal bending stress of the tooth form with load applied at the outer point of single pair tooth contact. $Y_F$ shall be determined separately for the pinion and the wheel. In the case of helical gears, the form factors for gearing shall be determined in the normal section, i.e. for the virtual spur gear with virtual number of teeth $Z_n$.

The tooth form factor, $Y_F$, is to be calculated as follows:

$$Y_F = \frac{6 h_F \cos \alpha_{Fen}}{m_n} \left( \frac{s_{Fn}}{m_n} \right)^2 \cos \alpha_n$$

Where:

- $h_F$ = bending moment arm for tooth root bending stress for application of load at the outer point of single tooth pair contact $\text{mm}$
- $s_{Fn}$ = tooth root normal chord in the critical section $\text{mm}$
- $\alpha_{Fen}$ = pressure angle at the outer point of single tooth pair contact in the normal section $\text{o}$

![Fig. 3.1 Dimensions of $h_F$, $s_{Fn}$ and $\alpha_{Fen}$ for external gear](image)

For the calculation of $h_F$, $s_{Fn}$ and $\alpha_{Fen}$, the procedure outlined in the reference standard ISO 6336-3 (Method B) is to be used.

M56.3.4 Stress correction factor, $Y_S$

The stress correction factor $Y_S$, is used to convert the nominal bending stress to the local tooth root stress, taking into account that not only bending stresses arise at the root.

$Y_S$ applies to the load application at the outer point of single tooth pair contact.

$Y_S$ shall be determined separately for the pinion and for the wheel. The stress correction factor, $Y_S$, is to be determined with the following equation (having range of validity: $1 \le q_s \le 8$):
\[
Y_s = (1.2 + 0.13L)q_s^{1.21 + 2.3/L}
\]

Where:

\[q_s = \frac{s_F n}{2 \rho_F}\]

where:

\[q_s\] = notch parameter,

\[\rho_F\] = root fillet radius in the critical section, mm

\[L = \frac{s_F n}{h_F}\]

For \(h_F\) and \(s_F n\) see clause 3.1

For the calculation of \(\rho_F\) the procedure outlined in the reference standard ISO 6336-3 is to be used.

**M56.3.5 Helix angle factor, \(Y_\beta\)**

The helix angle factor, \(Y_\beta\), converts the stress calculated for a point loaded cantilever beam representing the substitute gear tooth to the stress induced by a load along an oblique load line into a cantilever plate which represents a helical gear tooth.

The helix angle factor, \(Y_\beta\), is to be calculated as follows:

\[
Y_\beta = 1 - \varepsilon_\beta - \beta \frac{\beta}{120}
\]

where:

\[\beta\] = reference helix angle in degrees.

The value 1.0 is substituted for \(\varepsilon_\beta\) when \(\varepsilon_\beta > 1.0\), and 30° is substituted for \(\beta > 30^\circ\).

**M56.3.6 Rim thickness factor, \(Y_B\)**

The rim thickness factor, \(Y_B\), is a simplified factor used to de-rate thin rimmed gears. For critically loaded applications, this method should be replaced by a more comprehensive analysis. Factor \(Y_B\) is to be determined as follows:

a) for external gears:

if \(s_R / h \geq 1.2\) \(Y_B = 1\)

if \(0.5 < s_R / h < 1.2\) \(Y_B = 1.6 \cdot \ln \left(2.242 \frac{h}{s_R}\right)\)

where:

\[s_R\] = rim thickness of external gears, mm

\[h\] = tooth height, mm

The case \(s_R / h \leq 0.5\) is to be avoided.
M56
(cont)

b) for internal gears:

\[
\begin{align*}
\text{if } s_R / m_n & \geq 3.5 & Y_B &= 1 \\
\text{if } 1.75 < s_R / m_n < 3.5 & & Y_B &= 1.15 \cdot \ln \left( \frac{m_n}{s_R} \right) \\
\end{align*}
\]

where:

- \( s_R \) = rim thickness of internal gears, mm

The case \( s_R / m_n \leq 1.75 \) is to be avoided.

M56.3.7 Deep tooth factor, \( Y_{DT} \)

The deep tooth factor, \( Y_{DT} \), adjusts the tooth root stress to take into account high precision gears and contact ratios within the range of virtual contact ratio \( 2.05 \leq \varepsilon_{\text{in}} \leq 2.5 \), where:

\[
\varepsilon_{\text{in}} = -\frac{\varepsilon_a}{\cos^2 \beta_b}
\]

Factor \( Y_{DT} \) is to be determined as follows:

\[
\begin{align*}
\text{if ISO accuracy grade } \leq 4 \text{ and } \varepsilon_{\text{in}} > 2.5 & \quad Y_{DT} = 0.7 \\
\text{if ISO accuracy grade } \leq 4 \text{ and } 2.05 < \varepsilon_{\text{in}} \leq 2.5 & \quad Y_{DT} = 2.366 - 0.666 \cdot \varepsilon_{\text{in}} \\
in \text{all other cases} & \quad Y_{DT} = 1.0
\end{align*}
\]

M56.3.8 Bending endurance limit, \( \sigma_{FE} \)

For a given material, \( \sigma_{FE} \) is the local tooth root stress which can be permanently endured.

According to the reference standard ISO 6336-5 the number of \( 3 \times 10^6 \) cycles is regarded as the beginning of the endurance limit.

\( \sigma_{FE} \) is defined as the unidirectional pulsating stress with a minimum stress of zero (disregarding residual stresses due to heat treatment). Other conditions such as alternating stress or prestressing etc. are covered by the design factor \( Y_d \).

The \( \sigma_{FE} \) values are to correspond to a failure probability 1% or less.

The endurance limit mainly depends on:
- material composition, cleanliness and defects;
- mechanical properties;
- residual stresses;
- hardening process, depth of hardened zone, hardness gradient;
- material structure (forged, rolled bar, cast).

The bending endurance limit, \( \sigma_{FE} \) is to be determined, in general, making reference to values indicated in the reference standard ISO 6336-5, for material quality MQ.

M56.3.9 Design factor, \( Y_d \)

The design factor, \( Y_d \), takes into account the influence of load reversing and shrinkfit prestressing on the tooth root strength, relative to the tooth root strength with unidirectional load as defined for \( \sigma_{FE} \).
The design factor, $Y_d$, for load reversing, is to be determined as follows:

- $Y_d = 1.0$ in general;
- $Y_d = 0.9$ for gears with occasional part load in reversed direction, such as main wheel in reversing gearboxes;
- $Y_d = 0.7$ for idler gears

**M56.3.10 Life factor, $Y_N$**

The life factor, $Y_N$, accounts for the higher tooth root bending stress permissible in case a limited life (number of cycles) is required.

The factor mainly depends on:
- material and heat treatment;
- number of load cycles (service life);
- influence factors ($Y_{\delta_r}T$, $Y_{RrelT}$, $Y_x$).

The life factor, $Y_N$, is to be determined according to Method B outlined in the reference standard ISO 6336-3.

**M56.3.11 Relative notch sensitivity factor, $Y_{\delta_r}T$**

The relative notch sensitivity factor, $Y_{\delta_r}T$, indicates the extent to which the theoretically concentrated stress lies above the fatigue endurance limit. The factor mainly depends on material and relative stress gradient.

The relative notch sensitivity factor, $Y_{\delta_r}T$, is to be determined as follows:

$$Y_{\delta_r}T = \frac{1 + \sqrt{0.2\rho'(1 + 2q_s)}}{1 + \sqrt{1.2\rho'}}$$

where:

- $q_s = $ notch parameter (see clause 3.4)
- $\rho' = $ slip-layer thickness, mm, from the following table

<table>
<thead>
<tr>
<th>Material</th>
<th>$\rho'$, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>case hardened steels, flame or induction hardened steels</td>
<td>0.0030</td>
</tr>
<tr>
<td>through-hardened steels(^1), yield point $R_0=$ 500 N/mm(^2)</td>
<td>0.0281</td>
</tr>
<tr>
<td></td>
<td>600 N/mm(^2)</td>
</tr>
<tr>
<td></td>
<td>800 N/mm(^2)</td>
</tr>
<tr>
<td></td>
<td>1000 N/mm(^2)</td>
</tr>
<tr>
<td>nitrided steels</td>
<td>0.1005</td>
</tr>
</tbody>
</table>

\(^1\)The given values of $\rho'$ can be interpolated for values of $R_0$ not stated above

**M56.3.12 Relative surface factor, $Y_{RrelT}$**

The relative surface factor, $Y_{RrelT}$, takes into account the dependence of the root strength on the surface condition in the tooth root fillet, mainly the dependence on the peak to valley surface roughness.
The relative surface factor, $Y_{RelT}$, is to be determined as follows:

<table>
<thead>
<tr>
<th>$R_z &lt; 1$</th>
<th>$1 \leq R_z \leq 40$</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.120</td>
<td>$1.674 - 0.529(R_z + 1)^{0.1}$</td>
<td>case hardened steels, through-hardened steels $(\sigma_B \geq 800 \text{ N/mm}^2)$</td>
</tr>
<tr>
<td>1.070</td>
<td>$5.306 - 4.203(R_z + 1)^{0.01}$</td>
<td>normalised steels $(\sigma_B &lt; 800 \text{ N/mm}^2)$</td>
</tr>
<tr>
<td>1.025</td>
<td>$4.299 - 3.259(R_z + 1)^{0.0058}$</td>
<td>nitrided steels</td>
</tr>
</tbody>
</table>

Where:

$R_z = \text{mean peak-to-valley roughness of tooth root fillets, } \mu\text{m}$

$\sigma_B = \text{tensile strength, N/mm}^2$

The method applied here is only valid when scratches or similar defects deeper than $2R_z$ are not present.

If the roughness stated is an arithmetic mean roughness, i.e. $R_a$ value (=CLA value) (=AA value) the following approximate relationship can be applied:

$$R_a = \text{CLA} = \text{AA} = R_z / 6$$

**M56.3.13 Size factor, $Y_X$**

The size factor, $Y_X$, takes into account the decrease of the strength with increasing size.

The factor mainly depends on:
- material and heat treatment;
- tooth and gear dimensions;
- ratio of case depth to tooth size.

The size factor, $Y_X$, is to be determined as follows:

<table>
<thead>
<tr>
<th>$Y_X$</th>
<th>for $m_n \leq 5$</th>
<th>generally</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$1.03 - 0.06 m_n$</td>
<td>for $5 &lt; m_n &lt; 30$</td>
<td>normalised and through-hardened steels</td>
</tr>
<tr>
<td>0.85</td>
<td>for $m_n \geq 30$</td>
<td></td>
</tr>
<tr>
<td>$1.05 - 0.010 m_n$</td>
<td>for $5 &lt; m_n &lt; 25$</td>
<td>surface hardened steels</td>
</tr>
<tr>
<td>0.80</td>
<td>for $m_n \geq 25$</td>
<td></td>
</tr>
</tbody>
</table>

**M56.3.14 Safety factor for tooth root bending stress, $S_F$**

The safety factor for tooth root bending stress, $S_F$, can be assumed by the Society taking into account the type of application.

The following guidance values can be adopted:
- Main propulsion gears: 1.55 to 2.00
- Auxiliary gears: 1.40 to 1.45
For gearing of duplicated independent propulsion or auxiliary machinery, duplicated beyond that required for class, a reduced value can be assumed at the discretion of the Society.
Use of ammonia as a refrigerant

1. Ammonia refrigerating machinery shall be installed in dedicated gastight compartments. Except for small compartments, at least two access doors are to be provided.

2. Compartments containing ammonia machinery (including process vessels) are to be fitted with:
   a) a negative ventilation system independent of ventilation systems serving other ship spaces and having a capacity not less than 30 changes per hour based upon the total volume of the space; other suitable arrangements which ensure an equivalent effectiveness may be considered;
   b) a fixed ammonia detector system with alarms inside and outside the compartment;
   c) water screens above all access doors, operable manually from outside the compartment;
   d) an independent bilge system.

3. At least two sets of breathing apparatus and protective clothings are to be available.

4. Ammonia piping is not to pass through accommodation spaces.

5. In case of ammonia plants of fishing vessels under 55 m in length or other ammonia plants with a quantity of ammonia not greater than 25 kg said plants are allowed to be located in the machinery space.

   The area where the ammonia machinery is installed is to be served by a hood with a negative ventilation system, so as not to permit any leakage of ammonia from dissipating into other areas in the space.

   A water spray system is to be provided for the said area.

   In addition previous items 2 b), 3 and 4 apply.
M58   Charge air coolers
(1994)

Deleted Feb 2015, replaced by UR M72.
M59 Control and Safety Systems for Dual Fuel Diesel Engines

M59.1 Application

In addition to the requirements for oil firing diesel engines by the Classification Societies, and the requirements contained in chapter 5 and 16 of the IGC Code*, as far as found applicable, the following requirements are to be applied to dual-fuel diesel engines utilising high pressure Methane gas (NG: Natural Gas) fuel injection (hereinafter referred to as DFD engines).

M59.2 Operation mode

2.1 DFD engines are to be of the dual-fuel type employing pilot fuel ignition and to be capable of immediate change-over to oil fuel only.

2.2 Only oil fuel is to be used when starting the engine.

2.3 Only oil fuel is, in principle, to be used when the operation of an engine is unstable, and/or during manoeuvring and port operations.

2.4 In case of shut-off of the gas fuel supply, the engines are to be capable of continuous operation by oil fuel only.

M59.3 Protection of crankcase

3.1 Crankcase relief valves are to be fitted in way of each crankthrow. The construction and operating pressure of the relief valves are to be determined considering explosions due to gas leaks.

3.2 If a trunk piston type engine is used as DFD engine, the crankcase is to be protected by the following measures.

(1) Ventilation is to be provided to prevent the accumulation of leaked gas, the outlet for which is to be led to a safe location in the open through flame arrester.

(2) Gas detecting or equivalent equipment. (It is recommended that means for automatic injection of inert gas are to be provided).

(3) Oil mist detector.

3.3 If a cross-head type engine is used as DFD, the crankcase is to be protected by oil mist detector or bearing temperature detector.

M59.4 Protection for piston underside space of cross-head type engine

4.1 Gas detecting or equivalent equipment is to be provided for piston underside space of cross-head type engine.

M59.5 Engine Exhaust System

5.1 Explosion relief valves or other appropriate protection system against explosion are to be provided in the exhaust, scavenge and air inlet manifolds.

5.2 The exhaust gas pipes from DFD engines are not to be connected to the exhaust pipes of other engines or systems.

M59.6 Starting air line

6.1 Starting air branch pipes to each cylinder are to be provided with effective flame arresters.

M59.7 Combustion Monitoring

7.1 A failure mode and effect analysis (FMEA) examining all possible faults affecting the combustion process is to be submitted.

Details of required monitoring will be determined based on the outcome of the analysis. However, the following table may serve as guidance:

<table>
<thead>
<tr>
<th>Faulty condition</th>
<th>Alarm</th>
<th>Aut. shut-off of the interlocked valves*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function of gas fuel injection valves and pilot oil fuel injection valves</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Exhaust gas temperature at each cylinder outlet and deviation from average</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cylinder pressure or ignition failure of each cylinder</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

* It is recommended that the gas master valve is also closed.

M59.8 Gas fuel supply to engine

8.1 Flame arresters are to be provided at the inlet to the gas supply manifold for the engine.

8.2 Arrangements are to be made so that the gas supply to the engine can be shut-off manually from starting platform or any other control position.

8.3 The arrangement and installation of the gas piping are to provide the necessary flexibility for the gas supply piping to accommodate the oscillating movements of DFD engine, without risk of fatigue failure.

8.4 The connecting of gas line and protection pipes or ducts regulated in 9.1 to the gas fuel injection valves are to provide complete coverage by the protection pipe or ducts.

M59.9 Gas fuel supply piping systems

9.1 Gas fuel piping may pass through or extend into machinery spaces or gas-safe spaces other than accommodation spaces, service spaces and control stations provided that they fulfil one of the following:

(1) The system complying with 16.3.1.1 of the IGC Code, and in addition, with (a), (b) and (c) given below.
(a) The pressure in the space between concentric pipes is monitored continuously. Alarm is to be issued and automatic valves specified in 16.3.6 of the IGC Code (hereinafter referred to as “interlocked gas valves”) and the master gas fuel valves specified in 16.3.7 of the IGC Code (hereinafter referred to as “master gas valve”) are to be closed before the pressure drops to below the inner pipe pressure (however, an interlocked gas valve connected to vent outlet is to be opened).

(b) Construction and strength of the outer pipes are to comply with the requirements of 5.2 of the IGC Code.

(c) It is to be so arranged that the inside of the gas fuel supply piping system between the master gas valve and the DFD engine is to be automatically purged with inert gas, when the master gas valve is closed; or

(2) The system complying with 16.3.1.2 of the IGC Code, and in addition, with (a) through (d) given below.

(a) Materials, construction and strength of protection pipes or ducts and mechanical ventilation systems are to be sufficiently durable against bursting and rapid expansion of high pressure gas in the event of gas pipe burst.

(b) The capacity of mechanical ventilating system is to be determined considering the flow rate of gas fuel and construction and arrangement of protective pipes or ducts, as deemed appropriate by the Classification Society.

(c) The air intakes of mechanical ventilating systems are to be provided with non-return devices effective for gas fuel leaks. However, if a gas detector is fitted at the air intakes, these requirements may be dispensed with.

(d) The number of flange joints of protective pipes or ducts is to be minimised; or

(3) Alternative arrangements to those given in paragraph 9.1(1) and (2) will be specially considered based upon an equivalent level of safety.

9.2 High pressure gas piping system are to be ensured to have sufficient constructive strength by carrying out stress analysis taking into account the stresses due to the weight of the piping system including acceleration load when significant, internal pressure and loads induced by hog and sag of the ships.

9.3 All valves and expansion joints used in high pressure gas fuel supply lines are to be of an approved type.

9.4 Joints on entire length of the gas fuel supply lines are to be butt-welded joints with full penetration and to be fully radiographed, except where specially approved by the Classification Society.

9.5 Pipe joints other than welded joints at the locations specially approved by the society are to comply with the appropriate standards recognised by the society, or those whose structural strength has been verified through tests and analysis as deemed appropriate by the Classification Society.

9.6 For all butt-welded joints of high pressure gas fuel supply lines, post-weld heat treatment are to be performed depending on the kind of material.

M59.10 Shut-off of gas fuel supply

10.1 In addition to the causes specified in 16.3.6 of the IGC Code, supply of gas fuel to DFD engines is to be shut off by the interlocked gas valves in case following abnormality occurs;
10.2 In addition to the causes specified in 16.3.7 of IGC Code, the master gas valve is to be closed in case of any of the following:

(1) Oil mist detector or bearing temperature detector specified in 3.2(3) and 3.3 detects abnormality.
(2) Any kind of gas fuel leakage is detected.
(3) Abnormality specified in 9.1(1)(a)
(4) Abnormality specified in 11.1

10.3 The master gas valve is recommended to close automatically upon activation of the interlocked gas valves.

M59.11 Emergency stop of the DFD engines

11.1 DFD engine is to stopped before the gas concentration detected by the gas detectors specified in 16.2.2 of the IGC Code reached 60% of lower flammable limit.

M59.12 Gas fuel make-up plant and related storage tanks

12.1 Construction, control and safety system of high pressure gas compressors, pressure vessels and heat exchangers constituting a gas fuel make-up plant are so arranged as to the satisfaction of the Classification Society.

12.2 The possibility for fatigue failure of the high pressure gas piping due to vibration is to be considered.

12.3 The possibility for pulsation of gas fuel supply pressure caused by the high pressure gas compressor is to be considered.
M60 Control and Safety of Gas Turbines for Marine Propulsion Use

M60.1 Governor and Over speed protective devices

M60.1.1 Main gas turbines are to be provided with over speed protective devices to prevent the turbine speed from exceeding more than 15% of the maximum continuous speed.

M60.1.2 Where a main gas turbine incorporates a reverse gear, electric transmission, controllable pitch propeller or other free-coupling arrangement, a speed governor independent of the over speed protective device is to be fitted and is to be capable of controlling the speed of the unloaded gas turbine without bringing the over speed protective device into action.

M60.2 Miscellaneous automatic safety devices

M60.2.1 Details of the manufacturer’s proposed automatic safety devices to safeguard against hazardous conditions arising in the event of malfunctions in the gas turbine installation are to be submitted to the Classification Society together with the failure mode and effect analysis.

M60.2.2 Main gas turbines are to be equipped with a quick closing device (shut-down device) which automatically shuts off the fuel supply to the turbines at least in case of:

a) Over speed
b) Unacceptable lubricating oil pressure drop
c) Loss of flame during operation
d) Excessive vibration
e) Excessive axial displacement of each rotor (Except for gas turbines with rolling bearings)
f) Excessive high temperature of exhaust gas
g) Unacceptable lubricating oil pressure drop of reduction gear
h) Excessive high vacuum pressure at the compressor inlet

M60.2.3 The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the main gas turbine:

a) Lubricating oil supply
b) Oil fuel supply (or automatic control of oil fuel viscosity as alternative)
c) Exhaust gas

M60.2.4 Automatic or interlocked means are to be provided for clearing all parts of the main gas turbine of the accumulation of liquid fuel or for purging gaseous fuel, before ignition commences on starting or recommences after failure to start.
M60.2.5
Hand trip gear for shutting off the fuel in an emergency is to be provided at the manoeuvring station.

M60.2.6
Starting devices are to be so arranged that firing operation is discontinued and main fuel valve is closed within pre-determined time, when ignition is failed.

M60.3  Alarming devices

M60.3.1
Alarming devices listed in table 1 are to be provided.

M60.3.2
Alarms marked with “*” in Table 1 are to be activated at the suitable setting points prior to arriving the critical condition for the activation of shutdown devices.

M60.3.3
Suitable alarms are to be operated by the activation of shutdown devices.
### Table 1 List of alarm and shutdown

<table>
<thead>
<tr>
<th>Monitoring parameter</th>
<th>Alarm</th>
<th>Shutdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine speed</td>
<td><img src="image" alt="Alarm high value" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
<tr>
<td>Lubricating oil pressure</td>
<td><img src="image" alt="Alarm high value" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
<tr>
<td>Lubricating oil pressure of reduction gear</td>
<td><img src="image" alt="Alarm high value" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
<tr>
<td>Differential pressure across lubricating oil filter</td>
<td><img src="image" alt="Alarm high value" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
<tr>
<td>Lubricating oil temperature</td>
<td><img src="image" alt="Alarm high value" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
<tr>
<td>Oil fuel supply pressure</td>
<td><img src="image" alt="Alarm high value" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
<tr>
<td>Oil fuel temperature</td>
<td><img src="image" alt="Alarm high value" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
<tr>
<td>Cooling medium temperature</td>
<td><img src="image" alt="Alarm high value" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
<tr>
<td>Bearing temperature</td>
<td><img src="image" alt="Alarm high value" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
<tr>
<td>Flame and ignition Failure</td>
<td><img src="image" alt="Alarm activated" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
<tr>
<td>Automatic starting Failure</td>
<td><img src="image" alt="Alarm activated" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
<tr>
<td>Vibration</td>
<td><img src="image" alt="Alarm high value" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
<tr>
<td>Axial displacement of rotor</td>
<td><img src="image" alt="Alarm high value" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
<tr>
<td>Exhaust gas temperature</td>
<td><img src="image" alt="Alarm high value" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
<tr>
<td>Vacuum pressure at the compressor inlet</td>
<td><img src="image" alt="Alarm high value" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
<tr>
<td>Loss of control system</td>
<td><img src="image" alt="Alarm activated" /></td>
<td><img src="image" alt="Shut down" /></td>
</tr>
</tbody>
</table>

- ![Alarm high value](image) Alarm for high value
- ![Alarm low value](image) Alarm for low value
- ![Alarm activated](image) Alarm activated
- ![Shut down](image) Shut down
Starting Arrangements of Internal Combustion Engines

M61.1 Mechanical starting arrangements

M61.1.1 The arrangement for air starting is to be such that the necessary air for the first charge can be produced on board without external aid.

M61.1.2 Where the main engine is arranged for starting by compressed air, two or more air compressors are to be fitted. At least one of the compressors is to be driven independent of the main propulsion unit and is to have the capacity not less than 50% of the total required.

M61.1.3 The total capacity of air compressors is to be sufficient to supply within one hour the quantity of air needed to satisfy M61.1.5 by charging the receivers from atmospheric pressure. The capacity is to be approximately equally divided between the number of compressors fitted, excluding an emergency compressor which may be installed to satisfy M61.1.1.

M61.1.4 Where the main engine is arranged for starting by compressed air, at least two starting air receivers of about equal capacity are to be fitted which may be used independently.

M61.1.5 The total capacity of air receivers is to be sufficient to provide, without their being replenished, not less than 12 consecutive starts alternating between Ahead and Astern of each main engine of the reversible type, and not less than six starts of each main non-reversible type engine connected to a controllable pitch propeller or other device enabling the start without opposite torque. The number of starts refers to engine in cold and ready to start conditions. Additional number of starts may be required when the engine is in the warm running condition. When other consumers such as auxiliary engines starting systems, control systems, whistle, etc., are to be connected to starting air receivers, their air consumption is also to be taken into account.

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

M61.2 Electrical starting

M61.2.1 Where the main engine is arranged for electric starting, two separate batteries are to be fitted. The arrangement is to be such that the batteries cannot be connected in parallel. Each battery is to be capable of starting the main engine when in cold and ready to start conditions. The combined capacity of the batteries is to be sufficient without recharging to provide within 30 minutes the number of starts of main engines are required above in case of air starting.

M61.2.2 Electric starting arrangements for auxiliary engines are to have two separate batteries or may be supplied by separate circuits from the main engine batteries when such are provided. In the case of a single auxiliary engine only one battery may be required. The capacity of the batteries for starting the auxiliary engines is to be sufficient for at least three starts for each engine.

M61.2.3 The starting batteries are to be used for starting and the engine's own monitoring purposes only. Provisions are to be made to maintain continuously the stored energy at all times.
Rooms for emergency fire pumps in cargo ships

Deleted June 2014, converted to Rec 135.
Alarms and safeguards for emergency diesel engines

1. Field of application

These requirements apply to diesel engines required to be immediately available in an emergency and capable of being controlled remotely or automatically operated.

2. Information to be submitted

Information demonstrating compliance with these requirements is to be submitted to the relevant Classification Society. The information is to include instructions to test the alarm and safety systems.

3. Alarms and safeguards

.1 Alarms and safeguards are to be fitted in accordance with Table 1.

.2 The safety and alarm systems are to be designed to ‘fail safe’. The characteristics of the ‘fail safe’ operation are to be evaluated on the basis not only of the system and its associated machinery, but also the complete installation, as well as the ship.

.3 Regardless of the engine output, if shutdowns additional to those specified in Table 1 are provided except for the overspeed shutdown, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.

.4 The alarm system is to function in accordance with M29, with additional requirements that grouped alarms are to be arranged on the bridge.

.5 In addition to the fuel oil control from outside the space, a local means of engine shutdown is to be provided.

.6 Local indications of at least those parameters listed in Table 1 are to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.

Table 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>≥ 220kW</th>
<th>&lt;220kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel oil leakage from pressure pipes</td>
<td>❍</td>
<td>❍</td>
</tr>
<tr>
<td>Lubricating oil temperature</td>
<td>❍</td>
<td>❍</td>
</tr>
<tr>
<td>Lubricating oil pressure</td>
<td>❍</td>
<td>❍</td>
</tr>
<tr>
<td>Oil mist concentration in crankcase</td>
<td>❍</td>
<td></td>
</tr>
<tr>
<td>Pressure or flow of cooling water</td>
<td>❍</td>
<td></td>
</tr>
<tr>
<td>Temperature of cooling water ( or cooling air )</td>
<td>❍</td>
<td>❍</td>
</tr>
<tr>
<td>Overspeed activated</td>
<td>❍ + ❍</td>
<td></td>
</tr>
</tbody>
</table>

Note:

1 for engines having a power of more than 2250 kW or a cylinder bore of more than 300mm.

- ❍ Alarm for low value
- ❍ Alarm for high value
- ❍ Alarm activated
- ❍ Shut down
Design of integrated cargo and ballast systems on tankers

1. Application

These requirements are applicable to integrated cargo and ballast systems installed on tankers (i.e. cargo ships constructed or adapted for the carriage of liquid cargoes in bulk) contracted for construction on or after 1 January 2004, irrespective of the size or type of the tanker. Within the scope of these requirements, integrated cargo and ballast system means any integrated hydraulic and/or electric system used to drive both cargo and ballast pumps (including active control and safety systems and excluding passive components, e.g. piping).

2. Functional Requirements

The operation of cargo and/or ballast systems may be necessary, under certain emergency circumstances or during the course of navigation, to enhance the safety of tankers. As such, measures are to be taken to prevent cargo and ballast pumps becoming inoperative simultaneously due to a single failure in the integrated cargo and ballast system, including its control and safety systems.

3. Design features

The following design features are, inter alia, to be fitted:

.1 the emergency stop circuits of the cargo and ballast systems are to be independent from the circuits for the control systems. A single failure in the control system circuits or the emergency stop circuits are not to render the integrated cargo and ballast system inoperative;

.2 manual emergency stops of the cargo pumps are to be arranged in a way that they are not to cause the stop of the power pack making ballast pumps inoperable;

.3 the control systems are to be provided with backup power supply, which may be satisfied by a duplicate power supply from the main switch board. The failure of any power supply is to provide audible and visible alarm activation at each location where the control panel is fitted.

.4 in the event of failure of the automatic or remote control systems, a secondary means of control is to be made available for the operation of the integrated cargo and ballast system. This is to be achieved by manual overriding and/or redundant arrangements within the control systems.

Note:

1. This UR is to be uniformly implemented by all IACS Societies on tankers (as defined in M64.1) contracted for construction on or after 1 January 2004

2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.
Type Testing Procedure for Crankcase Explosion Relief Valves

1. Scope

1.1 To specify type tests and identify standard test conditions using methane gas and air mixture to demonstrate that classification society requirements are satisfied for crankcase explosion relief valves intended to be fitted to engines and gear cases.

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

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

2. Recognised Standards


2.2 ISO/IEC EN 17025:2005: General requirements for the competence of testing and calibration laboratories.


2.4 VDI 3673: Part 1: Pressure Venting of Dust Explosions.

2.5 IMO MSC/Circular 677 – Revised Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame into Cargo Tanks in Tankers

Note:
1) Engines are to be fitted with components and arrangements complying with this UR when:
   i) the engine is installed on existing ships (i.e. ships for which the date of contract for construction is before 1 January 2008) and the date of application for certification of the engine is on or after 1 January 2008; or
   ii) the engine is installed on new ships (i.e. ships for which the date of contract for construction is on or after 1 January 2008).

2) The "contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to IACS Procedural Requirement (PR) No. 29.
3. Purpose

3.1 The purpose of type testing crankcase explosion relief valves is fourfold:

3.1.1 To verify the effectiveness of the flame arrester.

3.1.2 To verify that the valve closes after an explosion.

3.1.3 To verify that the valve is gas/air tight after an explosion.

3.1.4 To establish the level of over pressure protection provided by the valve.

4. Test facilities

4.1 Test houses carrying out type testing of crankcase explosion relief valves are to meet the following requirements:

4.1.1 The test houses where testing is carried out are to be accredited to a National or International Standard, e.g. ISO/IEC 17025, and are to be acceptable to the classification societies.

4.1.2 The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.

4.1.3 The test facilities are to have equipment for controlling and measuring a methane gas in air concentration within a test vessel to an accuracy of ± 0.1%.

4.1.4 The test facilities are to be capable of effective point-located ignition of a methane gas in air mixture.

4.1.5 The pressure measuring equipment is to be capable of measuring the pressure in the test vessel in at least two positions, one at the valve and the other at the test vessel centre. The measuring arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognising the speed of events during an explosion. The result of each test is to be documented by video recording and by recording with a heat sensitive camera.

4.1.6 The test vessel for explosion testing is to have documented dimensions. The dimensions are to be such that the vessel is not “pipe like” with the distance between dished ends being not more than 2.5 times its diameter. The internal volume of the test vessel is to include any standpipe arrangements.

4.1.7 The test vessel is to be provided with a flange, located centrally at one end perpendicular to the vessel longitudinal axis, for mounting the explosion relief valve. The test vessel is to be arranged in an orientation consistent with how the valve will be installed in service, i.e., in the vertical plane or the horizontal plane.

4.1.8 A circular plate is to be provided for fitting between the pressure vessel flange and valve to be tested with the following dimensions:

   a) Outside diameter of 2 times the outer diameter of the valve top cover.

   b) Internal bore having the same internal diameter as the valve to be tested.
4.1.9 The test vessel is to have connections for measuring the methane in air mixture at the top and bottom.

4.1.10 The test vessel is to be provided with a means of fitting an ignition source at a position specified in item 5.3.

4.1.11 The test vessel volume is to be as far as practicable, related to the size and capability of the relief valve to be tested. In general, the volume is to correspond to the requirement in UR M9.3 for the free area of explosion relief valve to be not less than $115\text{cm}^2/\text{m}^3$ of crankcase gross volume.

Notes:

1. This means that the testing of a valve having $1150\text{cm}^2$ of free area, would require a test vessel with a volume of $10\text{m}^3$.

2. Where the free area of relief valves is greater than $115 \text{ cm}^2/\text{m}^3$ of the crankcase gross volume, the volume of the test vessel is to be consistent with the design ratio.

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

5. Explosion test process

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

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

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

5.4 The ignition is to be made using a maximum 100 joule explosive charge.

6. Valves to be tested

6.1 The valves used for type testing (including testing specified in item 6.3) are to be selected from the manufacturer’s normal production line for such valves by the classification society witnessing the tests.

6.2 For approval of a specific valve size, three valves are to be tested in accordance with 6.3 and 7. For a series of valves item 9 refers.

6.3 The valves selected for type testing are to have been previously tested at the manufacturer’s works to demonstrate that the opening pressure is in accordance with the specification within a tolerance of $\pm 20\%$ and that the valve is air tight at a pressure below the opening pressure for at least 30 seconds.
Note:

This test is to verify that the valve is air tight following assembly at the manufacturer’s works and that the valve begins to open at the required pressure demonstrating that the correct spring has been fitted.

6.4 The type testing of valves is to recognise the orientation in which they are intended to be installed on the engine or gear case. Three valves of each size are to be tested for each intended installation orientation, i.e. in the vertical and/or horizontal positions.

7. Method

7.1 The following requirements are to be satisfied at explosion testing:

7.1.1 The explosion testing is to be witnessed by a classification society surveyor.

7.1.2 Where valves are to be installed on an engine or gear case with shielding arrangements to deflect the emission of explosion combustion products, the valves are to be tested with the shielding arrangements fitted.

7.1.3 Successive explosion testing to establish a valve’s functionality is to be carried out as quickly as possible during stable weather conditions.

7.1.4 The pressure rise and decay during all explosion testing is to be recorded.

7.1.5 The external condition of the valves is to be monitored during each test for indication of any flame release by video and heat sensitive camera.

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

7.2.1 Stage 1:

7.2.1.1 Two explosion tests are to be carried out in the test vessel with the circular plate described in 4.1.8 fitted and the opening in the plate covered by a 0.05mm thick polythene film.

Note:

These tests establish a reference pressure level for determination of the capability of a relief valve in terms of pressure rise in the test vessel, see 8.1.6.

7.2.2 Stage 2:

7.2.2.1 Two explosion tests are to be carried out on three different valves of the same size. Each valve is to be mounted in the orientation for which approval is sought i.e., in the vertical or horizontal position with the circular plate described in 4.1.8 located between the valve and pressure vessel mounting flange.
7.2.2.2 The first of the two tests on each valve is to be carried out with a 0.05mm thick polythene bag, having a minimum diameter of three times the diameter of the circular plate and volume not less than 30% of the test vessel, enclosing the valve and circular plate. Before carrying out the explosion test the polythene bag is to be empty of air. The polythene bag is required to provide a readily visible means of assessing whether there is flame transmission through the relief valve following an explosion consistent with the requirements of the standards identified in Section 2.

Note:

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

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

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

7.2.3 Stage 3:

7.2.3.1 Carry out two further explosion tests as described in Stage 1. These further tests are required to provide an average baseline value for assessment of pressure rise, recognising that the test vessel ambient conditions may have changed during the testing of the explosion relief valves in Stage 2.

8. Assessment and records

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

8.1.1 The valves to be tested are to have evidence of design appraisal/approval by the classification society witness testing.

8.1.2 The designation, dimensions and characteristics of the valves to be tested are to be recorded. This is to include the free area of the valve and of the flame arrester and the amount of valve lift at 0.2bar.

8.1.3 The test vessel volume is to be determined and recorded.
8.1.4 For acceptance of the functioning of the flame arrester there is not to be any indication of flame or combustion outside the valve during an explosion test. This should be confirmed by the test laboratory taking into account measurements from the heat sensitive camera.

8.1.5 The pressure rise and decay during an explosion is to be recorded, with indication of the pressure variation showing the maximum overpressure and steady underpressure in the test vessel during testing. The pressure variation is to be recorded at two points in the pressure vessel.

8.1.6 The effect of an explosion relief valve in terms of pressure rise following an explosion is ascertained from maximum pressures recorded at the centre of the test vessel during the three stages. The pressure rise within the test vessel due to the installation of a relief valve is the difference between average pressure of the four explosions from Stages 1 and 3 and the average of the first tests on the three valves in Stage 2. The pressure rise is not to exceed the limit specified by the manufacturer.

8.1.7 The valve tightness is to be ascertained by verifying from the records at the time of testing that an underpressure of at least 0.3bar is held by the test vessel for at least 10 seconds following an explosion. This test is to verify that the valve has effectively closed and is reasonably gas-tight following dynamic operation during an explosion.

8.1.8 After each explosion test in Stage 2, the external condition of the flame arrester is to be examined for signs of serious damage and/or deformation that may affect the operation of the valve.

8.1.9 After completing the explosion tests, the valves are to be dismantled and the condition of all components ascertained and documented. In particular, any indication of valve sticking or uneven opening that may affect operation of the valve is to be noted. Photographic records of the valve condition are to be taken and included in the report.

9. Design series qualification

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

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

\[
\frac{n_1}{n_2} = \sqrt{\frac{S_1}{S_2}}
\]

\[
\frac{A_1}{A_2} = \frac{S_1}{S_2}
\]
Where:

\[ n_1 = \text{total depth of flame arrester corresponding to the number of lamellas of size 1 quenching device for a valve with a relief area equal to } S_1 \]

\[ n_2 = \text{total depth of flame arrester corresponding to the number of lamellas of size 2 quenching device for a valve with a relief area equal to } S_2 \]

\[ A_1 = \text{free area of quenching device for a valve with a relief area equal to } S_1 \]

\[ A_2 = \text{free area of quenching device for a valve with a relief area equal to } S_2 \]

9.3 The qualification of explosion relief valves of larger sizes than that which has been previously satisfactorily tested in accordance with Sections 7 and 8 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

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

9.3.2 One valve of the largest size, subject to 9.3.1, requiring qualification is subject to satisfactory testing required by 6.3 and 7.2.2 except that a single valve will be accepted in 7.2.2.1 and the volume of the test vessel is not to be less than one third of the volume required by 4.1.11.

9.3.3 The assessment and records are to be in accordance with Section 8 noting that 8.1.6 will only be applicable to Stage 2 for a single valve.

9.4 The qualification of explosion relief valves of smaller sizes than that which has been previously satisfactorily tested in accordance with Sections 7 and 8 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

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

9.4.2 One valve of the smallest size, subject to 9.4.1, requiring qualification is subject to satisfactory testing required by 6.3 and 7.2.2 except that a single valve will be accepted in 7.2.2.1 and the volume of the test vessel is not to be more than the volume required by 4.1.11.

9.4.3 The assessment and records are to be in accordance with Section 8 noting that 8.1.6 will only be applicable to Stage 2 for a single valve.

10. The report

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

10.1.1 Test specification.

10.1.2 Details of test pressure vessel and valves tested.

10.1.3 The orientation in which the valve was tested, (vertical or horizontal position).
10.1.4 Methane in air concentration for each test.

10.1.5 Ignition source.

10.1.6 Pressure curves for each test.

10.1.7 Video recordings of each valve test.

10.1.8 The assessment and records stated in 8.

11. Approval

11.1 The approval of an explosion relief valve is at the discretion of individual classification societies based on the appraisal plans and particulars and the test facility’s report of the results of type testing.
Draining and Pumping Forward Spaces in Bulk Carriers

Application

1. This requirement applies to bulk carriers constructed generally with single deck, top-side tanks and hopper side tanks in cargo spaces intended primarily to carry dry cargo in bulk, and includes such types as ore carriers and combination carriers, which are contracted for construction on or after 1 January 2005.

Dewatering capacity

2. The dewatering system for ballast tanks located forward of the collision bulkhead and for bilges of dry spaces any part of which extends forward of the foremost cargo hold[1] is to be designed to remove water from the forward spaces at a rate of not less than 320Am^3/h, where A is the cross-sectional area in m^2 of the largest air pipe or ventilator pipe connected from the exposed deck to a closed forward space that is required to be dewatered by these arrangements.

[1]. Reference is made to SOLAS regulation XII/13 and Unified Interpretation SC 179 "Dewatering of forward spaces of bulk carriers".

Note:

1) The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.
Type Testing Procedure for Crankcase Explosion Relief Valves

1. Scope

1.1 To specify type tests and identify standard test conditions using methane gas and air mixture to demonstrate that classification society requirements are satisfied for crankcase explosion relief valves intended to be fitted to engines and gear cases.

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

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

2. Recognised Standards


2.2 ISO/IEC EN 17025:2005: General requirements for the competence of testing and calibration laboratories.


2.4 VDI 3673: Part 1: Pressure Venting of Dust Explosions.

2.5 IMO MSC/Circular 677 – Revised Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame into Cargo Tanks in Tankers.

Note:

1) Engines are to be fitted with components and arrangements complying with this UR when:

i) the engine is installed on existing ships (i.e. ships for which the date of contract for construction is before 1 July 2008) and the date of application for certification of the engine (i.e. the date of whatever document the Classification Society requires/accepts as an application or request for certification of an individual engine) is on or after 1 July 2008; or

ii) the engine is installed on new ships (i.e. ships for which the date of contract for construction is on or after 1 July 2008).

2) The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.
3. Purpose

3.1 The purpose of type testing crankcase explosion relief valves is fourfold:

3.1.1 To verify the effectiveness of the flame arrester.

3.1.2 To verify that the valve closes after an explosion.

3.1.3 To verify that the valve is gas/air tight after an explosion.

3.1.4 To establish the level of over pressure protection provided by the valve.

4. Test facilities

4.1 Test houses carrying out type testing of crankcase explosion relief valves are to meet the following requirements:

4.1.1 The test houses where testing is carried out are to be accredited to a National or International Standard, e.g. ISO/IEC 17025, and are to be acceptable to the classification societies.

4.1.2 The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.

4.1.3 The test facilities are to have equipment for controlling and measuring a methane gas in air concentration within a test vessel to an accuracy of ± 0.1%.

4.1.4 The test facilities are to be capable of effective point-located ignition of a methane gas in air mixture.

4.1.5 The pressure measuring equipment is to be capable of measuring the pressure in the test vessel in at least two positions, one at the valve and the other at the test vessel centre. The measuring arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognising the speed of events during an explosion. The result of each test is to be documented by video recording and by recording with a heat sensitive camera.

4.1.6 The test vessel for explosion testing is to have documented dimensions. The dimensions are to be such that the vessel is not “pipe like” with the distance between dished ends being not more than 2.5 times its diameter. The internal volume of the test vessel is to include any standpipe arrangements.

4.1.7 The test vessel is to be provided with a flange, located centrally at one end perpendicular to the vessel longitudinal axis, for mounting the explosion relief valve. The test vessel is to be arranged in an orientation consistent with how the valve will be installed in service, i.e., in the vertical plane or the horizontal plane.

4.1.8 A circular plate is to be provided for fitting between the pressure vessel flange and valve to be tested with the following dimensions:

a) Outside diameter of 2 times the outer diameter of the valve top cover.

b) Internal bore having the same internal diameter as the valve to be tested.
4.1.9 The test vessel is to have connections for measuring the methane in air mixture at the top and bottom.

4.1.10 The test vessel is to be provided with a means of fitting an ignition source at a position specified in item 5.3.

4.1.11 The test vessel volume is to be as far as practicable, related to the size and capability of the relief valve to be tested. In general, the volume is to correspond to the requirement in UR M9.3 for the free area of explosion relief valve to be not less than 115 cm$^2$/m$^3$ of crankcase gross volume.

Notes:

1. This means that the testing of a valve having 1150 cm$^2$ of free area, would require a test vessel with a volume of 10 m$^3$.

2. Where the free area of relief valves is greater than 115 cm$^2$/m$^3$ of the crankcase gross volume, the volume of the test vessel is to be consistent with the design ratio.

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

5. Explosion test process

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

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

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

5.4 The ignition is to be made using a maximum 100 joule explosive charge.

6. Valves to be tested

6.1 The valves used for type testing (including testing specified in item 6.3) are to be selected from the manufacturer’s normal production line for such valves by the classification society witnessing the tests.

6.2 For approval of a specific valve size, three valves are to be tested in accordance with 6.3 and 7. For a series of valves item 9 refers.

6.3 The valves selected for type testing are to have been previously tested at the manufacturer’s works to demonstrate that the opening pressure is in accordance with the specification within a tolerance of ± 20% and that the valve is air tight at a pressure below the opening pressure for at least 30 seconds.
Note:

This test is to verify that the valve is air tight following assembly at the manufacturer’s works and that the valve begins to open at the required pressure demonstrating that the correct spring has been fitted.

6.4 The type testing of valves is to recognise the orientation in which they are intended to be installed on the engine or gear case. Three valves of each size are to be tested for each intended installation orientation, i.e. in the vertical and/or horizontal positions.

7. Method

7.1 The following requirements are to be satisfied at explosion testing:

7.1.1 The explosion testing is to be witnessed by a classification society surveyor.

7.1.2 Where valves are to be installed on an engine or gear case with shielding arrangements to deflect the emission of explosion combustion products, the valves are to be tested with the shielding arrangements fitted.

7.1.3 Successive explosion testing to establish a valve’s functionality is to be carried out as quickly as possible during stable weather conditions.

7.1.4 The pressure rise and decay during all explosion testing is to be recorded.

7.1.5 The external condition of the valves is to be monitored during each test for indication of any flame release by video and heat sensitive camera.

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

7.2.1 Stage 1:

7.2.1.1 Two explosion tests are to be carried out in the test vessel with the circular plate described in 4.1.8 fitted and the opening in the plate covered by a 0.05mm thick polythene film.

Note:

These tests establish a reference pressure level for determination of the capability of a relief valve in terms of pressure rise in the test vessel, see 8.1.6.

7.2.2 Stage 2:

7.2.2.1 Two explosion tests are to be carried out on three different valves of the same size. Each valve is to be mounted in the orientation for which approval is sought i.e., in the vertical or horizontal position with the circular plate described in 4.1.8 located between the valve and pressure vessel mounting flange.
7.2.2.2 The first of the two tests on each valve is to be carried out with a 0.05mm thick polythene bag, having a minimum diameter of three times the diameter of the circular plate and volume not less than 30% of the test vessel, enclosing the valve and circular plate. Before carrying out the explosion test the polythene bag is to be empty of air. The polythene bag is required to provide a readily visible means of assessing whether there is flame transmission through the relief valve following an explosion consistent with the requirements of the standards identified in Section 2.

Note:

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

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

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

7.2.3 Stage 3:

7.2.3.1 Carry out two further explosion tests as described in Stage 1. These further tests are required to provide an average baseline value for assessment of pressure rise, recognising that the test vessel ambient conditions may have changed during the testing of the explosion relief valves in Stage 2.

8. Assessment and records

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

8.1.1 The valves to be tested are to have evidence of design appraisal/approval by the classification society witnessing tests.

8.1.2 The designation, dimensions and characteristics of the valves to be tested are to be recorded. This is to include the free area of the valve and of the flame arrester and the amount of valve lift at 0.2bar.

8.1.3 The test vessel volume is to be determined and recorded.
8.1.4 For acceptance of the functioning of the flame arrester there is not to be any indication of flame or combustion outside the valve during an explosion test. This should be confirmed by the test laboratory taking into account measurements from the heat sensitive camera.

8.1.5 The pressure rise and decay during an explosion is to be recorded, with indication of the pressure variation showing the maximum overpressure and steady under-pressure in the test vessel during testing. The pressure variation is to be recorded at two points in the pressure vessel.

8.1.6 The effect of an explosion relief valve in terms of pressure rise following an explosion is ascertained from maximum pressures recorded at the centre of the test vessel during the three stages. The pressure rise within the test vessel due to the installation of a relief valve is the difference between average pressure of the four explosions from Stages 1 and 3 and the average of the first tests on the three valves in Stage 2. The pressure rise is not to exceed the limit specified by the manufacturer.

8.1.7 The valve tightness is to be ascertained by verifying from the records at the time of testing that an underpressure of at least 0.3bar is held by the test vessel for at least 10 seconds following an explosion. This test is to verify that the valve has effectively closed and is reasonably gas-tight following dynamic operation during an explosion.

8.1.8 After each explosion test in Stage 2, the external condition of the flame arrester is to be examined for signs of serious damage and/or deformation that may affect the operation of the valve.

8.1.9 After completing the explosion tests, the valves are to be dismantled and the condition of all components ascertained and documented. In particular, any indication of valve sticking or uneven opening that may affect operation of the valve is to be noted. Photographic records of the valve condition are to be taken and included in the report.

9. Design series qualification

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

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

\[
\frac{n_1}{n_2} = \sqrt{\frac{S_1}{S_2}}
\]

(b) \[
\frac{A_1}{A_2} = \frac{S_1}{S_2}
\]
Where:

\[ n_1 = \text{total depth of flame arrester corresponding to the number of lamellas of size 1 quenching device for a valve with a relief area equal to } S_1 \]

\[ n_2 = \text{total depth of flame arrester corresponding to the number of lamellas of size 2 quenching device for a valve with a relief area equal to } S_2 \]

\[ A_1 = \text{free area of quenching device for a valve with a relief area equal to } S_1 \]

\[ A_2 = \text{free area of quenching device for a valve with a relief area equal to } S_2 \]

9.3 The qualification of explosion relief valves of larger sizes than that which has been previously satisfactorily tested in accordance with Sections 7 and 8 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

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

9.3.2 One valve of the largest size, subject to 9.3.1, requiring qualification is subject to satisfactory testing required by 6.3 and 7.2.2 except that a single valve will be accepted in 7.2.2.1 and the volume of the test vessel is not to be less than one third of the volume required by 4.1.11.

9.3.3 The assessment and records are to be in accordance with Section 8 noting that 8.1.6 will only be applicable to Stage 2 for a single valve.

9.4 The qualification of explosion relief valves of smaller sizes than that which has been previously satisfactorily tested in accordance with Sections 7 and 8 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

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

9.4.2 One valve of the smallest size, subject to 9.4.1, requiring qualification is subject to satisfactory testing required by 6.3 and 7.2.2 except that a single valve will be accepted in 7.2.2.1 and the volume of the test vessel is not to be more than the volume required by 4.1.11.

9.4.3 The assessment and records are to be in accordance with Section 8 noting that 8.1.6 will only be applicable to Stage 2 for a single valve.

10. The report

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

10.1.1 Test specification.

10.1.2 Details of test pressure vessel and valves tested.

10.1.3 The orientation in which the valve was tested, (vertical or horizontal position).
10.1.4 Methane in air concentration for each test.

10.1.5 Ignition source.

10.1.6 Pressure curves for each test.

10.1.7 Video recordings of each valve test.

10.1.8 The assessment and records stated in 8.

11. Approval

11.1 The approval of an explosion relief valve is at the discretion of individual classification societies based on the appraisal of plans and particulars and the test facility’s report of the results of type testing.
Type Testing Procedure for Crankcase Oil Mist Detection and Alarm Equipment

1. Scope

1.1 To specify the tests required to demonstrate that crankcase oil mist detection and alarm equipment intended to be fitted to diesel engines satisfy classification society requirements.

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

2. Recognised Standards

2.1 IACS Unified Requirement E10 Test Specification for Type Approval.

3. Purpose

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

3.1.1 To verify the functionality of the system.
3.1.2 To verify the effectiveness of the oil mist detectors.
3.1.3 To verify the accuracy of oil mist detectors.
3.1.4 To verify the alarm set points.
3.1.5 To verify time delays between oil mist leaving the source and alarm activation.
3.1.6 To verify functional failure detection.
3.1.7 To verify the influence of optical obscuration on detection.

Note:

1) Engines are to be fitted with crankcase oil mist detection and alarm equipment complying with this UR when:
   i) an application for certification of an engine is dated on/after 1 January 2007; or
   ii) installed in new ships for which the date of contract for construction is on or after 1 January 2007.
2) Rev.2 of this UR is to be uniformly implemented by IACS Societies from 1 July 2016.
3) The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.
4. Test facilities

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

4.1.1 A full range of facilities for carrying out the environmental and functionality tests required by this procedure shall be available and be acceptable to the classification societies.

4.1.2 The test house that verifies the functionality of the equipment is to be equipped so that it can control, measure and record oil mist concentration levels in terms of mg/l to an accuracy of ± 10% in accordance with this procedure.

4.1.3 When verifying the functionality, test houses are to consider the possible hazards associated with the generation of the oil mist required and take adequate precautions. IACS will accept the use of low toxicity, low hazard oils as used in other applications, provided it is demonstrated to have similar properties to SAE 40 monograde mineral oil specified.

5. Equipment testing

5.1 The range of tests is to include the following:

5.1.1 For the alarm/monitoring panel:

(a) Functional tests described in Section 6.

(b) Electrical power supply failure test.

(c) Power supply variation test.

(d) Dry heat test.

(e) Damp heat test.

(f) Vibration test.

(g) EMC test.

(h) Insulation resistance test.

(i) High voltage test.

(j) Static and dynamic inclinations, if moving parts are contained.

5.1.2 For the detectors:

(a) Functional tests described in Section 6.

(b) Electrical power supply failure test.

(c) Power supply variation test.

(d) Dry heat test.
(e) Damp heat test.

(f) Vibration test.

(g) EMC test where susceptible.

(h) Insulation resistance test.

(i) High voltage test.

(j) Static and dynamic inclinations.

6. Functional tests

6.1 All tests to verify the functionality of crankcase oil mist detection and alarm equipment are to be carried out in accordance with 6.2 to 6.6 with an oil mist concentration in air, known in terms of mg/l to an accuracy of ±10%.

6.2 The concentration of oil mist in the test chamber is to be measured in the top and bottom of the chamber and these concentrations are not to differ by more than 10%. See also 8.1.1.1.

6.3 The oil mist detector monitoring arrangements are to be capable of detecting oil mist in air concentrations of between

(a) 0 and 10% of the lower explosive limit (LEL) or

(b) between 0 and a percentage of weight of oil in air determined by the Manufacturer based on the sensor measurement method (e.g. obscuration or light scattering) that is acceptable to the Society taking into account the alarm level specified in 6.4.

Note: The LEL corresponds to an oil mist concentration of approximately 50mg/l (~4.1% weight of oil in air mixture).

6.4 The alarm set point for oil mist concentration in air is to provide an alarm at a maximum level corresponding to not more than 5% of the LEL or approximately 2.5mg/l.

6.5 Where alarm set points can be altered, the means of adjustment and indication of set points are to be verified against the equipment manufacturer’s instructions.

6.6 The performance of the oil mist detector in mg/l is to be demonstrated. This is to include the following:

• range (oil mist detector)

• resolution (oil mist detector)

• sensitivity (oil mist detector)

Note: Sensitivity of a measuring system: quotient of the change in an indication of a measuring system and the corresponding change in a value of a quantity being measured.
Resolution: smallest change in a quantity being measured that causes a perceptible change in the corresponding indication.

6.7 Where oil mist is drawn into a detector via piping arrangements, the time delay between the sample leaving the crankcase and operation of the alarm is to be determined for the longest and shortest lengths of pipes recommended by the manufacturer. The pipe arrangements are to be in accordance with the manufacturer's instructions/recommendations. Piping is to be arranged to prevent pooling of oil condensate which may cause a blockage of the sampling pipe over time.

6.8 It is to be demonstrated that the openings of detector equipment does not become occluded or blocked under continuous splash and spray of engine lubricating oil, as may occur in the crankcase atmosphere. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by the classification society. The temperature, quantity and angle of impact of the oil to be used is to be declared and their selection justified by the manufacturer.

6.9 Detector equipment may be exposed to water vapour from the crankcase atmosphere which may affect the sensitivity of the equipment and it is to be demonstrated that exposure to such conditions will not affect the functional operation of the detector equipment. Where exposure to water vapour and/or water condensation has been identified as a possible source of equipment malfunctioning, testing is to demonstrate that any mitigating arrangements such as heating are effective. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by the classification society.

Note:
This testing is in addition to that required by 5.1.2(e) and is concerned with the effects of condensation caused by the detection equipment being at a lower temperature than the crankcase atmosphere.

6.10 It is to be demonstrated that an indication is given where lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication as required by M10.16.

7. Detectors and alarm equipment to be tested

7.1 The detectors and alarm equipment selected for the type testing are to be selected from the manufacturer's normal production line by the classification society witnessing the tests.

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

8. Method

8.1 The following requirements are to be satisfied at type testing:

8.1.1 Oil mist generation is to satisfy 8.1.1.1 to 8.1.1.5.

8.1.1.1 The ambient temperature in and around the test chamber is to be at the standard atmospheric conditions defined in IACS Unified Requirement E10 Test Specification for Type Approval before any test run is started.
8.1.2 Oil mist is to be generated with suitable equipment using an SAE 40 monograde mineral oil or equivalent and supplied to a test chamber. The selection of the oil to be used is to take into consideration risks to health and safety, and the appropriate controls implemented. A low toxicity, low flammability oil of similar viscosity may be used as an alternative. The oil mist produced is to have an average (or arithmetic mean) droplet size not exceeding 5 µm. The oil droplet size is to be checked using the sedimentation method or an equivalent method to a relevant international or national standard. If the sedimentation method is chosen, the test chamber is to have a minimum height of 1m and volume of not less than 1m³.

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

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

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

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

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

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

8.2 For type approval by a classification society the testing is to be witnessed by authorised personnel from the classification society.

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

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

9. Assessment

9.1 Assessment of oil mist detection equipment after testing is to address the following:
9.1.1 The equipment to be tested is to have evidence of design appraisal/approval by the classification society witnessing tests.

9.1.2 Details of the detection equipment to be tested are to be recorded and are to include:
- name of manufacturer;
- type designation;
- oil mist concentration assessment capability and alarm settings;
- The maximum percentage level of lens obscuration used in 7.2.

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

10. Design series qualification

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

11. The report

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

11.1.1 Test specification.

11.1.2 Details of equipment tested.

11.1.3 Results of tests.

To include a declaration by the manufacturer of the oil mist detector of its:
- Performance, in mg/L;
- Accuracy, of oil mist concentration in air;
- Precision, of oil mist concentration in air;
- Range, of oil mist detector;
- Resolution, of oil mist detector;
- Response time, of oil mist detector;
- Sensitivity, of oil mist detector;
- Obscuration of sensor detection, declared as percentage of obscuration. 0% totally clean, 100% totally obscure;
- Detector failure alarm;
12. Acceptance

12.1 Acceptance of crankcase oil mist detection equipment is at the discretion of individual classification societies based on the appraisal plans and particulars and the test house report of the results of type testing.

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

12.2.1 Description of oil mist detection equipment and system including alarms.

12.2.2 Copy of the test house report identified in 11.

12.2.3 Schematic layout of engine oil mist detection arrangements showing location of detectors/sensors and piping arrangements and dimensions.

12.2.4 Maintenance and test manual which is to include the following information:

(a) Intended use of equipment and its operation.

(b) Functionality tests to demonstrate that the equipment is operational and that any faults can be identified and corrective actions notified.

(c) Maintenance routines and spare parts recommendations.

(d) Limit setting and instructions for safe limit levels.

(e) Where necessary, details of configurations in which the equipment is and is not to be used.
Dimensions of propulsion shafts and their permissible torsional vibration stresses

M68.1 Scope

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

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

Explicitly the following applications are not covered by this UR:

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

M68.2 Alternative calculation methods

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

Notes:

1. This UR M68 replaces URs M33, M37, M38, M39 and M48.
2. This UR M68 applies to ships contracted for construction on or after 1 July 2006.
3. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contracted for construction”, refer to IACS Procedural Requirement (PR) No.29.
4. Rev.1 of UR M68 applies to ships contracted for construction on or after 1 July 2015.
5. Rev.2 of UR M68 applies to ships contracted for construction on or after 1 January 2017.
Moreover, an alternative calculation method is to take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and for peak operating loads (dimensioning for yield strength). The fatigue strength analysis may be carried out separately for different load assumptions, for example as given in M68.7.1.

**M68.3 Material limitations**

Where shafts may experience vibratory stresses close to the permissible stresses for transient operation, the materials are to have a specified minimum ultimate tensile strength ($\sigma_B$) of 500 N/mm². Otherwise materials having a specified minimum ultimate tensile strength ($\sigma_B$) of 400 N/mm² may be used.

For use in the following formulae in this UR, $\sigma_B$ is limited as follows:

- For carbon and carbon manganese steels, a minimum specified tensile strength not exceeding 600 N/mm² for use in M68.5 and not exceeding 760 N/mm² in M68.4.
- For alloy steels, a minimum specified tensile strength not exceeding 800 N/mm².
- For propeller shafts in general a minimum specified tensile strength not exceeding 600 N/mm² (for carbon, carbon manganese and alloy steels).

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

**M68.4 Shaft diameters**

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

$$d = F \cdot k \cdot \left[ \frac{p}{n_0} \frac{1}{1 - \frac{d_i}{d_o}^4 \frac{\sigma_B + 160}{560}} \right]^{\frac{1}{3}}$$

where:

- $d =$ minimum required diameter in mm
- $d_i =$ actual diameter in mm of shaft bore
- $d_o =$ outside diameter in mm of shaft. If the bore of the shaft is $\leq 0.40d_o$, the expression $1 - \frac{d_i}{d_o}^4$ may be taken as 1.0
- $F =$ factor for type of propulsion installation
  - $= 95$ for intermediate shafts in turbine installation, diesel installations with hydraulic (slip type) couplings, electric propulsion installations
  - $= 100$ for all other diesel installations and all propeller shafts
k = factor for the particular shaft design features, see M68.6

n₀ = speed in revolutions per minute of shaft at rated power

p = rated power in kW transmitted through the shaft (losses in gearboxes and bearings are to be disregarded)

σ₄ = specified minimum tensile strength in N/mm² of the shaft material, see M68.3

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

M68.5 Permissible torsional vibration stresses

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

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

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

\[
\pm \tau_c = \sigma_B + \frac{160}{18} C_K C_D \cdot (3 - 2.\lambda^2) \quad \text{for } \lambda < 0.9
\]

\[
\pm \tau_c = \sigma_B + \frac{160}{18} C_K C_D \cdot 1.38 \quad \text{for } 0.9 \leq \lambda < 1.05
\]

where:

\(\tau_c\) = permissible stress amplitude in N/mm² due to torsional vibration for continuous operation

\(\sigma_B\) = specified minimum ultimate tensile strength in N/mm² of the shaft material, see also M68.3

\(C_K\) = factor for the particular shaft design features, see M68.6

\(C_D\) = size factor

\[= 0.35 + 0.93d_o^{-0.2}\]

\(d_o\) = shaft outside diameter in mm

\(\lambda\) = speed ratio = \(n/n_0\)
Where the stress amplitudes exceed the limiting values of $\tau_c$ for continuous operation, including one cylinder misfiring conditions if intended to be continuously operated under such conditions, restricted speed ranges are to be imposed which are to be passed through rapidly.

Restricted speed ranges in normal operating conditions are not acceptable above $\lambda = 0.8$.

Restricted speed ranges in one-cylinder misfiring conditions of single propulsion engine ships are to enable safe navigation.

The limits of the barred speed range are to be determined as follows:

(a) The barred speed range is to cover all speeds where the acceptance limits ($\tau_c$) are exceeded. For controllable pitch propellers with the possibility of individual pitch and speed control, both full and zero pitch conditions have to be considered. Additionally the tachometer tolerance has to be added. At each end of the barred speed range the engine is to be stable in operation.

(b) In general and subject to (a) the following formula may be applied, provided that the stress amplitudes at the border of the barred speed range are less than $\tau_c$ under normal and stable operating conditions.

$\frac{16. n_c}{18 - \lambda_c} \leq n \leq \frac{(18 - \lambda_c) n_c}{16}$

where:

$n_c = \text{critical speed in revolutions per minute (resonance speed)}$

$\lambda_c = \frac{n_c}{n_0}$

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

$\pm \tau_T = 1.7 \cdot \frac{\tau_c}{\sqrt{C_k}}$

where:

$\tau_T = \text{permissible stress amplitude in N/mm}^2 \text{ due to steady state torsional vibration in a barred speed range.}$
### M68.6  Table of $k$ and $c_k$ factors for different design features (see M68.7.2)

<table>
<thead>
<tr>
<th>Feature Description</th>
<th>Intermediate shafts with</th>
<th>thrust shafts external to engines</th>
<th>Propeller shafts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integral coupling flange 1) and straight sections</td>
<td>shrinking fit coupling 2)</td>
<td>Keyway, tapered connection 3) 4)</td>
<td>Keyway, cylindrical connection 3) 4)</td>
</tr>
<tr>
<td></td>
<td>radial hole 5)</td>
<td>longitudinal slot 6)</td>
<td>On both sides of thrust collar 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In way of bearing when a roller bearing is used</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flange mounted or keyless taper fitted propellers 8)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Key fitted propellers 8)</td>
<td>Between forward end of aft most bearing and forward stem tube seal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$k$</th>
<th>1.0</th>
<th>1.10</th>
<th>1.10</th>
<th>1.20</th>
<th>1.10</th>
<th>1.10</th>
<th>1.22</th>
<th>1.26</th>
<th>1.15</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c_k$</td>
<td>1.0</td>
<td>0.60</td>
<td>0.45</td>
<td>0.50</td>
<td>0.30</td>
<td>0.85</td>
<td>0.85</td>
<td>0.55</td>
<td>0.55</td>
</tr>
</tbody>
</table>

**Note:**

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

**Footnotes**

1) Fillet radius is not to be less than 0.08$d$.

2) $k$ and $c_k$ refer to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2% and a blending radius as described in the table note.

3) At a distance of not less than 0.2$d_o$ from the end of the keyway the shaft diameter may be reduced to the diameter calculated with $k=1.0$.

4) Keyways are in general not to be used in installations with a barred speed range.

5) Diameter of radial bore ($d_{rh}$) not to exceed 0.3$d_o$.

The intersection between a radial and an eccentric ($r_{ec}$) axial bore (see below) is not covered by this UR.
6) Subject to limitations as slot length \((l)/\text{outside diameter} < 0.8\) and inner diameter \((d_i)/\text{outside diameter} < 0.7\) and slot width \((e)/\text{outside diameter} > 0.15\). The end rounding of the slot is not to be less than \(e/2\). An edge rounding should preferably be avoided as this increases the stress concentration slightly. The \(k\) and \(c_K\) values are valid for 1, 2 and 3 slots, i.e. with slots at 360 respectively 180 and respectively 120 degrees apart.

7) \(c_K = 0.3\) is an approximation within the limitations in 6). More accurate estimate of the stress concentration factor \((scf)\) may be determined from M68.7.3 or by direct application of FE calculation. In which case:

\[c_K = \frac{1.45}{scf}\]

Note that the \(scf\) is defined as the ratio between the maximum local principal stress and \(\sqrt{3}\) times the nominal torsional stress (determined for the bored shaft without slots).

8) Applicable to the portion of the propeller shaft between the forward edge of the aftermost shaft bearing and the forward face of the propeller hub (or shaft flange), but not less than 2.5 times the required diameter.

**M68.7 Notes**

1. **Shafts complying with this UR satisfy the following:**

   1. Low cycle fatigue criterion (typically < \(10^4\)), i.e. the primary cycles represented by zero to full load and back to zero, including reversing torque if applicable. This is addressed by the formula in M68.4.

   2. High cycle fatigue criterion (typically >> \(10^7\)), i.e. torsional vibration stresses permitted for continuous operation as well as reverse bending stresses. The limits for torsional vibration stresses are given in M68.5. The influence of reverse bending stresses is addressed by the safety margins inherent in the formula in M68.4.

   3. The accumulated fatigue due to torsional vibration when passing through a barred speed range or any other transient condition with associated stresses beyond those permitted for continuous operation is addressed by the criterion for transient stresses in M68.5.
2. **Explanation of k and c\(_K\)**

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

- The stress concentration factors (scf) relative to the stress concentration for a flange with fillet radius of 0.08\(d_o\) (geometric stress concentration of approximately 1.45).

\[
C\_K = \frac{1.45}{\text{scf}} \quad \text{and} \quad k = \left[ \frac{\text{scf}}{1.45} \right]^x
\]

where the exponent \(x\) considers low cycle notch sensitivity.

- The notch sensitivity. The chosen values are mainly representative for soft steels (\(\sigma_B < 600\)), while the influence of steep stress gradients in combination with high strength steels may be underestimated.

- The size factor \(c\_D\) being a function of diameter only does not purely represent a statistical size influence, but rather a combination of this statistical influence and the notch sensitivity.

The actual values for \(k\) and \(c\_K\) are rounded off.

3. **Stress concentration factor of slots**

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

\[
\text{scf} = \alpha_{(\text{hole})} + 0.8 \cdot \frac{(l - e)/d}{\sqrt{\left(1 - \frac{d}{e}\right) \cdot \frac{e}{d}}}
\]

This formula applies to:

- slots at 120 or 180 or 360 degrees apart.

- slots with semicircular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula.

- slots with no edge rounding (except chamfering), as any edge rounding increases the scf slightly.

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

\[
\alpha_{(\text{hole})} = 2.3 - 3. \cdot \frac{e}{d} + 15 \left( \frac{e}{d} \right)^2 + 10 \left( \frac{e}{d} \right)^2 \left( \frac{d}{e} \right)^2
\]

or simplified to \(\alpha_{(\text{hole})} = 2.3\)
Appendix I

Special approval of alloy steel used for intermediate shaft material

1. Application

This appendix is applied to the approval of alloy steel which has a minimum specified tensile strength greater than 800 N/mm², but less than 950 N/mm² intended for use as intermediate shaft material.

2. Torsional fatigue test

A torsional fatigue test is to be performed to verify that the material exhibits similar fatigue life as conventional steels. The torsional fatigue strength of said material is to be equal to or greater than the permissible torsional vibration stress $\tau_C$ given by the formulae in M68.5.

The test is to be carried out with notched and unnotched specimens respectively. For calculation of the stress concentration factor of the notched specimen, fatigue strength reduction factor $\beta$ should be evaluated in consideration of the severest torsional stress concentration in the design criteria.

2.1 Test conditions

Test conditions are to be in accordance with Table 1. Mean surface roughness is to be $<0.2\mu m$ Ra with the absence of localised machining marks verified by visual examination at low magnification (x20) as required by Section 8.4 of ISO 1352.

Test procedures are to be in accordance with Section 10 of ISO 1352.

<table>
<thead>
<tr>
<th>Test condition</th>
<th>Loading type</th>
<th>Stress ratio</th>
<th>Load waveform</th>
<th>Evaluation</th>
<th>Number of cycles for test termination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>Torsion</td>
<td>R=-1</td>
<td>Constant-amplitude sinusoidal</td>
<td>S-N curve</td>
<td>$1 \times 10^7$ cycles</td>
</tr>
</tbody>
</table>

2.2 Acceptance criteria

Measured high-cycle torsional fatigue strength $\tau_{c1}$ and low-cycle torsional fatigue strength $\tau_{c2}$ are to be equal to or greater than the values given by the following formulae:

$$\tau_{c1} \geq \tau_{c1,\sigma=0} = \frac{\sigma_B + 160}{6} \cdot C_K \cdot C_D$$

$$\tau_{c2} \geq 1.7 \frac{1}{\sqrt{C_K}} \tau_{c1}$$
where

\[ C_K = \text{factor for the particular shaft design features, see M68.7} \]
\[ \text{scf} = \text{stress concentration factor, see M68.7.3 (For unnotched specimen, 1.0.)} \]
\[ C_D = \text{size factor, see M68.5} \]
\[ \sigma_B = \text{specified minimum tensile strength in N/mm}^2 \text{ of the shaft material} \]

3. Cleanliness requirements

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

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

**Table 2** Cleanliness requirements

<table>
<thead>
<tr>
<th>Inclusion group</th>
<th>Series</th>
<th>Limiting chart diagram index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A</td>
<td>Fine</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Thick</td>
<td>1</td>
</tr>
<tr>
<td>Type B</td>
<td>Fine</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Thick</td>
<td>1</td>
</tr>
<tr>
<td>Type C</td>
<td>Fine</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Thick</td>
<td>1</td>
</tr>
<tr>
<td>Type D</td>
<td>Fine</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Thick</td>
<td>1</td>
</tr>
<tr>
<td>Type DS</td>
<td>-</td>
<td>1</td>
</tr>
</tbody>
</table>

4. Inspection

The ultrasonic testing required by UR W7 is to be carried out prior to acceptance. The acceptance criteria are to be in accordance with IACS Recommendation No. 68 or a recognized national or international standard.
Qualitative Failure Analysis for Propulsion and Steering on Passenger Ships

1. **Scope**

Detailing a qualitative failure analysis for propulsion and steering for new passenger ships including those having a length of 120 m or more or having three or more main vertical zones.

2. **Note**

This may be considered as the first step for demonstrating compliance with the revised SOLAS Chapter II-2, Regulation 21 – SOLAS 2006 Amendments, Resolution MSC.216(82), annex 3.

3. **Objectives**

3.1 For ships having at least two independent means of propulsion and steering to comply with SOLAS requirements for a safe return to port, items (a) and (b) below are applicable:

(a) Provide knowledge of the effects of failure in all the equipment and systems due to fire in any space, or flooding of any watertight compartment that could affect the availability of the propulsion and steering.

(b) Provide solutions to ensure the availability of propulsion and steering upon such failures in item (a).

3.2 Ships not required to satisfy the safe return to port concept will require the analysis of failure in single equipment and fire in any space to provide knowledge and possible solutions for enhancing availability of propulsion and steering.

4. **Systems to be considered**

4.1 The qualitative failure analysis is to consider the propulsion and steering equipment and all its associated systems which might impair the availability of propulsion and steering.

4.2 The qualitative failure analysis should include:

(a) Propulsion and electrical power prime movers, e.g.,
   - Diesel engines
   - Electric motors

---

**Note:**

1. This UR is to be uniformly implemented by IACS Societies for Passenger Ships contracted for construction on or after 1 January 2010.

2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.
M69 (cont)

(b) Power transmission systems, e.g.,
- Shafting
- Bearings
- Power converters
- Transformers
- Slip ring systems

(c) Steering gear
- Rudder actuator or equivalent for azimuthing propulsor
- Rudder stock with bearings and seals
- Rudder
- Power unit and control gear
- Local control systems and indicators
- Remote control systems and indicators
- Communication equipment

(d) Propulsors, e.g.,
- Propeller
- Azimuthing thruster
- Water jet

(e) Main power supply systems, e.g.,
- Electrical generators and distribution systems
- Cable runs
- Hydraulic
- Pneumatic

(f) Essential auxiliary systems, e.g.,
- Compressed air
- Oil fuel
- Lubricating oil
- Cooling water
- Ventilation
- Fuel storage and supply systems

(g) Control and monitoring systems, e.g.,
- Electrical auxiliary circuits
- Power supplies
- Protective safety systems
- Power management systems
- Automation and control systems

(h) Support systems, e.g.,
- Lighting
- Ventilation

To consider the effects of fire or flooding in a single compartment, the analysis is to address the location and layout of equipment and systems.

5. **Failure Criteria**

5.1 Failures are deviations from normal operating conditions such as loss or malfunction of a component or system such that it cannot perform an intended or required function.
5.2 The qualitative failure analysis should be based on single failure criteria, (not two independent failures occurring simultaneously).

5.3 Where a single failure cause results in failure of more than one component in a system (common cause failure), all the resulting failures are to be considered together.

5.4 Where the occurrence of a failure leads directly to further failures, all those failures are to be considered together.

6. Verification of Solutions

6.1 The shipyard is to submit a report to class societies that identifies how the objectives have been addressed. The report is to include the following information:

(a) Identify the standards used for analysis of the design.

(b) Identify the objectives of the analysis.

(c) Identify any assumptions made in the analysis.

(d) Identify the equipment, system or sub-system, mode of operation of the equipment.

(e) Identify probable failure modes and acceptable deviations from the intended or required function.

(f) Evaluate the local effects (e.g. fuel injection failure) and the effects on the system as a whole (e.g. loss of propulsion power) of each failure mode as applicable.

(g) Identify trials and testing necessary to prove conclusions.

Note: All stakeholders (e.g., class, owners, shipyard and manufacturers) should as far as possible be involved in the development of the report.

6.2 The report is to be submitted prior to approval of detail design plans. The report may be submitted in two parts:

(a) A preliminary analysis as soon as the initial arrangements of different compartments and propulsion plant are known which can form the basis of discussion. This is to include a structured assessment of all essential systems supporting the propulsion plant after a failure in equipment, fire or flooding in any compartment casualty.

(b) A final report detailing the final design with a detailed assessment of any critical system identified in the preliminary report.

6.3 Verification of the report findings are to be agreed between the class society and the shipyard.
M71  Type Testing of I.C. Engines

1.  General

1.1  Type approval of I.C. engine types consists of drawing approval, specification approval, conformity of production, approval of type testing programme, type testing of engines, review of the obtained results, and the issuance of the Type Approval Certificate. The maximum period of validity of a Type Approval Certificate is 5 years. The requirements for drawing approval and specification approval of engines and components are specified in separate URs.

1.2  For the purpose of this UR, the following definitions apply:

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

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

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

2.  Objectives

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

2.2  This applies to:

- Parts subjected to high cycle fatigue (HCF) such as connecting rods, cams, rollers and spring tuned dampers where higher stresses may be provided by means of elevated injection pressure, cylinder maximum pressure, etc.

- Parts subjected to low cycle fatigue (LCF) such as “hot” parts when load profiles such as idle - full load - idle (with steep ramps) are frequently used.

- Operation of the engine at limits as defined by its specified alarm system, such as running at maximum permissible power with the lowest permissible oil pressure and/or highest permissible oil inlet temperature.

Notes:

1.  The requirements of UR M71 are to be uniformly implemented by IACS Societies for engines for which the date of application for type approval certification is dated on or after 1 July 2016.

2.  The “date of application for type approval” is the date of the document accepted by the Classification Society as request for type approval certification of a new engine type or of an engine type that has undergone substantive modifications in respect of the one previously type approved, or for renewal of an expired type approval certificate.
3. **Validity**

3.1 Type testing is required for every new engine type intended for installation onboard ships subject to classification.

3.2 A type test carried out for a particular type of engine at any place of manufacture will be accepted for all engines of the same type built by licensees or the licensor, subject to each place of manufacture being found to be acceptable to the Society.

3.3 A type of engine is defined by:

- bore and stroke
- injection method (direct or indirect)
- valve and injection operation (by cams or electronically controlled)
- kind of fuel (liquid, dual-fuel, gaseous)
- working cycle (4-stroke, 2-stroke)
- turbo-charging system (pulsating or constant pressure)
- the charging air cooling system (e.g. with or without intercooler)
- cylinder arrangement (in-line or V) ¹)
- cylinder power, speed and cylinder pressures ²)

**Notes:**

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

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

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

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

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

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

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

* Only crankshaft calculation and crankshaft drawings, if modified.

**De-rated engine**

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

- Test at over speed (only if nominal speed has increased)
- Rated power, i.e. 100% output at 100% torque and 100% speed corresponding to load point 1., 2 measurements with one running hour in between
- Maximum permissible torque (normally 110%) at 100% speed corresponding to load point 3 or maximum permissible power (normally 110%) and speed according to nominal propeller curve corresponding to load point 3a., ½ hour
- 100% power at maximum permissible speed corresponding to load point 2, ½ hour

**Integration Test**

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

### 4. Safety precautions

4.1 Before any test run is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer/shipyard and is to be operational, and its correct functioning is to be verified.

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

4.3 The inspection for jacketing of high-pressure fuel oil lines and proper screening of pipe connections (as required in M71.8.9 fire measures) is also to be carried out before the test runs.

4.4 Interlock test of turning gear is to be performed when installed.

### 5. Test programme

5.1 The type testing is divided into 3 stages:

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

2. Stage B - witnessed tests.
   This is the testing made in the presence of Classification Society personnel.

3. Stage C - component inspection.
   This is the inspection of engine parts to the extent as required by the Society.

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

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

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

   - overall description of tests performed during stage A. Records are to be kept by the builders QA management for presentation to the Classification Society.

   - detailed description of the load and functional tests conducted during stage B.

   - inspection results from stage C.

5.5 As required in M71.2 the type testing is to substantiate the capability of the design and its suitability for the intended operation. Special testing such as LCF and endurance testing will normally be conducted during stage A.

5.6 High speed engines for marine use are normally to be subjected to an endurance test of 100 hours at full load. Omission or simplification of the type test may be considered for the type approval of engines with long service experience from non-marine fields or for the extension of type approval of engines of a well-known type, in excess of the limits given in M71.3.

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

6. Measurements and recordings

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

6.2 As a minimum, the following engine data are to be measured and recorded:

   - Engine r.p.m.

   - Torque

   - Maximum combustion pressure for each cylinder ¹)

   - Mean indicated pressure for each cylinder ¹)
- Charging air pressure and temperature
- Exhaust gas temperature
- Fuel rack position or similar parameter related to engine load
- Turbocharger speed
- All engine parameters that are required for control and monitoring for the intended use (propulsion, auxiliary, emergency).

Notes:

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

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

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

7. Stage A - internal tests

7.1 During the internal tests, the engine is to be operated at the load points important for the engine designer and the pertaining operating values are to be recorded. The load conditions to be tested are also to include the testing specified in the applicable type approval programme.

7.2 At least the following conditions are to be tested:
- Normal case:

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

- The limit points of the permissible operating range. These limit points are to be defined by the engine manufacturer.

- For high speed engines, the 100 hr full load test and the low cycle fatigue test apply as required in connection with the design assessment.

- Specific tests of parts of the engine, required by the Society or stipulated by the designer.
8. **Stage B - witnessed tests**

8.1 The tests listed below are to be carried out in the presence of a Surveyor. The achieved results are to be recorded and signed by the attending Surveyor after the type test is completed.

8.2 The over-speed test is to be carried out and is to demonstrate that the engine is not damaged by an actual engine overspeed within the overspeed shutdown system set-point. This test may be carried out at the manufacturer’s choice either with or without load during the speed overshoot.

8.3 **Load points**

The engine is to be operated according to the power and speed diagram (see Figure 1). The data to be measured and recorded when testing the engine at the various load points have to include all engine parameters listed in M71.6. The operating time per load point depends on the engine size (achievement of steady state condition) and on the time for collection of the operating values. Normally, an operating time of 0.5 hour can be assumed per load point, however sufficient time should be allowed for visual inspection by the Surveyor.

8.4 **The load points are:**

- Rated power (MCR), i.e. 100% output at 100% torque and 100% speed corresponding to load point 1, normally for 2 hours with data collection with an interval of 1 hour. If operation of the engine at limits as defined by its specified alarm system (e.g. at alarm levels of lub oil pressure and inlet temperature) is required, the test should be made here.

- 100% power at maximum permissible speed corresponding to load point 2.

- Maximum permissible torque (at least and normally 110%) at 100% speed corresponding to load at point 3, or maximum permissible power (at least and normally 110%) and 103.2% speed according to the nominal propeller curve corresponding to load point 3a. Load point 3a applies to engines only driving fixed pitch propellers or water jets. Load point 3 applies to all other purposes. Load point 3 (or 3a as applicable) is to be replaced with a load that corresponds to the specified overload and duration approved for intermittent use. This applies where such overload rating exceeds 110% of MCR. Where the approved intermittent overload rating is less than 110% of MCR, subject overload rating has to replace the load point at 100% of MCR. In such case the load point at 110% of MCR remains.

- Minimum permissible speed at 100% torque, corresponding to load point 4.

- Minimum permissible speed at 90% torque corresponding to load point 5. (Applicable to propulsion engines only).

- Part loads e.g. 75%, 50% and 25% of rated power and speed according to nominal propeller curve (i.e. 90.8%, 79.3% and 62.9% speed) corresponding to points 6, 7 and 8 or at constant rated speed setting corresponding to points 9, 10 and 11, depending on the intended application of the engine.

- Crosshead engines not restricted for use with C.P. propellers are to be tested with no load at the associated maximum permissible engine speed.
8.5 During all these load points, engine parameters are to be within the specified and approved values.

![Diagram of load points](image)

- **1** = range of continuous operation
- **2** = range of intermittent operation
- **3** = range of short-time overload operation

**Figure 1 Load points**

8.6 Operation with damaged turbocharger

For 2-stroke propulsion engines, the achievable continuous output is to be determined in the case of turbocharger damage.

Engines intended for single propulsion with a fixed pitch propeller are to be able to run continuously at a speed (r.p.m.) of 40% of full speed along the theoretical propeller curve when one turbocharger is out of operation. (The test can be performed by either by-passing the turbocharger, fixing the turbocharger rotor shaft or removing the rotor.)
8.7 Functional tests

- Verification of the lowest specified propulsion engine speed according to the nominal propeller curve as specified by the engine designer (even though it works on a water-brake). During this operation, no alarm shall occur.

- Starting tests, for non-reversible engines and/or starting and reversing tests, for reversible engines, for the purpose of determining the minimum air pressure and the consumption for a start.

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

8.8 Integration test

For electronically controlled diesel engines, integration tests are to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes. The scope of these tests is to be agreed with the Society for selected cases based on the FMEA required in UR M44.

8.9 Fire protection measures

Verification of compliance with requirements for jacketing of high-pressure fuel oil lines, screening of pipe connections in piping containing flammable liquids and insulation of hot surfaces:

- The engine is to be inspected for jacketing of high-pressure fuel oil lines, including the system for the detection of leakage, and proper screening of pipe connections in piping containing flammable liquids.

- Proper insulation of hot surfaces is to be verified while running the engine at 100% load, alternatively at the overload approved for intermittent use. Readings of surface temperatures are to be done by use of Infrared Thermoscanning Equipment. Equivalent measurement equipment may be used when so approved by the Society. Readings obtained are to be randomly verified by use of contact thermometers.

9. Stage C - Opening up for Inspections

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

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

9.3 For all the other engines, after the test run the components of one cylinder for in-line engines and two cylinders for V-engines are to be presented for inspection as follows (engines with long service experience from non-marine fields can have a reduced extent of opening):

- piston removed and dismantled
- crosshead bearing dismantled
- guide planes
- connecting rod bearings (big and small end) dismantled (special attention to serrations and fretting on contact surfaces with the bearing backsides)

- main bearing dismantled

- cylinder liner in the installed condition

- cylinder head, valves disassembled

- cam drive gear or chain, camshaft and crankcase with opened covers. (The engine must be turnable by turning gear for this inspection.)

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

9.5 If deemed necessary by the surveyor, further dismantling of the engine may be required.
Certification of Engine Components

1. General

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

1.2 Society Certificate (SC)

This is a document issued by the Society stating:

- conformity with Rule requirements.
- that the tests and inspections have been carried out on the certified product itself, or on samples taken from the certified product itself.
- that the inspection and tests were performed in the presence of the Surveyor or in accordance with special agreements, i.e. ACS.

1.3 Work’s Certificate (W)

This is a document signed by the manufacturer stating:

- conformity with requirements.
- that the tests and inspections have been carried out on the certified product itself, or on samples taken from the raw material, used for the product to be certified.
- that the tests were witnessed and signed by a qualified representative of the applicable department of the manufacturer.

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

- the test was witnessed by the Society Surveyor; or
- an Alternative Certification Scheme (ACS) agreement is in place between the Class Society and the manufacturer or material supplier; or
- the Work’s certificate is supported by tests carried out by an accredited third party that is accepted by the Society and independent from the manufacturer and/or material supplier.

Note:

1. The requirements of UR M72 are to be uniformly implemented by IACS Societies to engines with an application for certification dated on or after 1 July 2016.

2. Rev.1 of this UR is to be uniformly implemented by IACS Societies to engines with an application for certification dated on or after 1 July 2017.
1.4 Test Report (TR)

This is a document signed by the manufacturer stating:
- conformity with requirements.
- that the tests and inspections have been carried out on samples from the current production.

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

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

1.7 The manufacturer is not exempted from responsibility for any relevant tests and inspections of those parts for which documentation is not explicitly requested by the Society. Manufacturing works is to be equipped in such a way that all materials and components can be consistently produced to the required standard. This includes production and assembly lines, machining units, special tools and devices, assembly and testing rigs as well as all lifting and transportation devices.

2. Parts to be documented

2.1 The extent of parts to be documented depends on the type of engine, engine size and criticality of the part.

2.2 Symbols used are listed in Table M72.1. A summary of the required documentation for the engine components is listed in Table M72.2.

M72.1 Symbols used in Table M72.2

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>chemical composition</td>
</tr>
<tr>
<td>CD</td>
<td>crack detection by MPI or DP</td>
</tr>
<tr>
<td>CH</td>
<td>crosshead engines</td>
</tr>
<tr>
<td>D</td>
<td>cylinder bore diameter (mm)</td>
</tr>
<tr>
<td>GJL</td>
<td>gray cast iron</td>
</tr>
<tr>
<td>GJS</td>
<td>spheroidal graphite cast iron</td>
</tr>
<tr>
<td>GS</td>
<td>cast steel</td>
</tr>
<tr>
<td>M</td>
<td>mechanical properties</td>
</tr>
<tr>
<td>SC</td>
<td>society certificate</td>
</tr>
<tr>
<td>TR</td>
<td>test report</td>
</tr>
<tr>
<td>UT</td>
<td>ultrasonic testing</td>
</tr>
<tr>
<td>W</td>
<td>work certificate</td>
</tr>
<tr>
<td>X</td>
<td>visual examination of accessible surfaces by the Surveyor</td>
</tr>
</tbody>
</table>

2.3 For components and materials not specified in Table M72.2, consideration will be given by the Society upon full details being submitted and reviewed.
## M72.2 Summary of required documentation for engine components

<table>
<thead>
<tr>
<th>Part 4), 5), 6), 7)</th>
<th>Material properties 1)</th>
<th>Non-destructive examination 2)</th>
<th>Hydraulic testing 3)</th>
<th>Dimensional inspection, including surface condition</th>
<th>Visual inspection (surveyor)</th>
<th>Applicable to engines:</th>
<th>Component certificate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welded bedplate</td>
<td>W(C+M)</td>
<td>W(UT+CD)</td>
<td></td>
<td>fit-up + post-welding</td>
<td></td>
<td>All</td>
<td>SC</td>
</tr>
<tr>
<td>Bearing transverse</td>
<td>W(C+M)</td>
<td>W(UT+CD)</td>
<td></td>
<td>X</td>
<td></td>
<td>All</td>
<td>SC</td>
</tr>
<tr>
<td>girders GS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welded frame box</td>
<td>W(C+M)</td>
<td>W(UT+CD)</td>
<td></td>
<td>fit-up + post-welding</td>
<td></td>
<td>All</td>
<td>SC</td>
</tr>
<tr>
<td>Cylinder block GJL</td>
<td></td>
<td></td>
<td>W(9)</td>
<td></td>
<td></td>
<td>CH</td>
<td></td>
</tr>
<tr>
<td>Cylinder block GJS</td>
<td></td>
<td></td>
<td>W(9)</td>
<td></td>
<td></td>
<td>CH</td>
<td></td>
</tr>
<tr>
<td>Welded cylinder frames</td>
<td></td>
<td></td>
<td>W(9)</td>
<td>fit-up + post-welding</td>
<td></td>
<td>All</td>
<td>SC</td>
</tr>
<tr>
<td>Engine block GJL</td>
<td></td>
<td>W(9)</td>
<td></td>
<td></td>
<td></td>
<td>All</td>
<td>SC</td>
</tr>
<tr>
<td>Engine block GJS</td>
<td>W(M)</td>
<td>W(9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylinder liner</td>
<td>W(C+M)</td>
<td>W(9)</td>
<td></td>
<td></td>
<td></td>
<td>D&gt;300mm</td>
<td></td>
</tr>
<tr>
<td>Cylinder head GJL</td>
<td></td>
<td>W</td>
<td></td>
<td></td>
<td></td>
<td>D&gt;300mm</td>
<td></td>
</tr>
<tr>
<td>Cylinder head GJS</td>
<td></td>
<td>W</td>
<td></td>
<td></td>
<td></td>
<td>D&gt;300mm</td>
<td></td>
</tr>
<tr>
<td>Cylinder head GS</td>
<td>W(C+M)</td>
<td>W(UT+CD)</td>
<td>W</td>
<td></td>
<td></td>
<td>D&gt;300mm</td>
<td>SC</td>
</tr>
<tr>
<td>Forged cylinder head</td>
<td>W(C+M)</td>
<td>W(UT+CD)</td>
<td>W</td>
<td>X</td>
<td></td>
<td>D&gt;300mm</td>
<td>SC</td>
</tr>
<tr>
<td>Piston crown GS</td>
<td>W(C+M)</td>
<td>W(UT+CD)</td>
<td>W</td>
<td>X</td>
<td></td>
<td>D&gt;400mm</td>
<td>SC</td>
</tr>
<tr>
<td>Forged piston crown</td>
<td>W(C+M)</td>
<td>W(UT+CD)</td>
<td>W</td>
<td>X</td>
<td></td>
<td>D&gt;400mm</td>
<td>SC</td>
</tr>
<tr>
<td>Crankshaft: made in</td>
<td>SC(C+M)</td>
<td>W(UT+CD)</td>
<td>W</td>
<td>Random, of fillets and oil bores</td>
<td></td>
<td>All</td>
<td>SC</td>
</tr>
<tr>
<td>one piece</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi-built</td>
<td>See below</td>
<td>See below</td>
<td>See below</td>
<td>See below</td>
<td></td>
<td>All</td>
<td>SC</td>
</tr>
<tr>
<td>crankshaft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crank throw</td>
<td>SC(C+M)</td>
<td>W(UT+CD)</td>
<td>W</td>
<td>Random, of fillets and shrink fittings</td>
<td></td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>Forged main journal</td>
<td>SC(C+M)</td>
<td>W(UT+CD)</td>
<td>W</td>
<td>Random, of shrink fittings</td>
<td></td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>and journals with</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>flange</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### M72.2 Summary of required documentation for engine components (continued)

<table>
<thead>
<tr>
<th>Part 4), 5), 6), 7)</th>
<th>Material properties 1)</th>
<th>Non-destructive examination 2)</th>
<th>Hydraulic testing 3)</th>
<th>Dimensional inspection, including surface condition</th>
<th>Visual inspection (surveyor)</th>
<th>Applicable to engines:</th>
<th>Component certificate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust gas valve cage</td>
<td>SC(C+M)</td>
<td>W(UT+CD) CD again after final machining (grinding)</td>
<td>W</td>
<td>Random</td>
<td></td>
<td>CH</td>
<td></td>
</tr>
<tr>
<td>Piston rod, if applicable</td>
<td>SC(C+M)</td>
<td>W(UT+CD) CD again after final machining (grinding)</td>
<td></td>
<td>Random</td>
<td>D&gt;400mm</td>
<td></td>
<td>SC</td>
</tr>
<tr>
<td>Cross head</td>
<td>SC(C+M)</td>
<td>W(UT+CD) CD again after final machining (grinding and polishing)</td>
<td></td>
<td>Random</td>
<td></td>
<td>CH</td>
<td>SC</td>
</tr>
<tr>
<td>Connecting rod with cap</td>
<td>SC(C+M)</td>
<td>W(UT+CD)</td>
<td>W</td>
<td>Random, of all surfaces, in particular those shot peened</td>
<td></td>
<td>All</td>
<td>SC</td>
</tr>
<tr>
<td>Coupling bolts for crankshaft</td>
<td>SC(C+M)</td>
<td>W(UT+CD)</td>
<td>W</td>
<td>Random, of interference fit</td>
<td></td>
<td>All</td>
<td>SC</td>
</tr>
<tr>
<td>Bolts and studs for main bearings</td>
<td>W(C+M)</td>
<td>W(UT+CD)</td>
<td>W</td>
<td></td>
<td></td>
<td>D&gt;300mm</td>
<td></td>
</tr>
<tr>
<td>Bolts and studs for cylinder heads</td>
<td>W(C+M)</td>
<td>W(UT+CD)</td>
<td></td>
<td></td>
<td></td>
<td>D&gt;300mm</td>
<td></td>
</tr>
<tr>
<td>Bolts and studs for connecting rods</td>
<td>W(C+M)</td>
<td>W(UT+CD)</td>
<td>TR of thread making</td>
<td></td>
<td></td>
<td>D&gt;300mm</td>
<td></td>
</tr>
<tr>
<td>Tie rod</td>
<td>W(C+M)</td>
<td>W(UT+CD)</td>
<td>TR of thread making</td>
<td></td>
<td></td>
<td>CH</td>
<td>SC</td>
</tr>
<tr>
<td>High pressure fuel injection pump body</td>
<td>W</td>
<td>TR</td>
<td></td>
<td></td>
<td></td>
<td>D&gt;300mm</td>
<td></td>
</tr>
<tr>
<td>High pressure fuel injection valves (only for those not autofretted)</td>
<td>W</td>
<td>TR</td>
<td></td>
<td></td>
<td></td>
<td>D&gt;300mm</td>
<td>D≤300mm</td>
</tr>
</tbody>
</table>
### M72.2 Summary of required documentation for engine components (continued)

<table>
<thead>
<tr>
<th>Part 4), 5), 6), 7)</th>
<th>Material properties 1)</th>
<th>Non-destructive examination 2)</th>
<th>Hydraulic testing 3)</th>
<th>Dimensional inspection, including surface condition</th>
<th>Visual inspection (surveyor)</th>
<th>Applicable to engines:</th>
<th>Component certificate</th>
</tr>
</thead>
<tbody>
<tr>
<td>High pressure fuel injection pipes including common fuel rail</td>
<td>W(C+M)</td>
<td>W for those that are not autofretted</td>
<td>TR for those that are not autofretted</td>
<td></td>
<td></td>
<td>D&gt;300mm</td>
<td>D≤300mm</td>
</tr>
<tr>
<td>High pressure common servo oil system</td>
<td>W(C+M)</td>
<td>W</td>
<td></td>
<td></td>
<td></td>
<td>D&gt;300mm</td>
<td>D≤300mm</td>
</tr>
<tr>
<td>Cooler, both sides 8)</td>
<td>W(C+M)</td>
<td>W</td>
<td></td>
<td></td>
<td></td>
<td>D&gt;300mm</td>
<td></td>
</tr>
<tr>
<td>Accumulator of common rail fuel or servo oil system</td>
<td>W(C+M)</td>
<td>W</td>
<td></td>
<td></td>
<td></td>
<td>D&gt;300mm</td>
<td>All engines with accumulators with a capacity of &gt;0,5 l</td>
</tr>
<tr>
<td>Piping, pumps, actuators, etc. for hydraulic drive of valves, if applicable</td>
<td>W(C+M)</td>
<td>W</td>
<td></td>
<td></td>
<td></td>
<td>&gt;800 kW/cyl</td>
<td></td>
</tr>
<tr>
<td>Engine driven pumps (oil, water, fuel, bilge)</td>
<td></td>
<td>W</td>
<td></td>
<td></td>
<td></td>
<td>&gt;800 kW/cyl</td>
<td></td>
</tr>
<tr>
<td>Bearings for main, crosshead, and crankpin</td>
<td>TR(C)</td>
<td>TR (UT for full contact between basic material and bearing metal)</td>
<td>W</td>
<td></td>
<td></td>
<td>&gt;800 kW/cyl</td>
<td></td>
</tr>
</tbody>
</table>
1. Material properties include chemical composition and mechanical properties, and also surface treatment such as surface hardening (hardness, depth and extent), peening and rolling (extent and applied force).

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

3. Hydraulic testing is applied on the water/oil side of the component. Items are to be tested by hydraulic pressure at the pressure equal to 1.5 times the maximum working pressure. High pressure parts of the fuel injection system are to be tested by hydraulic pressure at the pressure equal to 1.5 maximum working pressure or maximum working pressure plus 300 bar, whichever is the less. Where design or testing features may require modification of these test requirements, special consideration may be given.

4. For turbochargers, see M73.

5. Crankcase safety valves are to be type tested in accordance with M66 and documented according to M9.

6. Oil mist detection systems are to be type tested in accordance with M67 and documented according to M10.

7. For Speed governor and overspeed protective devices, see M3.

8. Charge air coolers need only be tested on the water side.

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

1. Scope

1.1 These requirements are applicable for turbochargers with regard to design approval, type testing and certification and their matching on engines. Turbochargers are to be type approved, either separately or as a part of an engine. The requirements are written for exhaust gas driven turbochargers, but apply in principle also for engine driven chargers.

1.2 The requirements escalate with the size of the turbochargers. The parameter for size is the engine power (at MCR) supplied by a group of cylinders served by the actual turbocharger, (e.g. for a V-engine with one turbocharger for each bank the size is half of the total engine power).

1.3 Turbochargers are categorised in three groups depending on served power by cylinder groups with:

- Category A: ≤ 1000 kW
- Category B: > 1000 kW and ≤ 2500 kW
- Category C: > 2500 kW

2. Documentation to be submitted

2.1 Category A:

On request

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

Notes:

1. The requirements of UR M73, except for M73.4, are to be uniformly implemented by IACS Societies to turbochargers with the date of application for certification of the new turbocharger type on or after 1 July 2016.

The requirements of M73.4 are to be uniformly implemented by IACS Societies to turbochargers with the date of application for certification of an individual turbocharger on or after 1 July 2016.

2. The “date of application for certification” is the date of whatever document the Classification Society requires/accepts as an application or request for certification of a turbocharger.
2.2 Category B and C:

- Cross sectional drawing with principal dimensions and materials of housing components for containment evaluation.

- Documentation of containment in the event of disc fracture, see M73.3.2.

- Operational data and limitations as:

  - Maximum permissible operating speed (rpm)

  - Alarm level for over-speed

  - Maximum permissible exhaust gas temperature before turbine

  - Alarm level for exhaust gas temperature before turbine

  - Minimum lubrication oil inlet pressure

  - Lubrication oil inlet pressure low alarm set point

  - Maximum lubrication oil outlet temperature

  - Lubrication oil outlet temperature high alarm set point

  - Maximum permissible vibration levels, i.e. self- and externally generated vibration

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

  - Arrangement of lubrication system, all variants within a range.

  - Type test reports.

  - Test program.

2.3 Category C:

- Drawings of the housing and rotating parts including details of blade fixing.

- Material specifications (chemical composition and mechanical properties) of all parts mentioned above.

- Welding details and welding procedure of above mentioned parts, if applicable.

- Documentation\(^1\) of safe torque transmission when the disc is connected to the shaft by an interference fit, see M73.3.3.

- Information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue.

- Operation and maintenance manuals\(^1\).

\(^1\)Applicable to two sizes in a generic range of turbochargers.
3. Design requirements and corresponding type testing

3.1 General

3.1.1 The turbochargers shall be designed to operate under conditions given in M46 and M28. The component lifetime and the alarm level for speed shall be based on 45°C air inlet temperature.

3.1.2 The air inlet of turbochargers shall be fitted with a filter.

3.2 Containment

3.2.1 Turbochargers shall fulfil containment in the event of a rotor burst. This means that at a rotor burst no part may penetrate the casing of the turbocharger or escape through the air intake. For documentation purposes (test/calculation), it shall be assumed that the discs disintegrate in the worst possible way.

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

3.3.3 The minimum test speeds, relative to the maximum permissible operating speed, are:

- For the compressor: 120%.
- For the turbine: 140% or the natural burst speed, whichever is lower.

3.2.4 Containment tests shall be performed at working temperature.

3.2.5 A numerical analysis (simulation) of sufficient containment integrity of the casing based on calculations by means of a simulation model may be accepted in lieu of the practical containment test, provided that:

- The numerical simulation model has been tested and its suitability/accuracy has been proven by direct comparison between calculation results and the practical containment test for a reference application (reference containment test). This test shall be performed at least once by the manufacturer for acceptance of the numerical simulation method in lieu of tests.

- The corresponding numerical simulation for the containment is performed for the same speeds as specified for the containment test.

- Material properties for high-speed deformations are to be applied in the numeric simulation. The correlation between normal properties and the properties at the pertinent deformation speed are to be substantiated.

- The design of the turbocharger regarding geometry and kinematics is similar to the turbocharger that was used for the reference containment test. In general, totally new designs will call for a new reference containment test.

**) A generic range means a series of turbocharger which are of the same design, but scaled to each other.
3.3 **Disc-shaft shrinkage fit**

3.3.1 Applicable to Category C

3.3.2 In cases where the disc is connected to the shaft with interference fit, calculations shall substantiate safe torque transmission during all relevant operating conditions such as maximum speed, maximum torque and maximum temperature gradient combined with minimum shrinkage amount.

3.4 **Type testing**

3.4.1 Applicable to Categories B and C

3.4.2 The type test for a generic range of turbochargers may be carried out either on an engine (for which the turbocharger is foreseen) or in a test rig.

3.4.3 Turbochargers are to be subjected to at least 500 load cycles at the limits of operation. This test may be waived if the turbocharger together with the engine is subjected to this kind of low cycle testing, see M71.

3.4.4 The suitability of the turbocharger for such kind of operation is to be preliminarily stated by the manufacturer.

3.4.5 The rotor vibration characteristics shall be measured and recorded in order to identify possible sub-synchronous vibrations and resonances.

3.4.6 The type test shall be completed by a hot running test at maximum permissible speed combined with maximum permissible temperature for at least one hour. After this test, the turbocharger shall be opened for examination, with focus on possible rubbing and the bearing conditions.

3.4.7 The extent of the surveyor’s presence during the various parts of the type tests is left to the discretion of each Society.

4. **Certification**

4.1 The manufacturer shall adhere to a quality system designed to ensure that the designer’s specifications are met, and that manufacturing is in accordance with the approved drawings.

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

4.3 These audits shall focus on:

- Chemical composition of material for the rotating parts.
- Mechanical properties of the material of a representative specimen for the rotating parts and the casing.
- UT and crack detection of rotating parts.
- Dimensional inspection of rotating parts.
- Rotor balancing.
• Hydraulic testing of cooling spaces to 4 bars or 1.5 times maximum working pressure, whichever is higher.

• Overspeed test of all compressor wheels for a duration of 3 minutes at either 20% above alarm level speed at room temperature or 10% above alarm level speed at 45°C inlet temperature when tested in the actual housing with the corresponding pressure ratio. The overspeed test may be waived for forged wheels that are individually controlled by an approved non-destructive method.

4.4 Turbochargers shall be delivered with:

• For category C, a society certificate, which at a minimum cites the applicable type approval and the ACS, when ACS applies.

• For category B, a work’s certificate, which at a minimum cites the applicable type approval, which includes production assessment.

4.5 The same applies to replacement of rotating parts and casing.

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

5. Alarms & Monitoring

5.1 For all turbochargers of Categories B and C, indications and alarms as listed in the table are required.

5.2 Indications may be provided at either local or remote locations.

<table>
<thead>
<tr>
<th>Pos.</th>
<th>Monitored Parameters</th>
<th>Category of Turbochargers</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alarm</td>
<td>Indication</td>
</tr>
<tr>
<td>1</td>
<td>Speed</td>
<td>High&lt;sup&gt;(4)&lt;/sup&gt;</td>
<td>X&lt;sup&gt;(4)&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>Exhaust gas at each turbocharger inlet, temperature</td>
<td>high&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>X&lt;sup&gt;(1)&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>Lub. oil at turbocharger outlet, temperature</td>
<td></td>
<td>high</td>
</tr>
<tr>
<td>4</td>
<td>Lub. oil at turbocharger inlet, pressure</td>
<td>low</td>
<td>X</td>
</tr>
</tbody>
</table>

(1) For Category B turbochargers, the exhaust gas temperature may be alternatively monitored at the turbocharger outlet, provided that the alarm level is set to a safe level for the turbine and that correlation between inlet and outlet temperatures is substantiated.

(2) Alarm and indication of the exhaust gas temperature at turbocharger inlet may be waived if alarm and indication for individual exhaust gas temperature is provided for each cylinder and the alarm level is set to a value safe for the turbocharger.
(3) Separate sensors are to be provided if the lubrication oil system of the turbocharger is not integrated with the lubrication oil system of the diesel engine or if it is separated by a throttle or pressure reduction valve from the diesel engine lubrication oil system.

(4) On turbocharging systems where turbochargers are activated sequentially, speed monitoring is not required for the turbocharger(s) being activated last in the sequence, provided all turbochargers share the same intake air filter and they are not fitted with waste gates.
**Installation of Ballast Water Management Systems**

1. **Application**

   In addition to the requirements contained in BWM Convention (2004), the following requirements are applied to the installation of Ballast Water Management Systems.

2. **Definitions**

   2.1 Ballast Water Management System (hereinafter referred to as ‘BWMS’) means any system which processes ballast water such that it meets or exceeds the Ballast Water Performance Standard in Regulation D-2 of the BWM Convention. The BWMS includes ballast water management equipment, all associated control equipment, monitoring equipment and sampling facilities.

   2.2 Dangerous gas means any gas which may develop an explosive and/or toxic atmosphere being hazardous to the crew and/or the ship, e.g. hydrogen (H₂), hydrocarbon gas, ozone (O₃), chlorine (Cl₂) and chlorine dioxide (ClO₂), etc.

   2.3 Hazardous area means an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment. When a gas atmosphere is present, the following hazards may also be present: toxicity, asphyxiation, corrosivity and reactivity.

   2.4 Dangerous liquid means any liquid that is identified as hazardous in the Material Safety Data Sheet or other documentation relating to this liquid.

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**Note:**

1. This UR is to be uniformly implemented by IACS Societies for BWMS:
   
   i) where an application for approval for the plans of BWMS is made on or after 1 January 2017; or

   ii) which is installed in ships contracted for construction on or after 1 January 2017.

2. Rev.1 of this UR is to be uniformly implemented by IACS Societies for BWMS:

   i) where an application for approval for the plans of BWMS is made on or after 1 January 2017; or

   ii) which is installed in ships contracted for construction on or after 1 January 2017.

3. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.
3. **Installation**

3.1 **General requirements**

3.1.1 All valves, piping fittings and flanges are to comply with the relevant requirements of UR P2 and P4. In addition, special consideration can be given to the material used for this service with the agreement of Society.

3.1.2 The BWMS is to be provided with by-pass or override arrangement to effectively isolate it from any essential ship system to which it is connected.

3.1.3 The BWMS is to be operated at a flow rate within the Treatment Rated Capacity (TRC) range specified in the Type Approval Certificate (TAC) issued by the Flag Administration.

3.1.4 Where a vacuum may occur in the ballast line due to the height difference, a suitable protection means is to be provided, e.g. P/V valves or breather valves, and their outlets are to be led to safe area on open deck.

3.1.5 Electric and electronic components are not to be installed in a hazardous area unless they are of certified safe type for use in the area. Cable penetrations of decks and bulkheads are to be sealed when a pressure difference between the areas is to be maintained.

3.1.6 Where the operating principle of the BWMS involves the generation of a dangerous gas, the following requirements are to be satisfied:

1. Gas detection equipment is to be fitted in the spaces where dangerous gas could be present, and an audible and visual alarm is to be activated both locally and at the BWMS control station in the event of leakage. The gas detection device is to be designed and tested in accordance with IEC 60079-29-1 or recognized standards acceptable to the Society.

2. The ventilation line of a space where dangerous gas could be present is to be led to a safe area on open deck.

3. The arrangements used for gas relieving, i.e. degas equipment or equivalent, are to be provided with monitoring measures with independent shutdown. The open end of the gas relieving device is to be led to a safe area on open deck.

3.1.7 Ballast piping, including sampling lines from ballast tanks considered as hazardous areas, is not to be led to an enclosed space regarded as a safe area, without any appropriate measures, except ships carrying liquefied gases in bulk. However, a sampling point for checking the performance of BWMS, for ballast water containing dangerous gas, may be located in a safe area provided the following requirements are fulfilled:

1. The sampling facility (for BWMS monitoring/control) is to be located within a gas tight enclosure (hereinafter, referred to as a ‘cabinet’), and the following (i) through (iii) are to be complied.

   i) In the cabinet, a stop valve is to be installed in each sample pipe.

   ii) Gas detection equipment is to be installed in the cabinet and the valves specified in i) above are to be automatically closed upon activation of the gas detection equipment.
iii) Audible and visual alarm signals are to be activated both locally and at the BWMS control station when the concentration of explosive gases reaches a pre-set value, which should not be higher than 30% of the lower flammable limit (LFL) of the concerned product.

.2 The standard internal diameter of sampling pipes is to be the minimum necessary in order to achieve the functional requirements of the sampling system.

.3 The measuring system is to be installed as close to the bulkhead as possible, and the length of measuring pipe in any safe area is to be as short as possible.

.4 Stop valves are to be located in the safe area, in both the suction and return pipes close to the bulkhead penetrations. A warning plate stating "Keep valve closed when not performing measurements" is to be posted near the valves. Furthermore, in order to prevent backflow, a water seal or equivalent arrangement is to be installed on the hazardous area side of the return pipe.

.5 A safety valve is to be installed on the hazardous area side of each sampling pipe.

3.1.8 For the spaces, including hazardous areas, where toxicity, asphyxiation, corrosivity or reactivity is present, these hazards are to be taken into account and additional precautions for the ventilation of the spaces and protection of the crew are to be considered.

3.2 Additional requirements for tankers:

3.2.1 Hazardous area classification is to be in accordance with IEC 60092-502.

3.2.2 For tankers carrying flammable liquids having a flashpoint not exceeding 60 °C or products listed in the IBC Code having a flashpoint not exceeding 60 °C or cargoes heated to temperature above their flashpoint and cargoes heated to temperature within 15 °C of their flashpoint. In general, two independent BWMS may be required – i.e. one for ballast tanks in hazardous areas and the other for ballast tanks in non-hazardous areas.

3.2.3 The interconnection of ballast piping between hazardous areas and in non-hazardous areas may be accepted if an appropriate isolation arrangement is applied. Means of appropriate isolation are as follows:

.1 Two screw down check valves in series with a spool piece, or

.2 Two screw down check valves in series with a liquid seal at least 1.5 m in depth, or
.3 Automatic double block and bleed valves and a non-return valve

Examples of appropriate isolation arrangements are shown in Annex I. Isolation arrangements are to be fitted on the exposed deck in the hazardous area. Also, ballast water originating from a hazardous area is not to discharge into a non-hazardous area, except as given by 3.1.7.

3.3 Ventilation

3.3.1 BWMS not in hazardous areas:

1. A BWMS that does not generate dangerous gas is to be located in an adequately ventilated area.

2. A BWMS that generates dangerous gas is to be located in a space fitted with a mechanical ventilation system providing at least 6 air changes per hour or as specified by the BWMS manufacturer, whichever is greater.

3.3.2 BWMS in hazardous areas:

A BWMS, regardless of whether or not it generates dangerous gas, is to be located in a space fitted with mechanical ventilation complying with relevant requirements, e.g. IEC60092-502, IBC Code, IGC Code, etc.

3.4 Special requirements:

3.4.1 The length of pipe and the number of connections are to be minimised in piping systems containing dangerous gases/liquids in high concentration. The following requirements are also to be satisfied:

1. Pipe joints are to be of welded type except for connections to shut off valves, double walled pipes or pipes in ducts equipped with mechanical exhaust ventilation. Alternatively it is to be demonstrated that risk of leakage is minimized and the formation of toxic or flammable atmosphere is prevented.

2. Location of the piping system is to be away from heat sources and protected from mechanical damage.

3.4.2 For BWMS using chemical substances, handling procedures are to be in accordance with the Material Safety Data Sheet and BWM.2/Circ.20, and the following measures are to be taken as appropriate:

1. The materials used for the chemical storage tanks, piping and fittings are to be resistant to such chemicals.
.2 Chemical storage tanks are to have sufficient strength and be constructed such that maintenance and inspection can be easily performed.

.3 Chemical storage tank air pipes are to be led to a safe area on open deck.

.4 An operation manual containing chemical injection procedures, alarm systems, measures in case of emergency, etc, is to be kept onboard.

3.4.3 Where the BWMS is installed in an independent compartment, the compartment is to be:

.1 Provided with fire integrity equivalent to other machinery spaces.

.2 Positioned outside of any combustible, corrosive, toxic, or hazardous areas unless otherwise specifically approved.

3.4.4 A risk assessment may be conducted to ensure that risks, including but not limited to those arising from the use of dangerous gas affecting persons on board, the environment, the structural strength or the integrity of the ship are addressed.

4. Automation

4.1 In case of any by-pass or override operation of BWMS, an audible and visual alarm is to be given and these events are to be automatically recorded in control equipment. The valves in the by-pass line which trigger the by-pass operation are to be remote-controllable by control equipment or fitted with open/close indicator for automatic detection of the by-pass event.
Annex I (cont)

- BWMS which does not require after-treatment

- BWMS which requires after-treatment (Injection type)

*: Appropriate Isolation Means: Two (2) screw down check valves in series with a spool piece or a liquid seal, or automatic double block and bleed valves
M74 (cont)

Spool Piece

Liquid Seal

Bleed Valve

Double Block Valve

End of Document
Ventilation of emergency generator rooms

1. Introduction

Emergency generator rooms are provided with ventilation openings for the admission of combustion air to engines and the removal of heat. These openings are usually provided with louvers which can be closed (when fire breaks out in emergency generator rooms). The louvers may be hand-operated or power-operated. Alternatively, the louvers may be of fixed type with a closing door which may be hand-operated or automatic.

2. Requirements

The following requirements apply to ventilation louvers for emergency generator rooms and to closing appliances where fitted to ventilators serving emergency generator rooms:

2.1 Ventilation louvers and closing appliances may either be hand-operated or power-operated (hydraulic / pneumatic / electric) and are to be operable under a fire condition.

2.2 Hand-operated ventilation louvers and closing appliances are to be kept open during normal operation of the vessel. Corresponding instruction plates are to be provided at the location where hand-operation is provided.

2.3 Power-operated ventilation louvers and closing appliances shall be of a fail-to-open type. Closed ventilation louvers and closing appliances are acceptable during normal operation of the vessel.
Power-operated ventilation louvers and closing appliances shall open automatically whenever the emergency generator is starting / in operation.

2.4 It shall be possible to close ventilation openings by a manual operation from a clearly marked safe position outside the space where the closing operation can be easily confirmed. The louver status (open / closed) shall be indicated at this position. Such closing shall not be possible from any other remote position.

Note:

1. This UR is to be uniformly implemented by IACS Societies for ships contracted for construction on and after 1 January 2017.

2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.
Location of fuel tanks in cargo area on oil and chemical tankers

On oil and chemical tankers, fuel tanks located with a common boundary to cargo tanks shall not be situated within the cargo tank block. Such tanks may, however, be situated at the forward and aft ends of the cargo tank block instead of cofferdams. Fuel tanks shall extend neither fully nor partly into cargo or slop tanks. They may however be accepted when located as independent tanks on open deck in the cargo area subject to spill and fire safety considerations. Fuel tanks are not permitted to extend into the protective area of cargo tanks required by MARPOL Annex I and the IBC code. For chemical tankers due attention has to be paid to restrictions on cargoes that can be located adjacent to fuel tanks.

The arrangement of independent fuel tanks and associated fuel piping systems, including the pumps, can be as for fuel tanks and associated fuel piping systems located in the machinery spaces. For electrical equipment, requirements to hazardous area classification must however be taken into account.

Cargo tank block is the part of the ship extending from the aft bulkhead of the aftmost cargo or slop tank to the forward bulkhead of the forward most cargo or slop tank, extending to the full depth and beam of the ship, but not including the area above the deck of the cargo or slop tank.

NOTE:

1. This UR is to be uniformly implemented by IACS Members when an application for approval for systems is dated on or after 1 July 2017.
Storage and use of SCR reductants

1. General

The NOx Technical Code, in 2.2.5 and elsewhere, provides for the use of NOx Reducing Devices of which Selective Catalytic Reduction (SCR) is one option. SCR requires the use of a reductant which may be a urea/water solution or, in exceptional cases, aqueous ammonia or even anhydrous ammonia. These requirements apply to the arrangements for the storage and use of SCR reductants which are typically carried on board in bulk quantities.

2. Reductant using urea based ammonia (e.g. 40%/60% urea/water solution)

2.1 Where urea based ammonia (e.g. AUS 40 – aqueous urea solution specified in ISO 18611-1) is introduced, the storage tank is to be arranged so that any leakage will be contained and prevented from making contact with heated surfaces. All pipes or other tank penetrations are to be provided with manual closing valves attached to the tank. Tank and piping arrangements are to be approved.

2.2 The storage tank may be located within the engine room.

2.3 The storage tank is to be protected from excessively high or low temperatures applicable to the particular concentration of the solution. Depending on the operational area of the ship, this may necessitate the fitting of heating and/or cooling systems. The physical conditions recommended by applicable recognized standards (such as ISO 18611-3) are to be taken into account to ensure that the contents of the aqueous urea tank are maintained to avoid any impairment of the urea solution during storage.

2.4 If a urea storage tank is installed in a closed compartment, the area is to be served by an effective mechanical supply and exhaust ventilation system providing not less than 6 air changes per hour which is independent from the ventilation system of accommodation, service spaces, or control stations. The ventilation system is to be capable of being controlled from outside the compartment and is to be maintained in operation continuously except when the storage tank is empty and has been thoroughly air purged. If the ventilation stops, an audible and visual alarm shall be provided outside the compartment adjacent to each point of entry and inside the compartment, together with a warning notice requiring the use of such ventilation.

Note:

1. This UR is to be uniformly implemented by IACS Societies for the storage tank of SCR reductants:
   i) when an application for installation, i.e. submission date of plans, is made on or after 1 January 2018; or
   ii) which is installed in ships contracted for construction on or after 1 January 2018.

2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.
Alternatively, where a urea storage tank is located within an engine room a separate ventilation system is not required when the general ventilation system for the space is arranged so as to provide an effective movement of air in the vicinity of the storage tank and is to be maintained in operation continuously except when the storage tank is empty and has been thoroughly air purged.

2.5 Each urea storage tank is to be provided with temperature and level monitoring arrangements. High and low level alarms together with high and low temperature alarms are also to be provided.

2.6 Where urea based ammonia solution is stored in integral tanks, the following are to be considered during the design and construction:

• These tanks may be designed and constructed as integral part of the hull, (e.g. double bottom, wing tanks).
• These tanks are to be coated with appropriate anti-corrosion coating and cannot be located adjacent to any fuel oil and fresh water tank.
• These tanks are to be designed and constructed as per the structural requirements applicable to hull and primary support members for a deep tank construction.
• These tanks are to be fitted with but not limited to level gauge, temperature gauge, high temperature alarm, low level alarm, etc.
• These tanks are to be included in the ship’s stability calculation.

2.7 The reductant piping and venting systems are to be independent of other ship service piping and/or systems. Reductant piping systems are not to be located in accommodation, service spaces, or control stations. The vent pipes of the storage tank are to terminate in a safe location on the weather deck and the tank venting system is to be arranged to prevent entrance of water into the urea tank.

2.8 Reductant related piping systems, tanks, and other components which may come into contact with the reductant solution are to be of a suitable grade of non-combustible compatible material established to be suitable for the application.

2.9 For the protection of crew members, the ship is to have on board suitable personnel protective equipment. Eyewash and safety showers are to be provided, the location and number of these eyewash stations and safety showers are to be derived from the detailed installation arrangements.

2.10 Urea storage tanks are to be arranged so that they can be emptied of urea, purged and vented.

3. Reductant using aqueous ammonia (28% or less concentration of ammonia)

Aqueous ammonia is not to be used as a reductant in a SCR except where it can be demonstrated that it is not practicable to use a urea based reductant. Where an application is made to use aqueous ammonia as the reductant then the arrangements for its loading, carriage and use are to be derived from a risk based analysis.
4. **Reductant using anhydrous ammonia (99.5% or greater concentration of ammonia by weight)**

Anhydrous ammonia is not to be used as a reductant in a SCR except where it can be demonstrated that it is not practicable to use a urea based reductant and where the Flag Administration agrees to its use. Where it is not practicable to use a urea reductant then it is also to be demonstrated that it is not practicable to use aqueous ammonia. Where an application is made to use anhydrous ammonia as the reductant then the arrangements for its loading, carriage and use are to be derived from a risk based analysis.