

Requirements concerning MACHINERY INSTALLATIONS

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M1

(1969)
(Rev.1
1985)
(Rev.2
Apr 1999)
(Deleted
Aug 2004)

Cylinder overpressure monitoring of internal combustion engines

Deleted in Aug 2004

End of
Document

M2
(1971)**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.

End of Document

M3

(1971)
 (Rev.1
 1984)
 (Rev.2
 1986)
 (Rev.3
 1990)
 (Rev.4
 June 2002)
 (Corr.1
 Aug 2003)
 (Rev.5
 Feb 2006)
 (Rev.6
 Nov 2018)

Speed governor and overspeed protective device

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

3.1.1 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%.

3.1.2 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. The overspeed protective device, including its driving mechanism, has to be independent from the required governor.

3.1.3 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 3.1.1, 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.

Notes:

1. The requirements introduced with M3 Rev.6 are to be uniformly implemented by IACS Societies for speed governors and overspeed protective devices:
 - i) when an application for certification of the device is dated on or after 1 January 2020; or
 - ii) which are installed in new ships contracted for construction on or after 1 January 2020.
2. 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.
3. The "date of application for certification of the device" is the date of whatever document the Classification Society requires/accepts as an application or request for certification of an individual device.

M3
(cont)**M3.2 Speed governor, overspeed protective and governing characteristics of generator prime movers**

3.2.1 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 $\pm 10\%$ of the rated frequency with a recovery time to steady state conditions not exceeding 5 seconds, when the maximum electrical step load is switched on or off.

In the case when a step load equivalent to the rated output of a generator is switched off, a transient speed variation in excess of 10% of the rated speed may be acceptable, provided this does not cause the intervention of the overspeed device as required by 3.2.5.

3.2.2 At all loads between no load and rated power the permanent speed variation should not be more than $\pm 5\%$ of the rated speed.

3.2.3 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 for guidance on 4-stroke diesel engines expected maximum possible sudden power increase) and provided that this is already allowed for in the designing stage. This is to be verified in the form of system specifications to be approved and to be demonstrated at ship's trials. In this case, due consideration is to be given to the power required for the electrical equipment to be automatically switched on after black-out and to the sequence in which it is connected. 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.

3.2.4 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.

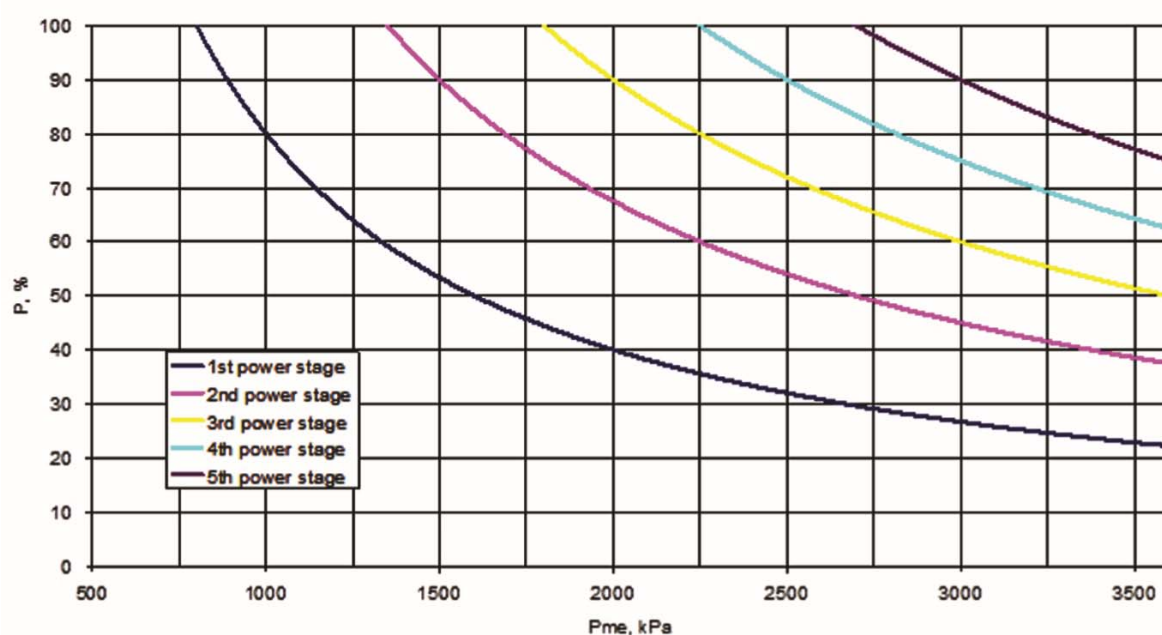
M3

(cont)

3.2.5 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%.

3.2.6 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.



Legend:

P_{me} : declared power mean effective pressure

P : power increase referred to declared power at site conditions

1 : first power stage

2 : second power stage

3 : third power stage

4 : fourth power stage

5 : fifth power stage

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

End of
Document

M4 Deleted

(1971)

(Deleted) Limits of flash point of oil fuel are covered by F35 as revised and should be referred to.

End of
Document

M5
(1971)
(Rev.1
1987)

Mass production of internal combustion engines, procedure for inspection

Deleted Feb 2015, replaced by UR Z26.

End of Document

M6
(1972)
(Rev.1
1985)
(Rev.2
1994)
(Rev.3
May
1998)

Test pressures for parts of internal combustion engines ¹⁾

Deleted Feb 2015, replaced by UR M72.

End of Document

M7

(1972)
(Rev.1
1987)

Re-categorised as “recommendation” No.26

End of
Document

M8 Re-categorised as “recommendation” No.27

(1972)
(Rev.1
1989)

End of
Document

M9

(1972)
(Rev.1
1991)
(Corr.
1997)
(Rev.2
June
2000)
(Rev.3
Jan
2005)
(Corr.1
Nov
2005)
(Corr.2
Sept
2007)

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

(cont)

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 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 be 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

End of Document

M10 Protection of internal combustion engines against crankcase explosions

(1972)
(Rev.1
1991)
(Corr.
1997)
(Rev.2
Jan
2005)
(Corr.1
Nov
2005)
(Corr.2
Oct
2007)
(Rev.3
Sept
2008)
(Rev.4
July
2013)

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 m³.

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 2.5×10^{-4} N/mm² (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

(cont)

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 (cont)

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

M11 Protective devices for starting air mains

(1972)

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.

End of Document

M12 **Fire extinguishing systems for scavenge manifolds**

(1972)

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.

End of Document

M13 Re-categorised as “Recommendation” No.28

(1973)
(Rev.1
1989)

End of Document

M14 **Mass production of internal combustion engines: definition of mass production**

(1973)

Deleted Feb 2015, replaced by UR Z26.

End of Document

M15(1974)
(Rev. 1
1989)**Re-categorized as “recommendation”
No. 29**END

M16(1974)
(Rev. 1
Jan 2005)**Devices 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.

END

M17 Deleted 1 July 1998END

M18 Parts of internal combustion engines for which material tests are required

(1972)
(Rev.1
1986)
(Rev.2
1996)
(Rev.3
May
1998)
(Rev.4
June
2000)

Deleted Feb 2015, replaced by UR M72.

End of Document

M19 **Parts of internal combustion engines for which**
(1974) **nondestructive tests are required**

Deleted Feb 2015, replaced by UR M72.

End of Document

M20 Periodical Survey of Machinery

(1974)
(Rev. 1
1977)
(Rev. 2
1983)
(Rev. 3
1992)
(Rev. 4
1995)

Deleted in November 2001. Requirements relocated to URs Z18 and Z21.

M21 Mass production of internal combustion engines: type test conditions

(1974)
(Corr.
Feb
1999)
(Corr.
Sept
2003)

Deleted Feb 2015, replaced by UR M71.

End of Document

M23

(1975)
(Rev.2
1981)
(Rev.3
1991)

Mass production of engines: mass produced exhaust driven turboblowers

Deleted Feb 2015, replaced by UR M73.

End of Document

M24

(1975)
(Rev.1
1976)
(Rev.2
Aug 2023)

Requirements concerning use of crude oil or slops as fuel for tanker boilers

M24.1 This UR applies to tankers where crude oil or slops are used as fuel for boilers, except for the requirement(s) in this UR which create conflict with the statutory requirements related to alternative design and arrangements required by SOLAS II-1/55 that do not need to be complied with (i.e statutory requirements take precedence over this UR).

M24.2 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.

M24.3 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.

M24.4 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.

M24.5 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.

Note:

1. Rev.2 of this UR is to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 January 2025.
2. 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.

M24 (cont)

M24.6 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.

M24.7 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.

M24.8 The piping for crude oil or slops and the draining pipes for the tray defined in M24.10 are to have a thickness as follows:

External diameter of pipes, d_e			thickness, t
	$d_e \leq$	82.5 mm	$t \geq$ 6.3 mm
88.9 mm	$< d_e \leq$	108 mm	$t \geq$ 7.1 mm
114.3 mm	$< d_e \leq$	139.7 mm	$t \geq$ 8 mm
152.4 mm	$\leq d_e$		$t \geq$ 8.8 mm

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 M24.10. 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.

M24.9 In way of the bulkhead to which the duct defined in M24.8 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 M24.11) to ensure that whenever crude oil is circulating the fans are running.

M24.10 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.

M24 (cont)

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.

M24.11 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.

M24.12 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.

M24.13 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.

M24.14 A gas detector plant shall be fitted with intakes in the duct defined in M24.8, 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.

M24.15 Means are to be provided for the boiler to be automatically purged before firing.

M24.16 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 M24.10. The emission of extinguishing medium should automatically stop the exhaust fan of the boiler hood (see M24.9).

M24
(cont)

M24.17 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 M24.14 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 M24.8 and turn the boilers to normal running on fuel oil.

M24.18 One pilot burner in addition to the normal burning control is required.

End of Document

M25 Astern power for main propulsion

(1975)
(Rev.1
1984)
(Rev.2
1997)
(Rev.3
July
2003)
(Rev.4
June
2017)

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 revolutions¹.

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 revolutions¹ 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.

M25.4 Main propulsion systems are to undergo tests to demonstrate the astern response characteristics.

The tests are to be carried out at least over the manoeuvring range of the propulsion system and from all control positions. A test plan is to be provided by the yard and accepted by the surveyor. If specific operational characteristics have been defined by the manufacturer these shall be included in the test plan.

M25.5 The reversing characteristics of the propulsion plant, including the blade pitch control system of controllable pitch propellers, are to be demonstrated and recorded during trials.

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

Note:

1. Rev.4 of this UR is to be uniformly implemented by IACS Societies on:
 - (a) ships contracted for construction on or after 1 July 2018.
 - (b) ships other than those specified in the preceding (a) on which astern testing is carried out in accordance with Z18 on or after 1 July 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.

End of Document

M26 Safety devices of steam turbines

(1976)
(Corr.1
Feb 2005)

1 Governors and speed control

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.

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.

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.

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.

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 1.1).

2 Miscellaneous safety arrangements

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.

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

(cont)

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.

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.

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.

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.

End of Document

M27
(1976)

Bilge level alarms for unattended machinery spaces

Deleted in March 2022

M28 Ambient reference conditions

(1978)

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:

Total barometric pressure	1000 mbar
Air temperature	+45°C
Relative humidity	60%
Sea water temperature (charge air coolant-inlet)	32°C

Note: The engine manufacturer shall not be expected to provide simulated ambient reference conditions at a test bed.

End of Document

M29

(1978)
(Rev. 1
1979)
(Rev.2
1995)
(Rev.3
1997)

Alarm systems for vessels with periodically unattended machinery spaces

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
cont'd**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**
(1978)
(Rev. 1
1997)

Safety systems for vessels with periodically unattended machinery spaces

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**
(1978) **vessels with periodically unattended machinery**
(Del **spaces**
Jan 2023)

Deleted in Jan 2023

End of Document

M32 Definition of diesel engine type

(1979)

Deleted Feb 2015, replaced by UR M71.

End of Document

M33 Scantlings of intermediate shafts

(1981)
(Rev.1
1981)

UR M33 was replaced by UR M68 in February 2005.

End of Document

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:

$$d_b = 0.65 \sqrt{\frac{d^3 (T + 160)}{iDT_b}}$$

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.

Filletts 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.



M35 Alarms, remote indications and safeguards for main reciprocating I.C. engines installed in unattended machinery spaces

(1980)
(Rev.1
1993)
(Rev.2
1996)
(Rev.3
1997)
Rev.4
1999)
(Rev.5
Aug 2008)
(Rev.6
July 2013)
(Rev.7
Mar 2016)
(Rev.8
Jan 2019)

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.
5. The requirements of M35 Rev.8 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 2020; or
 - ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2020.

M35

(cont)

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.

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).

M35

(cont)

Table 1 Cross-head diesel engines

Monitored parameters for cross-head diesel engines	Gr 1			Gr 2	Gr 3
	Remote Indication	Alarm activation	Slow down with alarm	Automatic start of standby pump with alarm	Shut down with alarm
1.0 Fuel oil system					
Fuel oil pressure after filter (engine inlet)	x	low		x	
Fuel oil viscosity before injection pumps or Fuel oil temp before injection pumps		high low			
Leakage from high pressure pipes		x			
Level of fuel oil in daily service tank ¹		low			
Common rail fuel oil pressure		low			
2.0 Lubricating oil system					
Lub oil to main bearing and thrust bearing, pressure	x	low	x	x	x
Lub oil to crosshead bearing pressure ²	x	low	x	x	x
Lub oil to camshaft pressure ²		low		x	x
Lub oil to camshaft temp ²		high			
Lub oil inlet temp		high			
Thrust bearing pads temp or bearing outlet temp		high	x		x
Activation of oil mist detection arrangements (or activation of the temperature monitoring systems or equivalent devices of: - the engine main, crank and crosshead bearing oil outlet; or - the engine main, crank and crosshead bearing) ³		x	x		
Flow rate cylinder lubricator. Each apparatus		low	x		
Level in lubricating oil tanks ⁴		low			
Common rail servo oil pressure		low			
3.0 Turbocharger system					
Turbocharger lub oil inlet pressure ⁹		low			
Turbocharger lub oil outlet temp each bearing ¹⁰		high			
Speed of turbocharger ¹¹	x	high			
4.0 Piston cooling system					
Piston coolant inlet pressure ⁵		low	x	x	
Piston coolant outlet temp each cylinder		high	x		
Piston coolant outlet flow each cylinder ⁸		low	x		
Level of piston coolant in expansion tank		low			
5.0 Sea water cooling system					
Sea water pressure		low		x	

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 1 (continued)

M35
(cont)

Monitored parameters for cross-head diesel engines	Gr 1			Gr 2	Gr 3
	Remote Indication	Alarm activation	Slow down with alarm	Automatic start of standby pump with alarm	Shut down with alarm
6.0 Cylinder fresh cooling water system					
Cylinder water inlet pressure		low	x	x	
Cylinder water outlet temp (from each cylinder) or Cylinder water outlet temp (general) ⁶		high	x		
Oily contamination of engine cooling water system ⁷		x			
Level of cylinder cooling water in expansion tank		low			
7.0 Starting and control air systems					
Starting air pressure before main shut-off valve	x	low			
Control air pressure		low			
Safety air pressure		low			
8.0 Scavenge air system					
Scavenge air receiver pressure	x				
Scavenge air box temp (fire)		high	x		
Scavenge air receiver water level		high			
9.0 Exhaust gas system					
Exhaust gas temp after each cylinder	x	high	x		
Exhaust gas temp after each cylinder. Deviation from average.		high			
Exhaust gas temp before each T/C	x	high			
Exhaust gas temp after each T/C	x	high			
10.0 Fuel valve coolant					
Pressure of fuel valve coolant		low		x	
Temperature of fuel valve coolant		high			
Level of fuel valve coolant in expansion tank		low			
11.0 Engine speed/direction of rotation.	x				
Wrong way		x			
12.0 Engine overspeed					x
13.0 Control-Safety-Alarm system power supply failure		x			

M35
(cont)

- 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)

M35

(cont)

Table 2 Trunk-piston diesel engines

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

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)

M35

(cont)

Monitored parameters for trunk-piston diesel engines	Gr 1			Gr 2	Gr 3
	Remote Indication	Alarm activation	Slow down with alarm	Automatic start of standby pump with alarm	Shut down with alarm
7.0 Scavenge air system					
Scavenge air receiver temp		high			
8.0 Exhaust Gas system					
Exhaust gas temp after each cylinder ⁷	x	high	x		
Exhaust gas temp after each cylinder. Deviation from average ⁷		high			
9.0 Engine speed	x				
10.0 Engine overspeed					x
11.0 Control-Safety-Alarm system power supply failure		x			

- 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: for each engine, one oil mist detector (or engine bearing temperature monitoring system or equivalent device) having two independent outputs for initiating the alarm and shut-down would satisfy the requirement for independence between alarm and shut-down systems.
- 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)

End of
Document

M36 Alarms and safeguards for auxiliary reciprocating internal combustion engines driving generators in unattended machinery spaces

(1980)
(Rev. 1
1993)
(Rev. 2
June 2000)
(Rev. 3
Sep 2008)
(Rev. 4
July 2013)
(Rev. 5
Mar 2016)
(Rev. 6
Dec 2018)

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.
5. The requirements of M36 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 2020; or
 - ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2020.

M36

(cont)

Table 1

Monitored parameters	Alarm	Shut down
Fuel oil leakage from high pressure pipes	x	
Lubricating oil temperature	high	
Lubricating oil pressure	low	x
Activation of oil mist detection arrangements (or activation of the temperature monitoring systems or equivalent devices of: - the engine main and crank bearing oil outlet; or - the engine main and crank bearing) ³	x	x
Pressure or flow of cooling water	low	
Temperature of cooling water or cooling air	high	
Level in cooling water expansion tank, if not connected to main system	low	
Level in fuel oil daily service tank	low	
Starting air pressure	low	
Overspeed activated		x
Fuel oil viscosity before injection pumps or fuel oil temp before injection pumps ¹	low high	
Exhaust gas temperature after each cylinder ²	high	
Common rail fuel oil pressure	low	
Common rail servo oil pressure	low	
Speed of turbocharger ⁴	high	

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: for each engine one oil mist detector (or engine bearing temperature monitoring system or equivalent device) having two independent outputs for initiating the alarm and shut-down would satisfy the requirement for independence between alarm and shut-down systems.
4. Only required for turbochargers of Categories B and C. (see M73.5)

End of
Document

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
(1981) (intermediate shafts) - see M33

UR M38 was replaced by UR M68 in February 2005.

END

M39 k-factors for different shaft design features
(1981) (propeller shafts) - see M37

UR M39 was replaced by UR M68 in February 2005.

M40 Ambient conditions – Temperatures

(1981)

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

Air

Installations, components	Location, arrangement	Temperature range (°C)
Machinery and electrical installations ¹	In enclosed spaces	0 to +45 ²
	On machinery components, boilers, In spaces subject to higher and lower temperatures	According to specific local conditions
	On the open deck	–25 to +45 ²

Water

Coolant	Temperature (°C)
Seawater Charge air coolant inlet to charge air cooler	+32 ² see UR M28

NOTES

- Electronic appliances are to be suitable for proper operation even with an air temperature of +55°C.
- 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)

M42 Steering Gear

(1981)
(Rev.1
1986)
(Rev.2
1995)
(Rev.3
1997)
(Rev.4
June 2011)
(Rev.5
Feb 2021)
(Corr.1
Oct 2021)
(Rev.6
Mar 2022)

Preamble

In addition to the requirements contained in SOLAS II-1/29 and SOLAS II-1/30 as well as related Guidelines (see Annex 2 of IMCO document MSC XLV/4) the following requirements apply to new ocean-going vessels of 500 gross tonnage 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.

Note:

1. Rev.4 of this UR applies to ships contracted for construction 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.
3. Rev.5 of this UR is to be uniformly implemented by IACS Societies on ships for which the date of contract for construction is on or after 1 July 2022.
4. Rev.6 of this UR is to be uniformly implemented by IACS Societies on ships for which the date of contract for construction is on or after 1 July 2023.

M42

(cont)

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.

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 SOLAS II-1/29.17 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 membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_B}{A} \text{ or } \frac{\sigma_y}{B}$$

M42

(cont)

where:

σ_B =specified minimum tensile strength of material at ambient temperature

σ_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

	Steel	Cast Steel	Nodular Cast Iron
A	3.5	4	5
B	1.7	2	3

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 SOLAS II-1/29.2.2 and SOLAS II-1/29.17.1 as well as 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 SOLAS II-1/29.2.3, 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.

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(cont)

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 SOLAS II-1/29.14 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.

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.

M42
(cont)

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 SOLAS II-1/29.3.2 and SOLAS II-1/29.4.2. 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 SOLAS II-1/29.14.
- (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 SOLAS II-1/29 and SOLAS II-1/30 as well as 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

M42

(cont)

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. Steering gear control system is also understood to cover “the equipment required to control the steering gear power actuating system”.
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 SOLAS II-1/29.3.2.
9. Hydraulic locking means all situations where two hydraulic systems (usually identical) oppose each other in such a way that it may lead to loss of steering. It can either be caused by pressure in the two hydraulic systems working against each other or by hydraulic “by-pass” meaning that the systems puncture each other and cause pressure drop on both sides or make it impossible to build up pressure.

End of Document

M43 Bridge control of propulsion machinery for (1982) **unattended machinery spaces**

- M43.1 Under all sailing conditions, including manoeuvring, 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 manoeuvring 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.



M44 Documents for the approval of diesel engines

(1982)

(Rev.1

1983)

(Rev.2

1984)

(Rev.3

1986)

(Rev.4

1989)

(Rev.5

1992)

(Rev.6

Nov 2003)

(Rev.7

May

2004)

(Rev.8

Mar 2015

Complete

Revision)

(Rev.9

Dec 2015)

(Corr.1

June

2016)

(Corr.2

Nov 2016)

(Rev.10

Feb 2021)

(Corr.1

Feb 2022)

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.
4. The requirements of M44 Rev.10 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 2022.

M44
(cont)

- 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.

M44 (cont)

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.

M44
(cont)**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.

M44
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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

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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.

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Table 1 Documentation to be submitted for information, as applicable

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

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Table 2 Documentation to be submitted for approval, as applicable

No.	Item
1	Bedplate and crankcase of welded design, with welding details and welding instructions ^{1,2}
2	Thrust bearing bedplate of welded design, with welding details and welding instructions ¹
3	Bedplate/oil sump welding drawings ¹
4	Frame/framebox/gearbox of welded design, with welding details and instructions ^{1,2}
5	Engine frames, welding drawings ^{1,2}
6	Crankshaft, details, each cylinder No.
7	Crankshaft, assembly, each cylinder No.
8	Crankshaft calculations (for each cylinder configuration) according to the attached data sheet and UR M53
9	Thrust shaft or intermediate shaft (if integral with engine)
10	Shaft coupling bolts
11	Material specifications of main parts with information on non-destructive material tests and pressure tests ³
	Schematic layout or other equivalent documents on the engine of:
12	Starting air system
13	Fuel oil system
14	Lubricating oil system
15	Cooling water system
16	Hydraulic system
17	Hydraulic system (for valve lift)
18	Engine control and safety system
19	Shielding of high pressure fuel pipes, assembly ⁴
20	Construction of accumulators (for electronically controlled engine)
21	Construction of common accumulators (for electronically controlled engine)
22	Arrangement and details of the crankcase explosion relief valve (see UR M9) ⁵
23	Calculation results for crankcase explosion relief valves (see UR M9)
24	Details of the type test program and the type test report ⁷
25	High pressure parts for fuel oil injection system ⁶
26	Oil mist detection and/or alternative alarm arrangements (see UR M10)
27	Details of mechanical joints of piping systems (see UR P2)
28	Documentation verifying compliance with inclination limits (see UR M46)
29	Documents as required in UR E22, as applicable

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.

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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

No.	Item
1	Engine particulars as per data sheet in Appendix 3
2	Material specifications of main parts with information on non-destructive material tests and pressure tests ¹
3	Bedplate and crankcase of welded design, with welding details and welding instructions ²
4	Thrust bearing bedplate of welded design, with welding details and welding instructions ²
5	Frame/framebox/gearbox of welded design, with welding details and instructions ²
6	Crankshaft, assembly and details
7	Thrust shaft or intermediate shaft (if integral with engine)
8	Shaft coupling bolts
9	Bolts and studs for main bearings
10	Bolts and studs for cylinder heads and exhaust valve (two stroke design)
11	Bolts and studs for connecting rods
12	Tie rods
	Schematic layout or other equivalent documents on the engine of: ³
13	Starting air system
14	Fuel oil system
15	Lubricating oil system
16	Cooling water system
17	Hydraulic system
18	Hydraulic system (for valve lift)
19	Engine control and safety system
20	Shielding of high pressure fuel pipes, assembly ⁴
21	Construction of accumulators for hydraulic oil and fuel oil
22	High pressure parts for fuel oil injection system ⁵
23	Arrangement and details of the crankcase explosion relief valve (see UR M9) ⁶
24	Oil mist detection and/or alternative alarm arrangements (see UR M10)
25	Cylinder head
26	Cylinder block, engine block
27	Cylinder liner
28	Counterweights (if not integral with crankshaft), including fastening
29	Connecting rod with cap
30	Crosshead
31	Piston rod
32	Piston, assembly ⁷
33	Piston head
34	Camshaft drive, assembly ⁷
35	Flywheel
36	Arrangement of foundation (for main engines only)
37	Fuel oil injection pump
38	Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly
39	Construction and arrangement of dampers
	For electronically controlled engines, assembly drawings or arrangements of:
40	Control valves
41	High-pressure pumps

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No.	Item
42	Drive for high pressure pumps
43	Valve bodies, if applicable
44	Operation and service manuals ⁸
45	Test program resulting from FMEA (for engine control system) ⁹
46	Production specifications for castings and welding (sequence)
47	Type approval certification for environmental tests, control components ¹⁰
48	Quality requirements for engine production

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.

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UR M44 - APPENDIX 1 - GLOSSARY

Term	Definition
Acceptance criteria	A set of values or criteria which a design, product, service or process is required to conform with, in order to be considered in compliance
Accepted	Status of a design, product, service or process, which has been found to conform to specific acceptance criteria
Alternative Certification Scheme (ACS)	A system, by which a society evaluates a manufacturer's quality assurance and quality control arrangements for compliance with Rule requirements, then authorizes a manufacturer to undertake and witness testing normally required to be done in the presence of a Surveyor. The Alternative Certification Scheme as presently administrated by the Member Societies is generally known as: ABS: Product Quality Assurance BV: Alternative Survey Scheme CCS: Type Approval-A CRS: Examination of the manufacturing process and quality assurance system DNV-GL: Manufacturing Survey Arrangement IRS: IRS Quality Assurance Scheme KR: Quality Assurance System LR: LR Quality Schemes NK: Approval of Manufacturers PRS: Alternative Certification Scheme RINA: Alternative Survey Scheme RS: Agreement on Survey
Appraisal	Evaluation by a competent body
Approval	The granting of permission for a design, product, service or process to be used for a stated purpose under specific conditions based upon a satisfactory appraisal
Assembly	Equipment or a system made up of components or parts
Assess	Determine the degree of conformity of a design, product, service, process, system or organization with identified specifications, Rules, standards or other normative documents
Audit	Planned systematic and independent examination to determine whether the activities are documented, the documented activities are implemented, and the results meet the stated objectives
Auditor	Individual who has the qualifications and experience to perform audits
Certificate	A formal document attesting to the compliance of a design, product, service or process with acceptance criteria

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Term	Definition
Certification	A procedure whereby a design, product, service or process is approved in accordance with acceptance criteria
Class	Short for Classification Society
Class approval	Approved by a Classification Society
Classification	Specific type of certification, which relates to the Rules of the relevant Classification Society
Competent body	Organization recognized as having appropriate knowledge and expertise in a specific area
Component	Part, member of equipment or system
Conformity	Where a design, product, process or service demonstrates compliance with its specific requirements
Contract	Agreement between two or more parties relating to the scope of service
Contractor	see Supplier
Customer	Party who purchases or receives goods or services from another
Design	All relevant plans, documents, calculations described in the performance, installation and manufacturing of a product
Design analysis	Investigative methodology selectively used to assess the design
Design appraisal	Evaluation of all relevant plans, calculations and documents related to the design
Design review	Part of the appraisal process to evaluate specific aspects of the design
Drawings approval/ plan approval	Part of the design approval process which relates to the evaluation of drawings and plans
Equipment	Part of a system assembled from components
Equivalent	An acceptable, no less effective alternative to specified criteria
Evaluation	Systematic examination of the extent to which a design, product, service or process satisfies specific criteria
Examination	Assessment by a competent person to determine compliance with requirements
Inspection	Examination of a design, product service or process by an Inspector
Inspection plan	List of tasks of inspection to be performed by the Inspector

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Term	Definition
Installation	The assembling and final placement of components, equipment and subsystems to permit operation of the system
Manufacturer	Party responsible for the manufacturing and quality of the product
Manufacturing process	Systematic series of actions directed towards manufacturing a product
Manufacturing process approval	Approval of the manufacturing process adopted by the manufacturer during production of a specific product
Material	Goods supplied by one manufacturer to another manufacturer that will require further forming or manufacturing before becoming a new product
Modification	A limited change that does not affect the current approval
Modification notice	Information about a design modification with new modification index or new drawing number replacing the earlier drawing
Performance test	Technical operation where a specific performance characteristic is determined
Producer	See manufacturer
Product	Result of the manufacturing process
Prototype test	Investigations on the first or one of the first new engines with regard to optimization, fine tuning of engine parameters and verification of the expected running behaviour
Quality assurance	All the planned and systematic activities implemented within the quality system, and demonstrated as needed to provide adequate confidence that an entity will fulfil requirements for quality. Refer to ISO 9001:2015
Regulation	Rule or order issued by an executive authority or regulatory agency of a government and having the force of law
Repair	Restore to original or near original condition from the results of wear and tear or damages for a product or system in service
Requirement	Specified characteristics used for evaluation purposes
Information	Additional technical data or details supplementing the drawings requiring approval
Revision	Means to record changes in one or more particulars of design drawings or specifications
Specification	Technical data or particulars which are used to establish the suitability of materials, products, components or systems for their intended use

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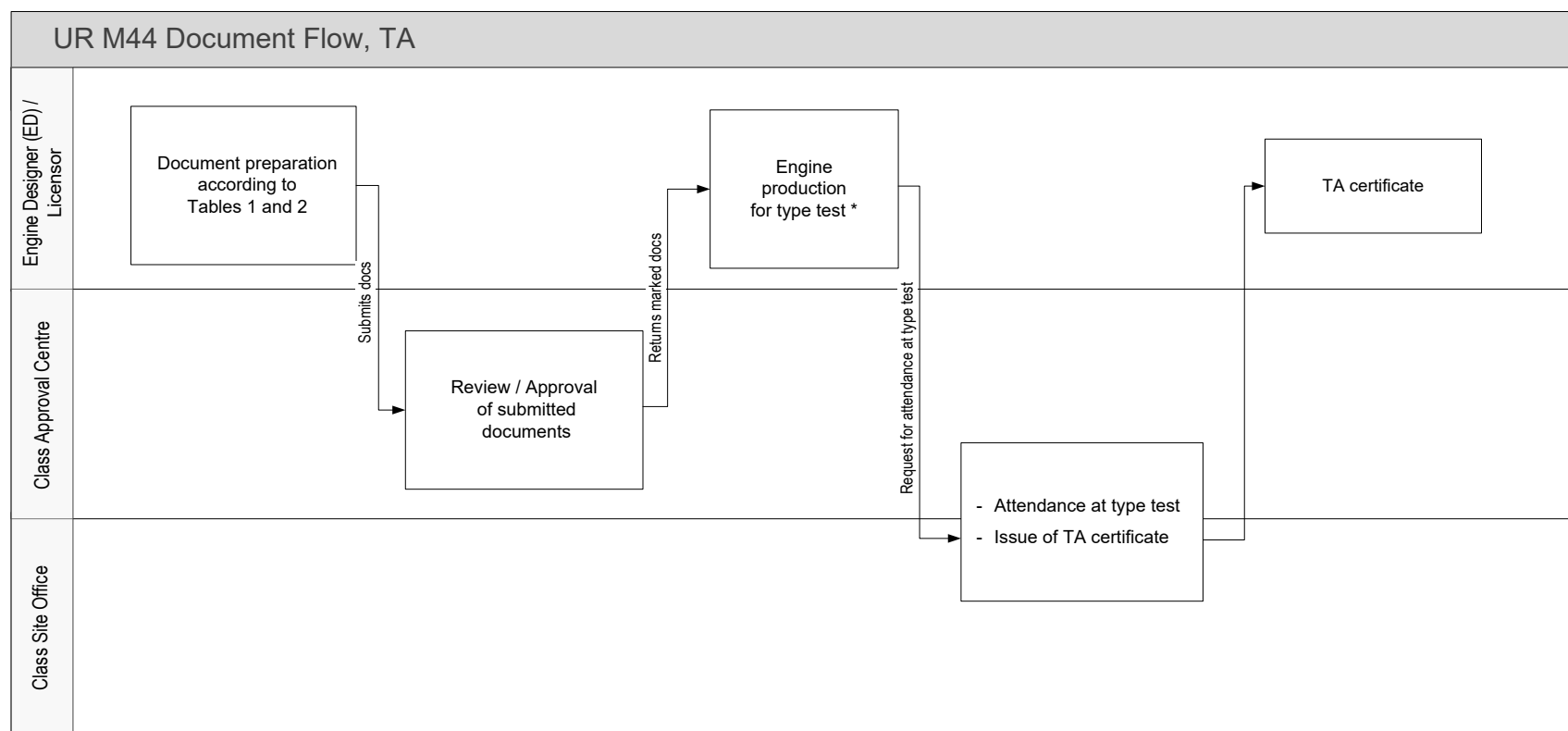
Term	Definition
Substantive modifications or major modifications or major changes	Design modifications, which lead to alterations in the stress levels, operational behaviour, fatigue life or an effect on other components or characteristics of importance such as emissions
Subsupplier/subcontractor	One who contracts to supply material to another supplier
Supplier	One who contracts to furnish materials or design, products, service or components to a customer or user
Test	A technical operation that consists of the determination of one or more characteristics or performance of a given product, material, equipment, organism, physical phenomenon, process or service according to a specified procedure. A technical operation to determine if one or more characteristic(s) or performance of a product, process or service satisfies specific requirements
Traceability	Ability to follow back through the design and manufacturing process to the origin
Type approval	The establishment of the acceptability of a product through the systematic: 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
Type approval test	Last step of the type approval procedure. Test program in accordance with UR M71
Witness	Individual physically present at a test and being able to record and give evidence about its outcome

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UR M44 - APPENDIX 2 - REPRESENTATIVE DOCUMENT FLOW DIAGRAMS

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.

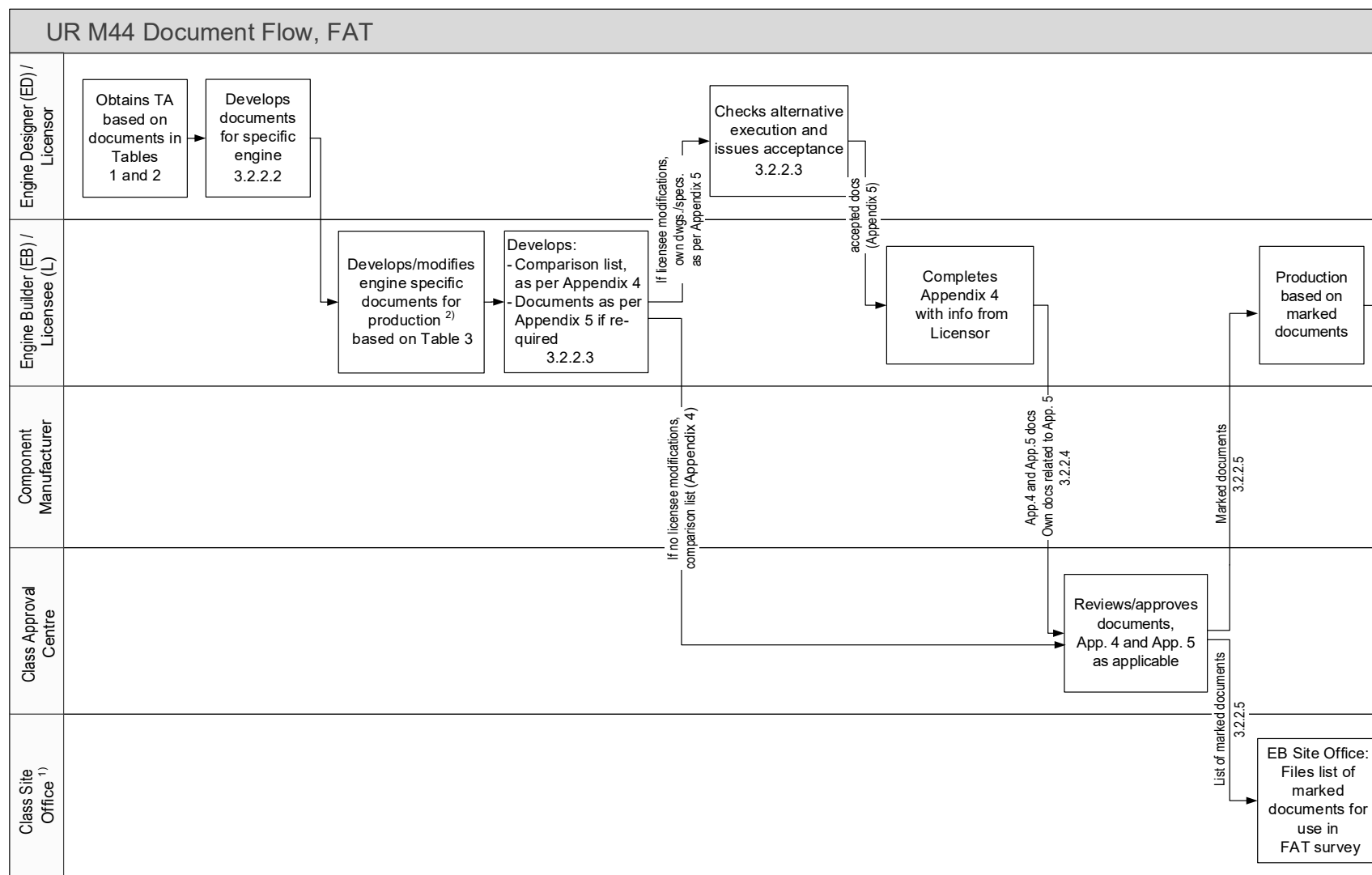


* May also be produced by licensee

Figure 1 Type approval document flow

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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

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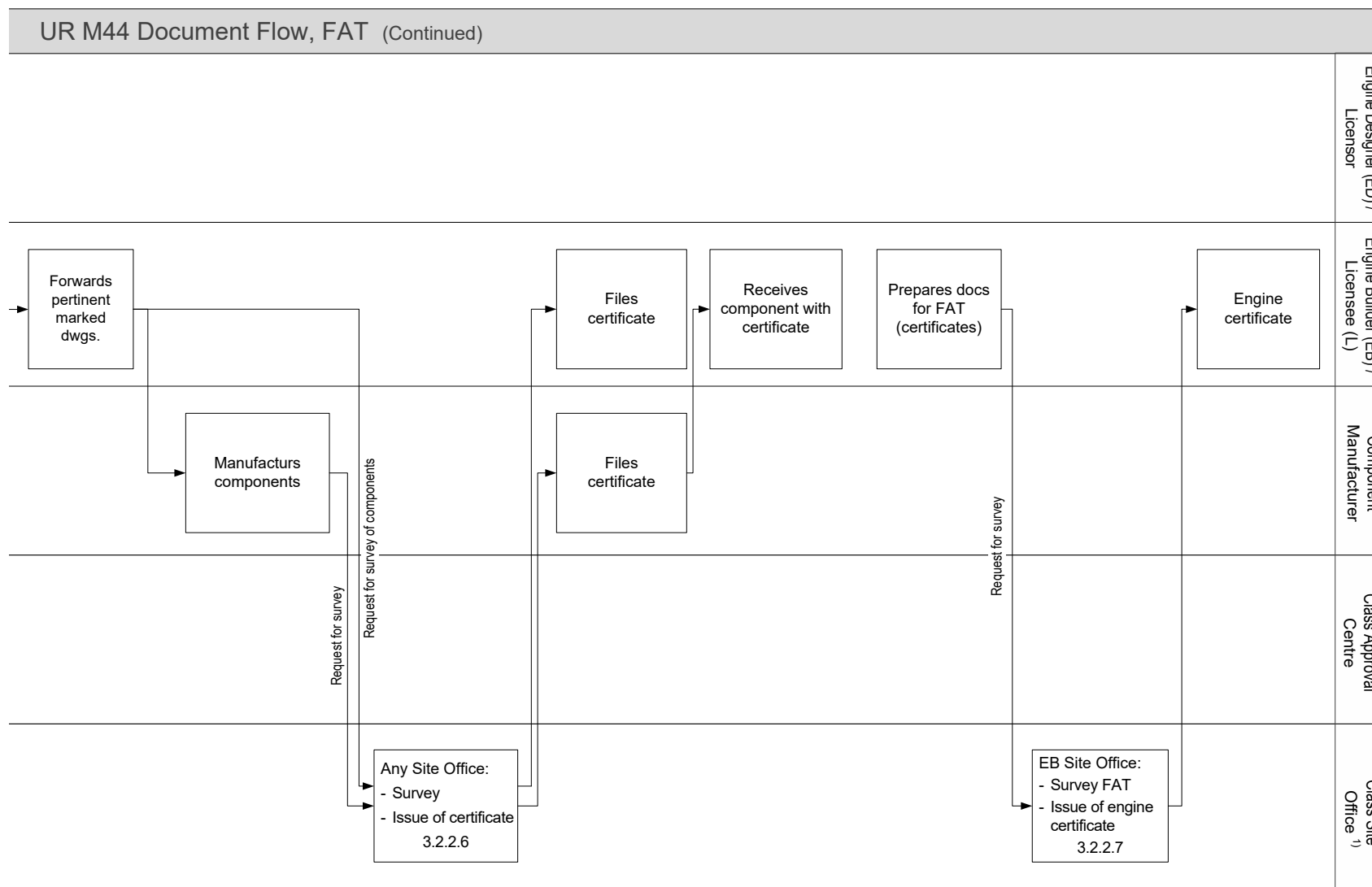


Figure 2 Engine certificate document flow (continued)

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UR M44 - APPENDIX 3 - Internal Combustion Engine Approval Application Form and Data Sheet

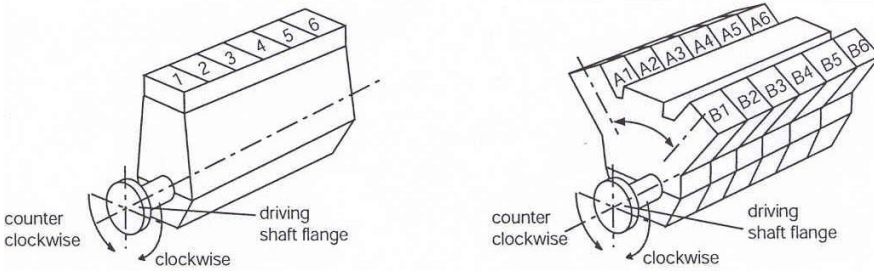
Class Application number (if applicable):

Engine Manufacturer's Application Identification Number:

General Data			
Engine Designer: Contact Person: Address:		Engine Manufacturer(s), Licensee(s) and/or Manufacturing Sites* Name Country	
1. Document purpose (select options from either 1a or 1b)			
1a. Type Approval Application			
Service Requested		Required activities [†]	
☐ New Type Approval ☐ Renew Type Approval ☐ Amend Type Approval ☐ Design Evaluation ☐ Update TA Supplement ☐ Other		• 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), as amended, for emergency engines	
For TA Cert amendments or Supplement updates, details of what is to be changed:			
For 'Other', Details of the requirements to be considered:			
1b. Addendum for Individual Engine FAT and Certification			
☐ Individual engine requiring FAT and Certification, only where the performance data for the engine being certified differs from the details provided on the original Type Approval Application. Only section 3b requires completion. Where changes to other sections are necessary, a new Type Approval Application may be required.			
Reference number of Internal Combustion Engine Approval Application Form previously submitted and reference number of the Type Approval Certificate.		(Copy of original application form to be attached to this document)	
2. Existing documentation			
Previous Class Type Approval Certificate No. or related Design Approval No. (if applicable)			
Formerly issued documentation for engine (E.g. previous type test reports, in-service experience justification reports, etc.)	Issuing Body:	Document Type:	Document No.:
Existing Certification (E.g. Manufacturer's quality certification ISO 9001:2015 etc.)	Issuing Body:	Document Type:	Document No.:
3. Design (mark all that apply)			
3a. Engine Particulars:			
Engine Type Manufactured Since [‡] :		Number of delivered marine engines [‡] :	
Application	☐ Direct drive Propulsion ☐ Auxiliary ☐ Emergency ☐ Single engine / ☐ Multi-engine installation ☐ Aux. Services / ☐ Electric Propulsion		
Mechanical Design	☐ 2-stroke ☐ 4-stroke ☐ In-line ☐ Vee (V-angle °) ☐ Other () ☐ Cross-head ☐ Trunk-piston ☐ Reversible ☐ Non-reversible Cylinder bore(mm) Length of piston stroke (mm)		
Supercharging	☐ Without supercharging ☐ With supercharging ☐ Without charge air cooling ☐ With charge air cooling ☐ Constant-pressure charging system ☐ Pulsating pressure charging system		
Valve operation	☐ Cam control ☐ Electronic control		
Fuel Injection	☐ Direct injection ☐ Indirect injection ☐ Cam controlled injection ☐ Electronically controlled injection		

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Fuel Types ^s (Classification according to ISO 8216-1:2017)	☐ Marine residual fuel ☐ Marine distillate fuel ☐ Marine distillate fuel ☐ Low flashpoint liquid fuel (specify fuel type) ☐ Gas (specify gas type) ☐ Other (specify) ☐ Dual Fuel (specify combinations of fuels to be used simultaneously)		cSt (Max. kinematic viscosity at 50°C) DMA, DMB, DMC DMX
3b. Performance Data (Related to: Barometric pressure 1,000 mbar; Air temperature 45°C; Relative humidity 60%; Seawater temperature 32°C)			
Model reference No. (if applicable)			
Max. continuous rating	kW/cyl		
Rated speed	1/min		
Mean indicated pressure	MPa		
Mean effective pressure	MPa		
Max. firing pressure	MPa		
Charge air pressure	MPa		
Compression ratio	-		
Mean piston speed	m/s		
3c. Crankshaft			
Design	☐ Solid ☐ Semi-built ☐ Built		
Method of Manufacture	☐ Cast ☐ Forged ☐ Slab forged ☐ Approved die forged ☐ Continuous grain flow process		
State approved forge/works name:			
Is the crankshaft hardened by an approved process which includes the fillet radii of crankpins and journals? ☐ Yes ☐ No			
If yes, state process:			
Crankshaft material specification:			
U.T.S. (N/mm ²)		Yield strength (N/mm ²)	
Hardness value (Brinell/Vickers)		Elongation (%)	
Dimensional Data			
If shrunk on webs, state shrinkage allowance (mm)		Yield strength of crankweb material (N/mm ²)	
Centre of gravity of connecting rod from large end centre (mm)		Radius of gyration of connecting rod (mm)	
Mass of each crankweb (kg)		Centre of gravity of web from journal axis (mm)	
Mass of each counterweight (kg)		Centre of gravity of each counterweight from journal axis (mm)	
Axial length of main bearing (mm)		Main bearing working clearance (mm)	
Mass of flywheel at driving end (kg)		Mass of flywheel at opposite end (kg)	
Nominal alternating torsional stress in crankpin (N/mm ²)		Nominal alternating torsional stress in crank journal (N/mm ²)	
Length between centres (Total length)(mm)			
3d. Firing order			
			
State numbering system of cylinders from left to right as per above diagrams (as applicable)			
Number of cylinders	Clockwise firing order	Counter-clockwise firing order	

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4. Engine Ancillary Systems					
4a. Turbochargers		☐ Fitted		☐ Not Fitted	
Turbocharger oil supply by:		☐ Engine lub. oil system		☐ TC internal lub. oil system	
No. of cylinders	No. of aux blowers	No. of charge air coolers	No. of TC	TC manufacturer & type	TC type approval certificate No.
				/	
				/	
				/	
				/	
				/	
				/	
4b. Speed governor					
Engine application (Main/Aux/Emergency)		Manufacturer / type		Mode of operation	Type approval cert. No. (if electric / electronic gov.)
		/			
		/			
		/			
4c. Overspeed protection					
Independent overspeed protection available		☐ Yes ☐ No		Mode of operation:	
Manufacturer / type, if electronic:		/		Type approval certificate No.	
4d. Electronic systems					
Engine control and management system					
<i>Note: use Remarks section to identify when a different engine control system will be used for Type Test</i>					
Hardware: Manufacturer & Model:		/		Type approval certificate No.	
Software: Name & Version:		/		Software conformity certificate No.	
Additional electronic system 1:		System function:			
Manufacturer & type:		/			
		Type approval certificate No.			
Additional electronic system 2:		System function:			
Manufacturer & type:		/			
		Type approval certificate No.			
Additional electronic system 3:		System function:			
Manufacturer & type:		/			
		Type approval certificate No.			
4e. Starting System					
Type:					
4f. Safety devices/functions					
A flame arrestor or a bursting disk is installed		before each starting valve		☐ Yes ☐ No	
in the starting air system:		in the starting air manifold		☐ Yes ☐ No	
Crankcase relief valves available		☐ Yes ☐ No		Manufacturer / type: /	
Type approval certificate No.					
No. of cyl.	Total crankcase gross volume incl. attachments (m ³)	Type & size (mm) of relief valve		Relief area per relief valve (mm ²)	No. of relief valves
		/			
		/			
		/			
		/			
Method used for detection of potentially explosive crankcase condition:					
☐ Oil mist detector: Manufacturer / type: / Type approval certificate No.					
☐ Alternative method: ☐ crankcase pressure monitoring ☐ bearing temperature monitoring ☐ other:					
(mark all that apply) ☐ oil splash temperature monitoring ☐ recirculation arrangements					
Cylinder overpressure warning device available ☐ Yes ☐ No					
Type:		Opening pressure (bar):			
4g. Attached ancillary equipment (Mark all that apply)					
Engine driven pumps:					
☐ Main lubricating oil pump		☐ Sea cooling water pump		☐ LT-fresh cooling water pump	
☐ HT-fresh cooling water pump		☐ Fuel oil booster pump		☐ Hydraulic oil pump ☐ Other ()	
Engine attached motor driven pumps:					
☐ Lubricating oil pump		☐ Cooling fresh water pump		☐ Fuel oil booster pump	
☐ Hydraulic oil pump		☐ Other ()			

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Engine attached cooler or heater:				
☐ Lubricating oil cooler	☐ Lubricating oil heater	☐ Fuel oil valve cooler		
☐ Hydraulic oil cooler	☐ Cooling fresh water cooler			
Engine attached filter:				
Lubricating oil filter	☐ Single	☐ Duplex	☐ Automatic	
Fuel oil filter	☐ Single	☐ Duplex	☐ Automatic	
5. Inclination limits (engine operation is safeguarded under the following limits)		Athwartships		Fore-and-aft
		Static	Dynamic	Static Dynamic
Main & Auxiliary machinery	☐ 15.0°	☐ 22.5°	☐ 5.0°	☐ 7.5°
Emergency machinery	☐ 22.5°	☐ 22.5°	☐ 10.0°	☐ 10.0°
Emergency machinery on ships for the carriage of liquefied gas and liquid chemicals	☐ 30.0°	☐ 30.0°		
6. Main engine emergency operation				
At failure of one auxiliary blower, engine can be started and operated at partial load		☐ Yes	☐ No	
At failure of one turbocharger, engine operation can be continued		☐ Yes	☐ No	
7. References: Additional Information Attached to Application				
Document Name/Number	Summary of information contained in document			
8. Further Remarks:				

- * All parties that affect the final complete engine (e.g. manufacture, modify, adjust) are to be listed. All sites where such work is carried out may be required to complete CoP assessment.
- † DA = Design Appraisal, TT = Type Test, CoP = Assessment of Conformity of Production. See '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.

Completed By:

Signature: _____

Company:

Job Title:

Stamp:

Date:

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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.

M44

(cont)

UR M44 - APPENDIX 4 - Tabular Listing of Licensor's and Licensee's Drawing and Data

Licensee: _____

Licensor: _____

Licensee Engine No. : _____

Engine type: _____

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

I attest the above information to be correct and accurate.

Person in Charge (Licensee):

Printed Name

Signature

Date: _____

M44

(cont)

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

End of Document

M45 Ventilation of Machinery Spaces

(1982)

(Rev.1

Deleted in Nov 2022

1987)

(Rev.2

Feb 2011)

(Del

Nov 2022)

End of Document

M46

(1982)
(Rev.1
June 2002)
(Rev.2
Dec 2018)
(Rev.3
Aug 2023)

Ambient conditions – Inclinations and Ship Accelerations and Motions

M46.1 General

The ambient conditions specified under M46.2 and M46.3 are to be applied to the layout, selection and arrangement of shipboard machinery, equipment and appliances (addressed in this UR) to ensure proper operation.

Note:

1. The requirements of UR M46 Rev.2 are to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 January 2020.
2. The requirements of UR M46 Rev.3 are to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 January 2025.
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.

M46

(cont)

M46.2 Inclinations

Inclinations applied to respective components are as follows.

Installations, components	Angle of inclination [°] ²			
	Athwartships		Fore-and-aft	
	static	dynamic	static	dynamic
Main and auxiliary machinery	15	22.5	5 ⁴	7.5
Safety equipment, e.g. emergency power installations, emergency fire pump and their devices	22.5 ³	22.5 ³	10	10
Switch gear, electrical and electronic appliances ¹				
and remote-control systems				

Notes:

1. No undesired switching operations or operational changes are to occur.
2. Athwartships and fore-and-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.

M46.3 Shipboard accelerations

3.1 Main propulsion and steering machinery and auxiliary machinery that is essential to the propulsion and steering, and the safety of the ship shall be capable of operation under the effects of acceleration and motions.

3.2 The requirements in M46.4 to M46.6 apply where documented evidence of equipment suitability is specifically required by other relevant URs for such equipment or requested by the Classification Society.

M46.4 Documentation

4.1 For ships subject to the SOLAS Convention, ship builders are to identify and document the ship accelerations and motions periods to which machinery and equipment might be subjected to. The expected accelerations and ship motions periods are to be within machinery and equipment manufacturers requirements. The estimations are to consider vessel type, machinery or equipment location and expected service conditions.

M46
(cont)**M46.5 Evaluation of equipment suitability**

5.1 Machinery and equipment manufacturers are to submit evidence to the Classification Society that their machinery or equipment can operate under the required static and dynamic conditions stated in M46.2 and at least at the levels of shipboard accelerations as stated in M46.4 and/or specified in the relevant URs. Documentation of satisfactory performance shall take the form of:

- .1 Report of testing under representative conditions; or
- .2 Report of theoretical verification using recognised computational techniques accompanied by detailed and relevant validation data; or
- .3 Historical data which provides relevant demonstration of satisfactory experience in service.

M46.6 Installation and operation

6.1 Machinery and equipment manufacturers are to submit details of the requirements /recommendations for installation of the machinery and equipment onboard to ensure satisfactory operation in service under the required static and dynamic conditions as described in M46.2 and at least at the levels of shipboard accelerations as stated in M46.4 and/or specified in the relevant URs.

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

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

End of Document

M47 Bridge control of propulsion machinery for (1983) 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.

END

M48 Permissible limits of stresses due to (1983) torsional vibrations for intermediate, thrust and propeller shafts

UR M48 was replaced by UR M68 in February 2005.

END



M49 Availability of Machinery

(1984)
(Rev 1
1996)
(Rev. 2
1998)

Deleted in Dec 2003

(E8 has been merged with UR M49 to form a new UR M61 (Dec 2003))



M50 Programme for type testing of non-mass produced I.C. engines

(1986)
(Rev.1
1987)
(Rev.2
1991)
(Corr.
Feb
1999)
(Rev.3
Jan
2008)

Deleted Feb 2015, replaced by UR M71.

End of Document

M51 Factory Acceptance Test and Shipboard Trials of I.C. Engines

(1987)
(Rev.1
1990)
(Corr.1
1997)
(Rev.2
July 2003)
(Rev.3
Jan 2008)
(Rev.4
Feb 2015
Complete
revision)
(Corr.1
Oct 2018)

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 over-speed 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.

M51
(cont)

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)

M51

(cont)

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. |
|----|---|------------------|

M51 (cont)

- 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 M51.3.3.3.

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.

M51 (cont)

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.

M51
(cont)

- 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).

M51**(cont)***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 $1.032n_0$
(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.

M51

(cont)

- 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).

End of Document

M52 Length of aft stern bush bearing

(1986)
(Rev.1
Jan 2019)
(Rev.2
Nov 2019)

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.

2.3. Synthetic materials for application as oil lubricated stern tube bearings are to be Type Approved.

M52.3 Water lubricated bearings

3.1 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.

3.2 For a bearing of synthetic material, 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, provided the bearing design and material is substantiated by experiments to the satisfaction of the Society.

3.3 Synthetic materials for application as water lubricated stern tube bearings are to be Type Approved.

Note:

1. The requirements of M52 Rev.1 are to be uniformly implemented by IACS Societies on or after 1 January 2020.
2. The requirements of M52 Rev.2 are to be uniformly implemented by IACS Societies on or after 1 January 2021.

M52

(cont)

M52.4 Grease lubricated bearings

4.1 The length of a grease lubricated bearing is to be not less than 4.0 times the rule diameter of the shaft in way of the bearing.

End of Document

M53 Calculations for I.C. Engine Crankshafts

(1986)
(Rev.1,
Dec 2004)
(Rev.2,
Jan 2011)
(Rev.3
June 2017)
(Rev.4
Aug 2019)
(Rev.5
May 2023)

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Note:

1. Rev.1 is to be applied to crankshafts whose application for design approval is dated on or after 1 January 2007.
2. Rev.2 is to be applied to crankshafts whose application for design approval is dated on or after 1 January 2012.
3. Rev.3 is to be applied to crankshafts whose application for design approval is dated on or after 1 July 2018.
4. Rev.4 is to be applied to crankshafts whose application for design approval is dated on or after 1 January 2021.
5. Rev.5 is to be applied to crankshafts whose application for design approval is dated on or after 1 July 2024.

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(cont)

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(cont)

M 53.1 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

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(cont)

- 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 α_v [°] (see fig. 1)

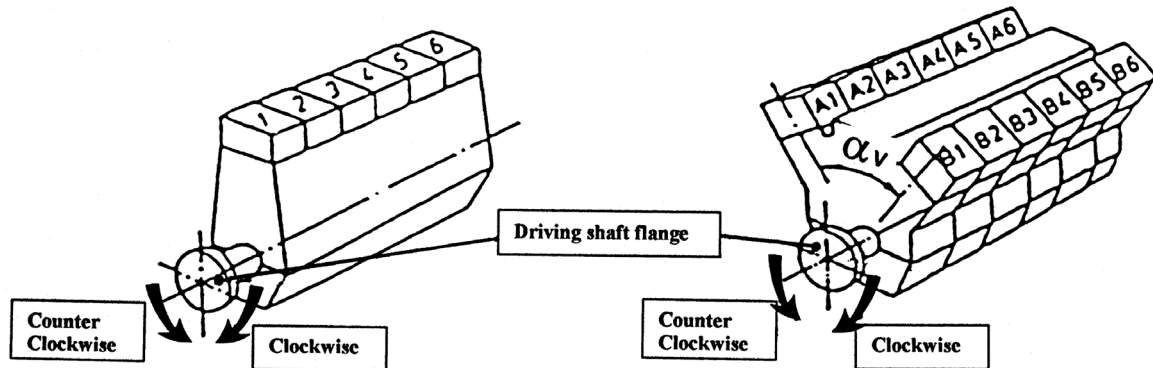


Fig. 1 – Designation of the cylinders

- cylinder diameter [mm]
- stroke [mm]
- maximum net cylinder pressure P_{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 α_N [°]
- connecting-rod length L_N [mm]

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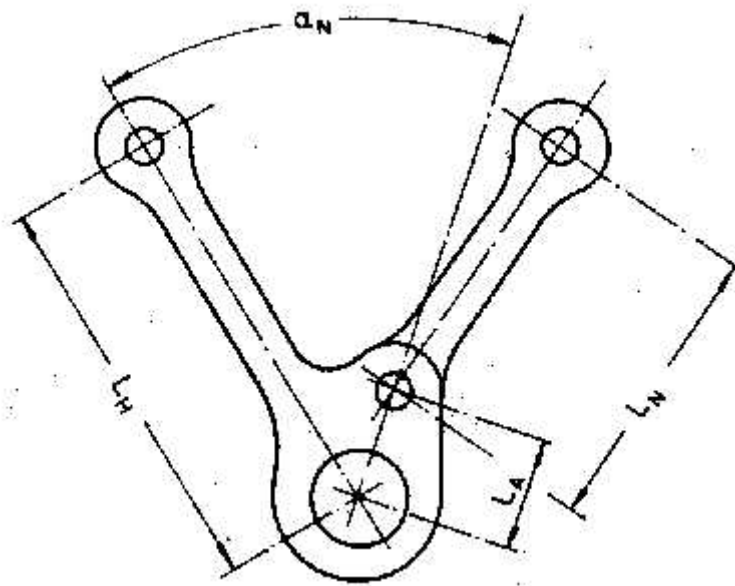


Fig. 2 – articulated-type connecting-rod

- 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 A_5 [%]
 - 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 specified so as to enable calculation according to Appendix V.
- Particulars of alternating torsional stress calculations, see item M 53.2.2.

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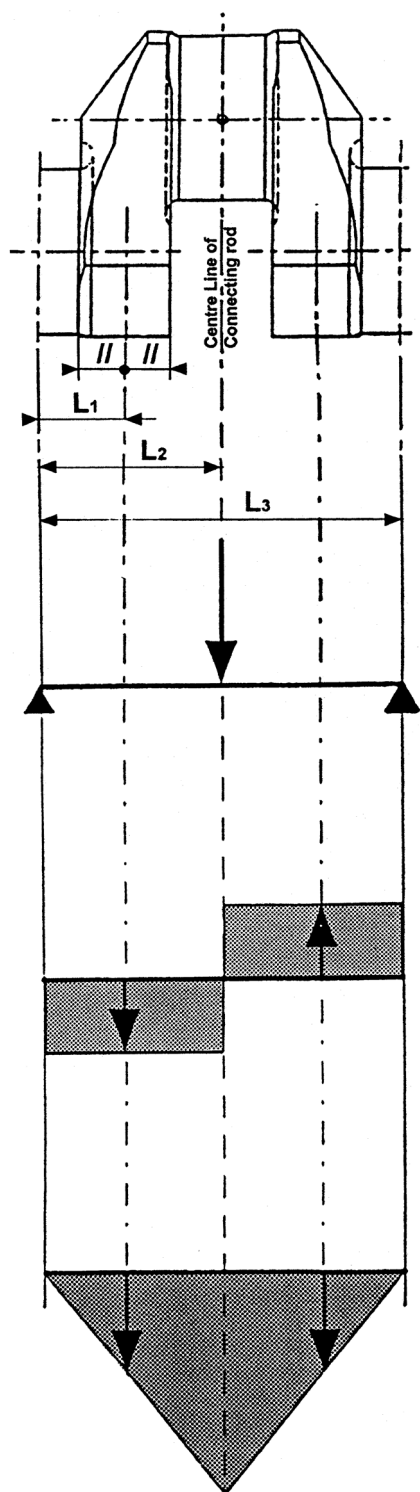


Fig. 3 Crankthrow for in line engine

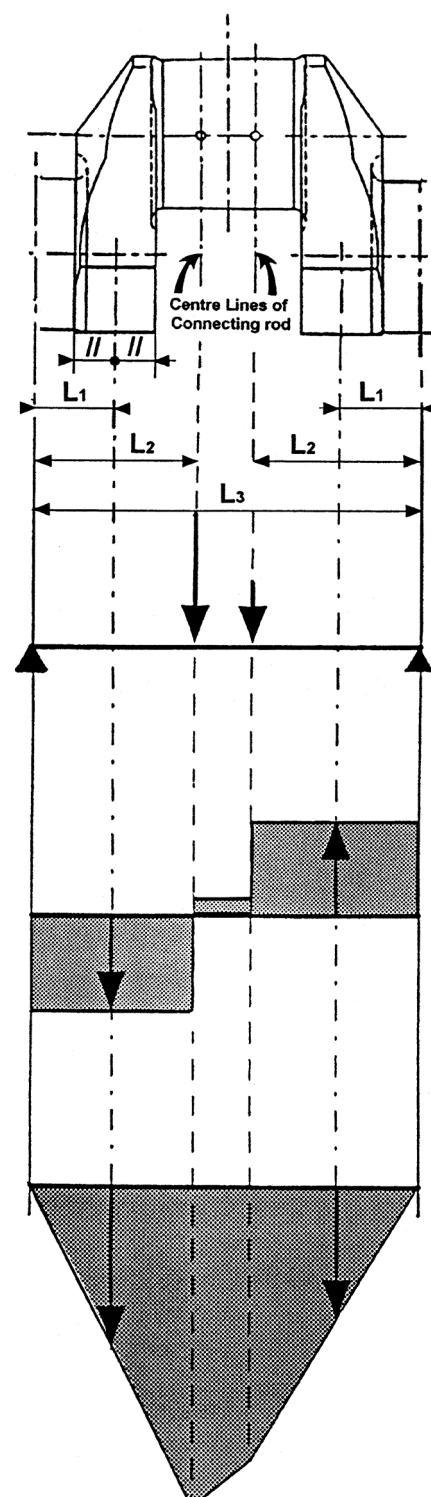


Fig. 4 Crankthrow for V engine with 2 adjacent connecting-rods

L_1 = Distance between main journal centre line and crankweb centre
(see also Fig 5 for crankshaft without overlap)

L_2 = Distance between main journal centre line and connecting-rod centre

L_3 = Distance between two adjacent main journal centre lines

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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

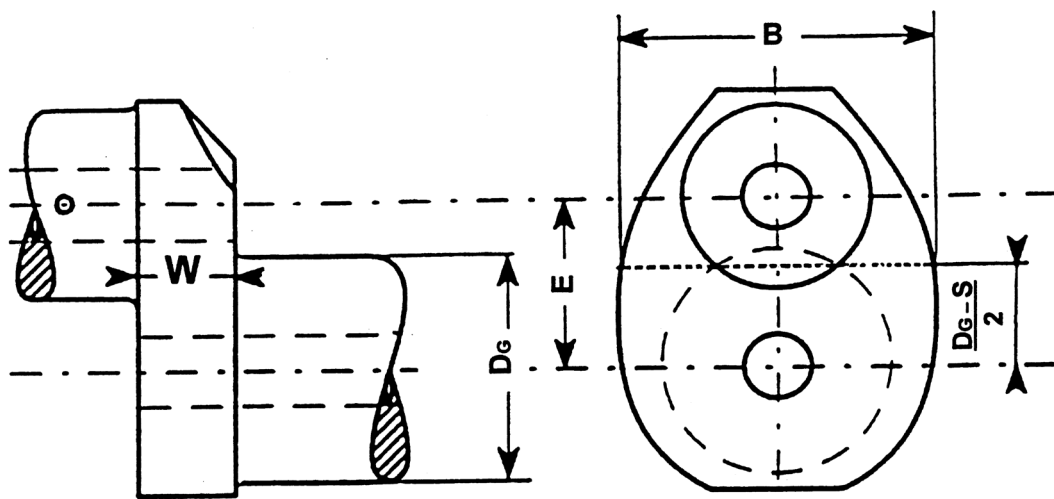
The bending moment M_{BRF} and the radial force Q_{RF} are taken as acting in the centre of the solid web (distance L_1) and are derived from the radial component of the connecting-rod force.

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).

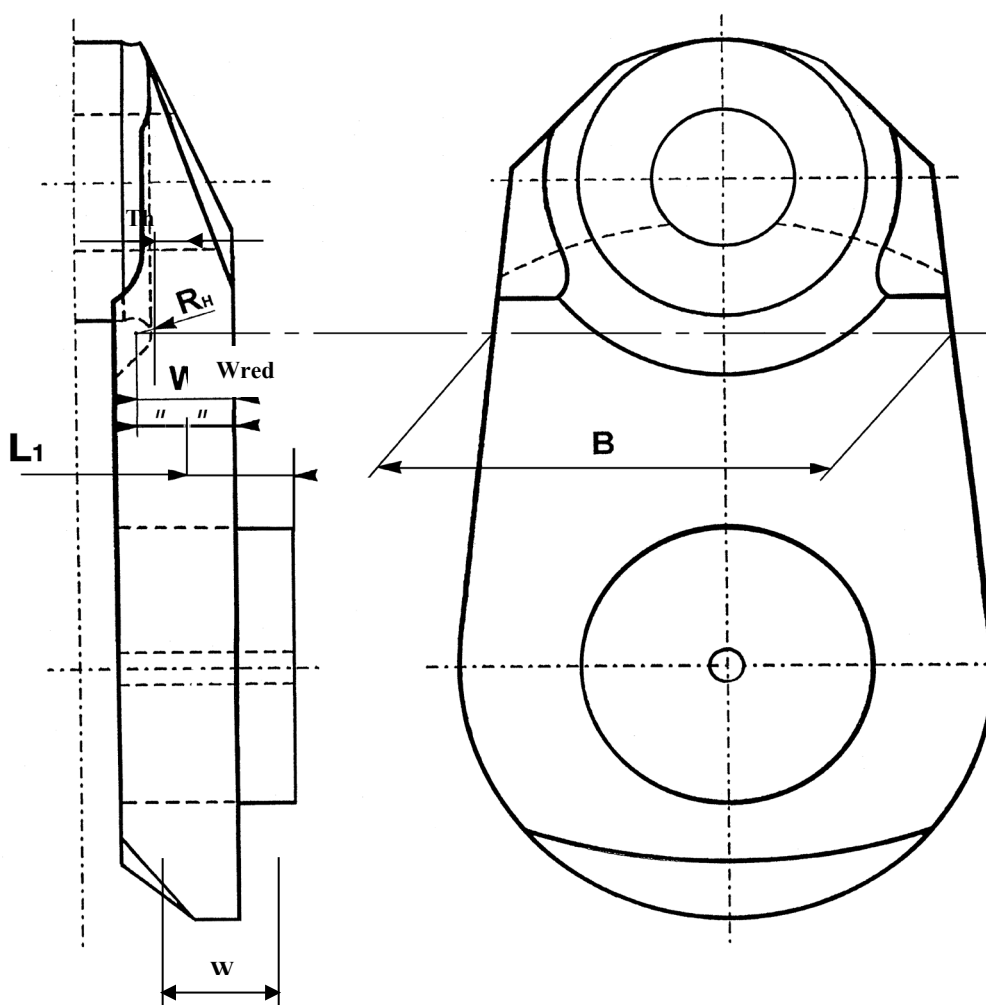
Mean stresses are neglected.

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Overlapped crankshaft



Crankshaft without overlap

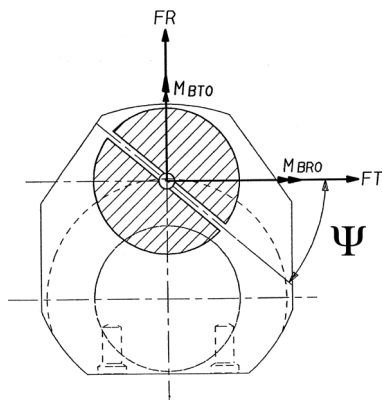
Fig. 5 – Reference area of crankweb cross section

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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.



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

M_{BTO} 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:

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

where:

X_N is considered as alternating force, moment or stress

$X_{\max}$ is maximum value within one working cycle

$X_{\min}$ is minimum value within one working cycle

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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:

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

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

where:

σ_{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)

$$M_{\text{BRFN}} = \pm \frac{1}{2} [M_{\text{BRFmax}} - M_{\text{BRFmin}}]$$

W_{eqw} [mm³] section modulus related to cross-section of web

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

K_e empirical factor considering to some extent the influence of adjacent crank and bearing restraint
with: $K_e = 0.8$ for 2-stroke engines
 $K_e = 1.0$ for 4-stroke engines

σ_{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)

$$Q_{\text{RFN}} = \pm \frac{1}{2} [Q_{\text{RFmax}} - Q_{\text{RFmin}}]$$

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:

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

M53**(cont)**

where:

 σ_{BON} [N/mm²] nominal alternating bending stress related to the crank pin diameter M_{BON} [Nm] alternating bending moment calculated at the outlet of crankpin oil bore

$$M_{\text{BON}} = \pm \frac{1}{2} [M_{\text{BO}_{\text{max}}} - M_{\text{BO}_{\text{min}}}]$$

with

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

and ψ [°] angular position (see fig. 6) W_e [mm³] section modulus related to cross-section of axially bored crankpin

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

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:

$$\sigma_{\text{BH}} = \pm (\alpha_{\text{B}} \cdot \sigma_{\text{BFN}})$$

where:

 σ_{BH} [N/mm²] alternating bending stress in crankpin fillet α_{B} [-] stress concentration factor for bending in crankpin fillet (determination - see item M53.3)

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

$$\sigma_{\text{BG}} = \pm (\beta_{\text{B}} \cdot \sigma_{\text{BFN}} + \beta_{\text{Q}} \cdot \sigma_{\text{QFN}})$$

where:

 σ_{BG} [N/mm²] alternating bending stress in journal fillet β_{B} [-] stress concentration factor for bending in journal fillet (determination - see item M53.3) β_{Q} [-] stress concentration factor for compression due to radial force in journal fillet (determination - see item M53.3)

M53

(cont)

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

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

where:

σ_{BO} [N/mm ²]	alternating bending stress in outlet of crankpin oil bore
γ_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:

$$\tau_N = \pm \frac{M_{TN}}{W_p} \bullet 10^3$$

$$M_{TN} = \pm \frac{1}{2} [M_{Tmax} - M_{Tmin}]$$

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

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

M53**(cont)**

where:

τ_N [N/mm ²]	nominal alternating torsional stress referred to crankpin or journal
M_{TN} [Nm]	maximum alternating torque
W_P [mm ³]	polar section modulus related to cross-section of axially bored crankpin or bored journal
M_{Tmax} [Nm]	maximum value of the torque
M_{Tmin} [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:

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

where:

τ_H [N/mm ²]	alternating torsional stress in crankpin fillet
α_T [-]	stress concentration factor for torsion in crankpin fillet (determination - see item M53.3)
τ_N [N/mm ²]	nominal alternating torsional stress related to crankpin diameter

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

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

M53**(cont)**

where:

τ_G [N/mm ²]	alternating torsional stress in journal fillet
β_T [-]	stress concentration factor for torsion in journal fillet (determination - see item M53.3)
τ_N [N/mm ²]	nominal alternating torsional stress related to journal diameter

For the outlet of crankpin oil bore:

$$\sigma_{TO} = \pm(\gamma_T \bullet \tau_N)$$

where:

σ_{TO} [N/mm ²]	alternating stress in outlet of crankpin oil bore due to torsion
γ_T [-]	stress concentration factor for torsion in outlet of crankpin oil bore (determination- see item M53.3)
τ_N [N/mm ²]	nominal alternating torsional stress related to crankpin diameter

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M 53.3 EVALUATION OF STRESS CONCENTRATION FACTORS

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 (α_B , β_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 (β_Q) in the journal fillet is defined as the ratio of the maximum equivalent stress (VON MISES) – occurring in the fillet due to the radial force – to the nominal compressive stress related to the web cross-section.

The stress concentration factor for torsion (α_T , β_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 (γ_B) and torsion (γ_T) are defined as the ratio of the maximum principal stress – occurring at the outlet of the crankpin oil-hole under bending and torsional loads – to the corresponding nominal stress related to the axially bored crankpin cross section (see 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. This is always to be performed when dimensions are outside of any of the validity ranges for the empirical formulae presented in 3.2 to 3.4.

Appendix III and VI describes how FE analyses can be used for the calculation of the stress concentration factors. Care should be taken to avoid mixing equivalent (von Mises) stresses and principal stresses.

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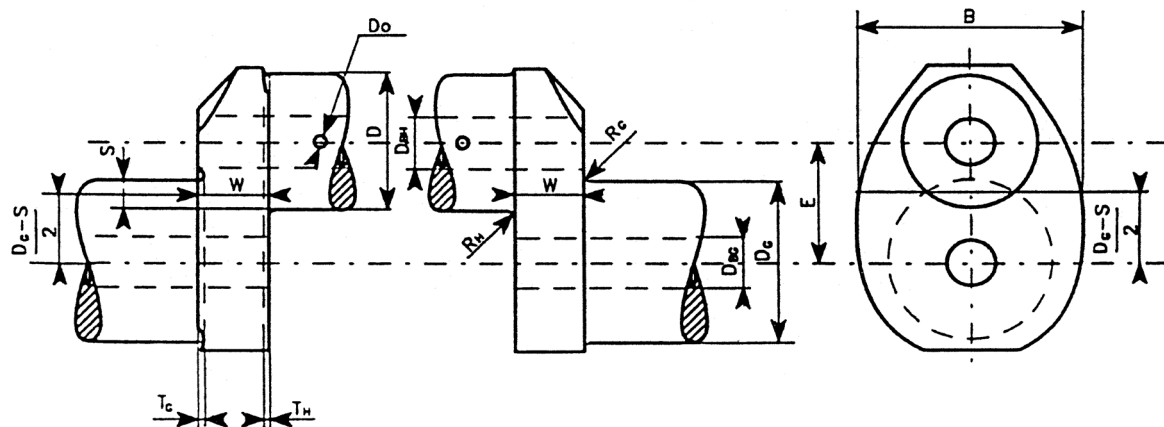


Fig. 7 – Crank dimensions

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

$$W_{red} = W - (T_H - R_H) \text{ [refer to fig. 5]}$$

- 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:

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Crankpin fillet	Journal fillet
$r = R_H / D$	$r = R_G / D$
$s = S/D$	
$w = W/D$ crankshafts with overlap	
W_{red}/D crankshafts without overlap	
$b = B/D$	
$d_o = D_o/D$	
$d_G = D_{BG}/D$	
$d_H = D_{BH}/D$	
$t_H = T_H/D$	
$t_G = T_G/D$	

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

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

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

- If calculated $f(\text{recess}) < 1$ 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 (α_B) is:

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

where:

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

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

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

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(cont)

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

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

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

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

The stress concentration factor for torsion (α_T) is:

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

where:

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

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

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

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

The stress concentration factor for bending (β_B) is:

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

where:

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

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

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

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

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

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

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

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

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

where:

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

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(cont)

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

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

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

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

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

The stress concentration factor for torsion (β_T) is:

$$\beta_T = \alpha_T$$

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

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 α_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 (γ_B) is:

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

The stress concentration factor for torsion (γ_T) is:

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

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(cont)

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 σ_{add} as given by table:

Type of engine	$\sigma_{add}[\text{N/mm}^2]$
Crosshead engines	± 30 (*)
Trunk piston engines	± 10

(*) The additional stress of $\pm 30 \text{ N/mm}^2$ is composed of two components

- 1) an additional stress of $\pm 20 \text{ N/mm}^2$ resulting from axial vibration
- 2) an additional stress of $\pm 10 \text{ N/mm}^2$ resulting from misalignment / bedplate deformation

It is recommended that a value of $\pm 20 \text{ N/mm}^2$ 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:

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

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(cont)

For the journal fillet:

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

For the outlet of crankpin oil bore:

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

where:

σ_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:

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

with:

$R_x = R_H$ in the fillet area

$R_x = D_o/2$ in the oil bore area

Related to the journal diameter:

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

where:

σ_{DW} [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)

factor 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

M53 (cont)

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. Guidance for calculation of surface treated fillets and oil bore outlets is presented in Appendix V.

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. For evaluation of test results, see Appendix IV.

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.

M53

(cont)

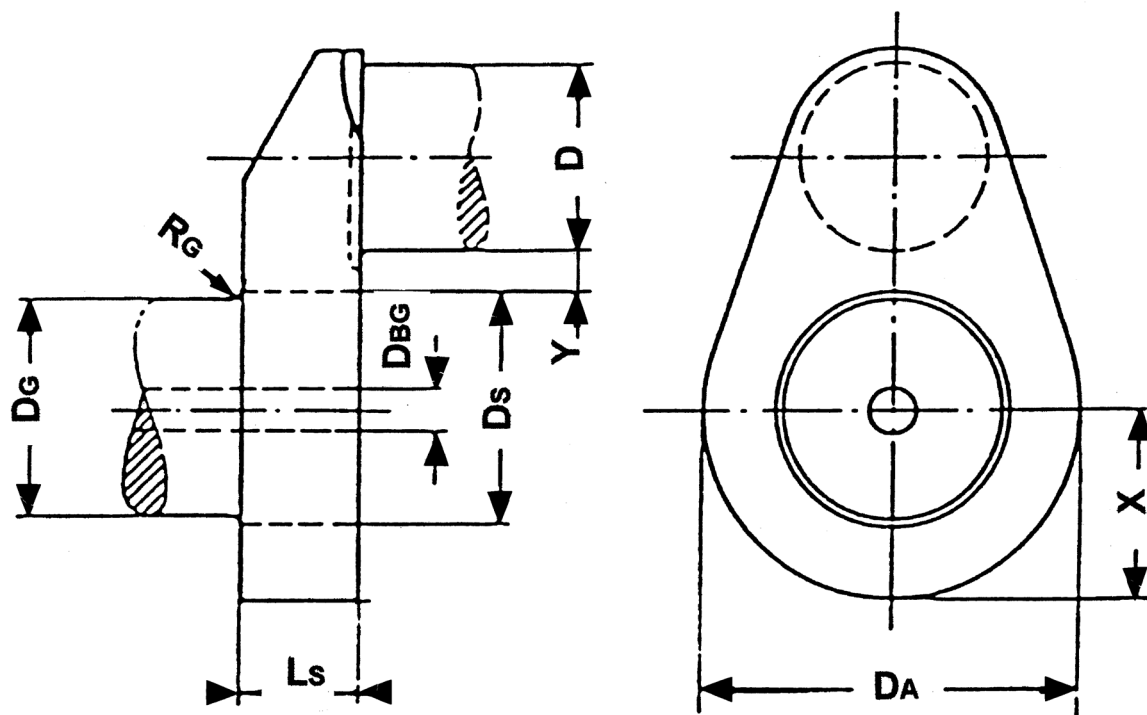


Fig. 8 – Crankthrow of semi-built crankshaft

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 $y \geq 0.05 \cdot D_S$ Where y is less than $0.1 \cdot D_S$ 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.

M53

(cont)

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 $Z_{\min}$ and $Z_{\max}$ 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 $Z_{\min}$ and $Z_{\max}$ are not applicable due to multizone-plasticity problems.

In such case $Z_{\min}$ and $Z_{\max}$ 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:

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

where:

S_R [-]	safety factor against slipping, however a value not less than 2 is to be taken unless documented by experiments.
$M_{\max}$ [Nm]	absolute maximum value of the torque $M_{T\max}$ in accordance with M 53 2.2.2
μ [-]	coefficient for static friction, however a value not greater than 0.2 is to be taken unless documented by experiments.
σ_{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.

M53

(cont)

8.3 Necessary minimum oversize of shrink-fit

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

$$Z_{\min} \geq \frac{\sigma_{sw} \cdot D_S}{E_m}$$

and

$$Z_{\min} \geq \frac{4000}{\mu \cdot \pi} \cdot \frac{S_R \cdot M_{\max}}{E_m \cdot D_S \cdot L_S} \cdot \frac{1 - Q_A^2 \cdot Q_S^2}{(1 - Q_A^2) \cdot (1 - Q_S^2)}$$

where:

$Z_{\min}$ [mm] minimum oversize

E_m [N/mm²] Young's modulus

σ_{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:

$$Z_{\max} \leq D_S \cdot \left(\frac{\sigma_{sw}}{E_m} + \frac{0.8}{1000} \right)$$

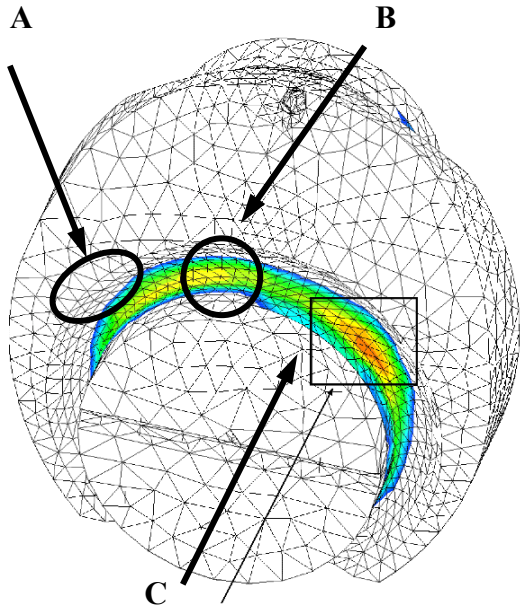
This condition serves to restrict the shrinkage induced mean stress in the fillet.

Definition of Stress Concentration Factors in crankshaft fillets

Appendix I

M53

(cont)



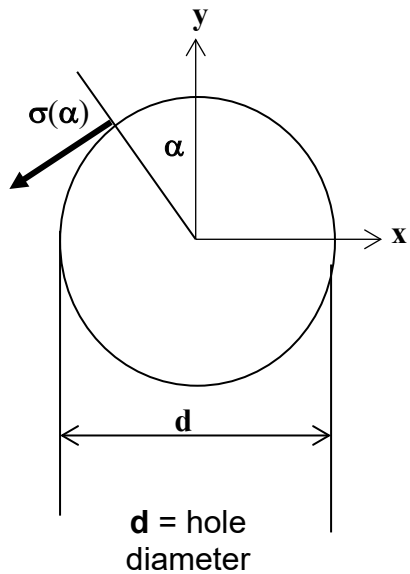
	Stress	Max $ \sigma_3 $	Max σ_1	
Torsional loading	Location of maximal stresses	A	C	B
	Typical principal stress system Mohr's circle diagram with $\sigma_2 = 0$	$ \sigma_3 > \sigma_1$	$\sigma_1 > \sigma_3 $	$\sigma_1 \approx \sigma_3 $
	Equivalent stress and S.C.F.	$\tau_{\text{equiv}} = \frac{\sigma_1 - \sigma_3}{2}$ $\text{S.C.F.} = \frac{\tau_{\text{equiv}}}{\tau_n} \text{ for } \alpha_T, \beta_T$		
Bending loading	Location of maximal stresses	B	B	B
	Typical principal stress system Mohr's circle diagram with $\sigma_3 = 0$	$\sigma_2 \neq 0$		
	Equivalent stress and S.C.F.	$\sigma_{\text{equiv}} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \cdot \sigma_2}$ $\text{S.C.F.} = \frac{\sigma_{\text{equiv}}}{\sigma_n} \text{ for } \alpha_B, \beta_B, \beta_Q$		

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

Appendix II

M53

(cont)



Stress type	Nominal stress tensor	Uniaxial stress distribution around the edge	Mohr's circle diagram
Tension	$\begin{bmatrix} \sigma_n & 0 \\ 0 & 0 \end{bmatrix}$	$\sigma_\alpha = \sigma_n \gamma_B / 3 [1 + 2 \cos(2\alpha)]$	$\gamma_B = \sigma_{\max} / \sigma_n \text{ for } \alpha = k\pi$
Shear	$\begin{bmatrix} 0 & \tau_n \\ \tau_n & 0 \end{bmatrix}$	$\sigma_\alpha = \gamma_T \tau_n \sin(2\alpha)$	$\gamma_T = \sigma_{\max} / \tau_n \text{ for } \alpha = \frac{\pi}{4} + k \frac{\pi}{2}$
Tension + shear	$\begin{bmatrix} \sigma_n & \tau_n \\ \tau_n & 0 \end{bmatrix}$	$\sigma_\alpha = \frac{\gamma_B}{3} \sigma_n \left\{ 1 + 2 \left[\cos(2\alpha) + \frac{3}{2} \frac{\gamma_T \tau_n}{\gamma_B \sigma_n} \sin(2\alpha) \right] \right\}$	$\sigma_{\max} = \frac{\gamma_B}{3} \sigma_n \left[1 + 2 \sqrt{1 + \frac{9}{4} \left(\frac{\gamma_T \tau_n}{\gamma_B \sigma_n} \right)^2} \right]$ $\text{for } \alpha = \frac{1}{2} \text{tg}^{-1} \left(\frac{3\gamma_T \tau_n}{2\gamma_B \sigma_n} \right)$

M53

(cont)

Appendix III

Guidance 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

M53 (cont)

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.

M53 (cont)

- 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.

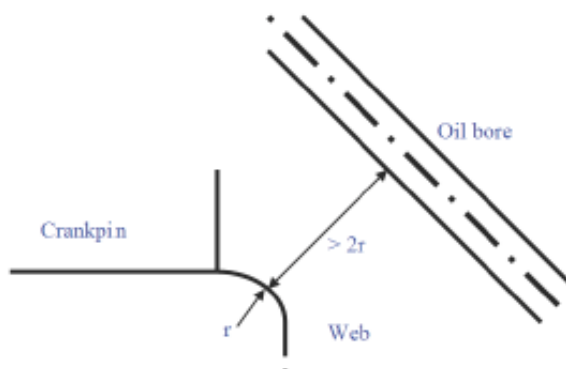


Figure 2.1. Oil bore proximity to fillet.

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 σ_1 , σ_2 and σ_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_i should differ less than by 5 % from the 100 % averaged nodal stress results at this node_i at the examined location.

M53 (cont)

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.

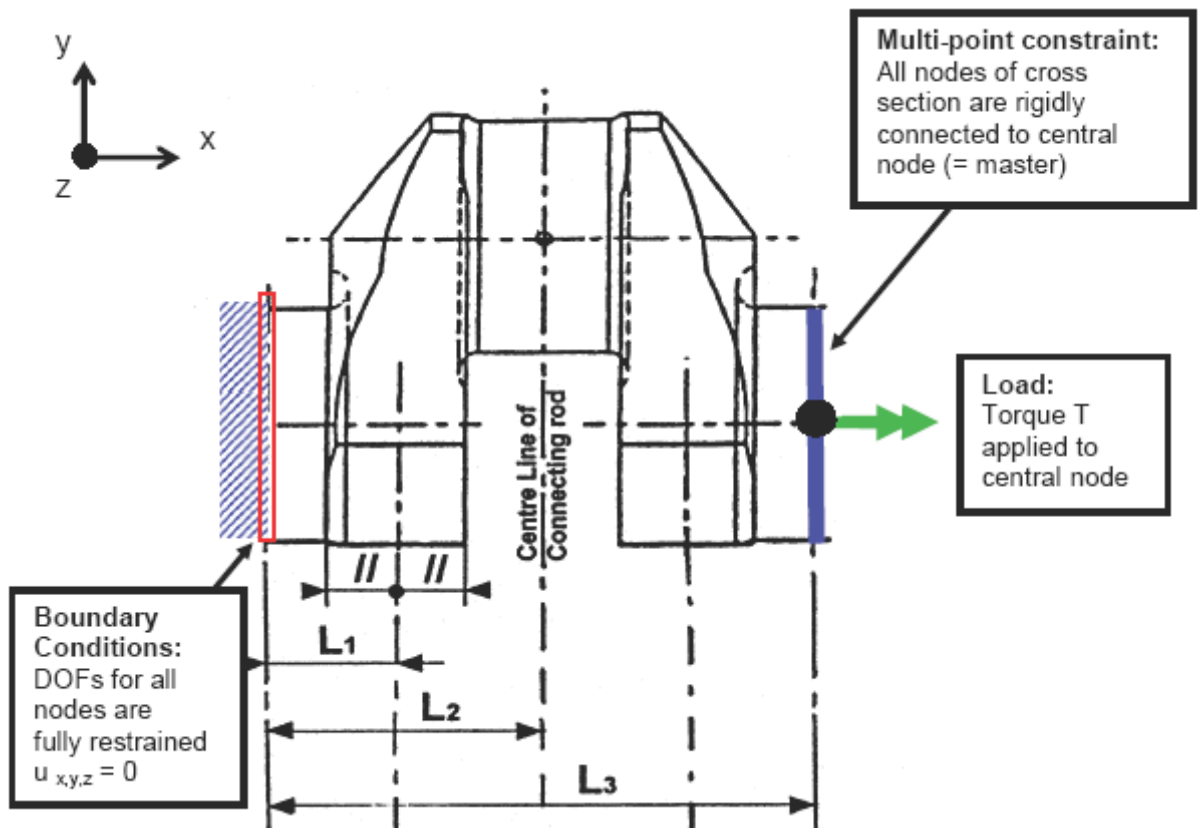


Figure 3.1 Boundary and load conditions for the torsion load case.

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

$$\tau_{equiv} = \max \left(\frac{|\sigma_1 - \sigma_2|}{2}, \frac{|\sigma_2 - \sigma_3|}{2}, \frac{|\sigma_1 - \sigma_3|}{2} \right)$$

The maximum value taken for the subsequent calculation of the SCF:

$$\alpha_T = \frac{\tau_{equiv,\alpha}}{\tau_N}$$

M53 (cont)

$$\beta_T = \frac{\tau_{equiv,\beta}}{\tau_N}$$

where τ_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.

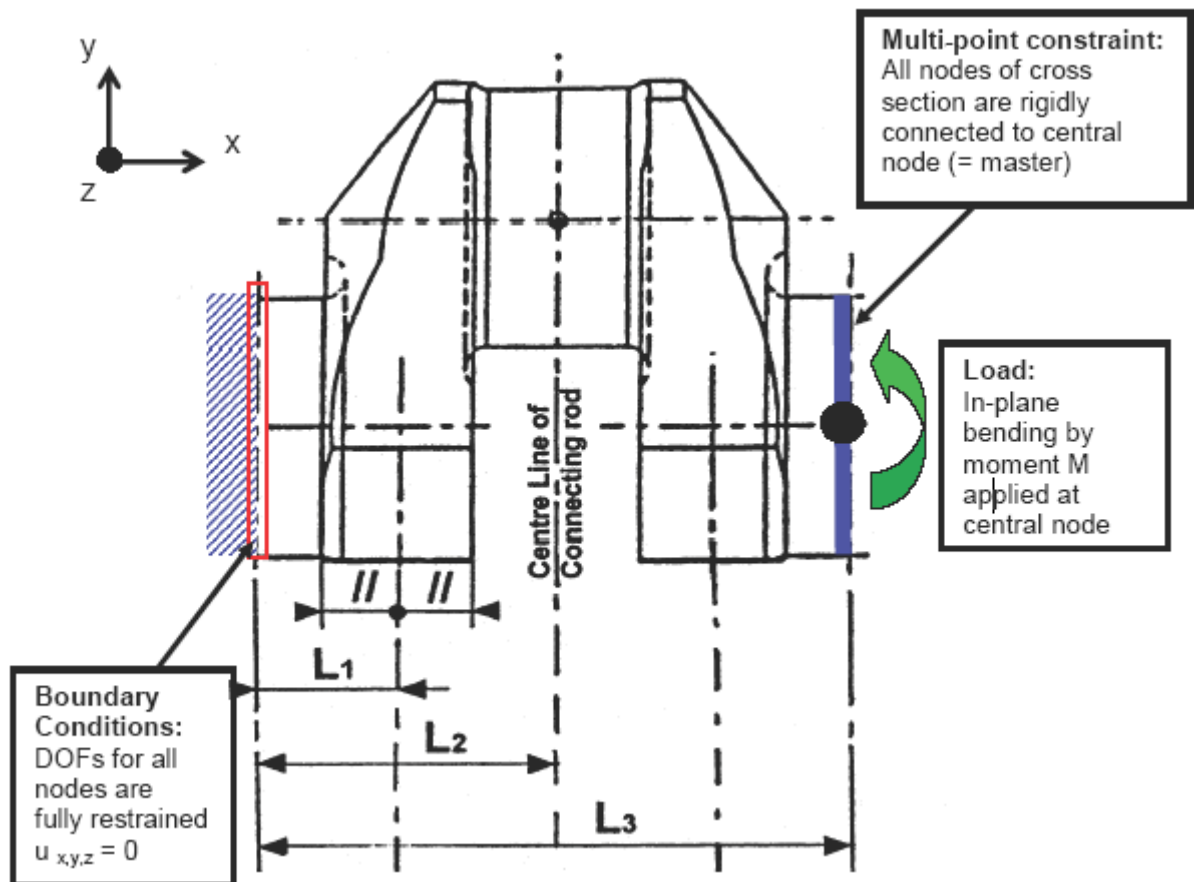


Figure 3.2 Boundary and load conditions for the pure bending load case.

M53 (cont)

For all nodes in both the journal and pin fillet von Mises equivalent stresses σ_{equiv} are extracted. The maximum value is used to calculate the SCF according to:

$$\alpha_B = \frac{\sigma_{equiv,\alpha}}{\sigma_N}$$

$$\beta_B = \frac{\sigma_{equiv,\beta}}{\sigma_N}$$

Nominal stress σ_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, β_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.

M53

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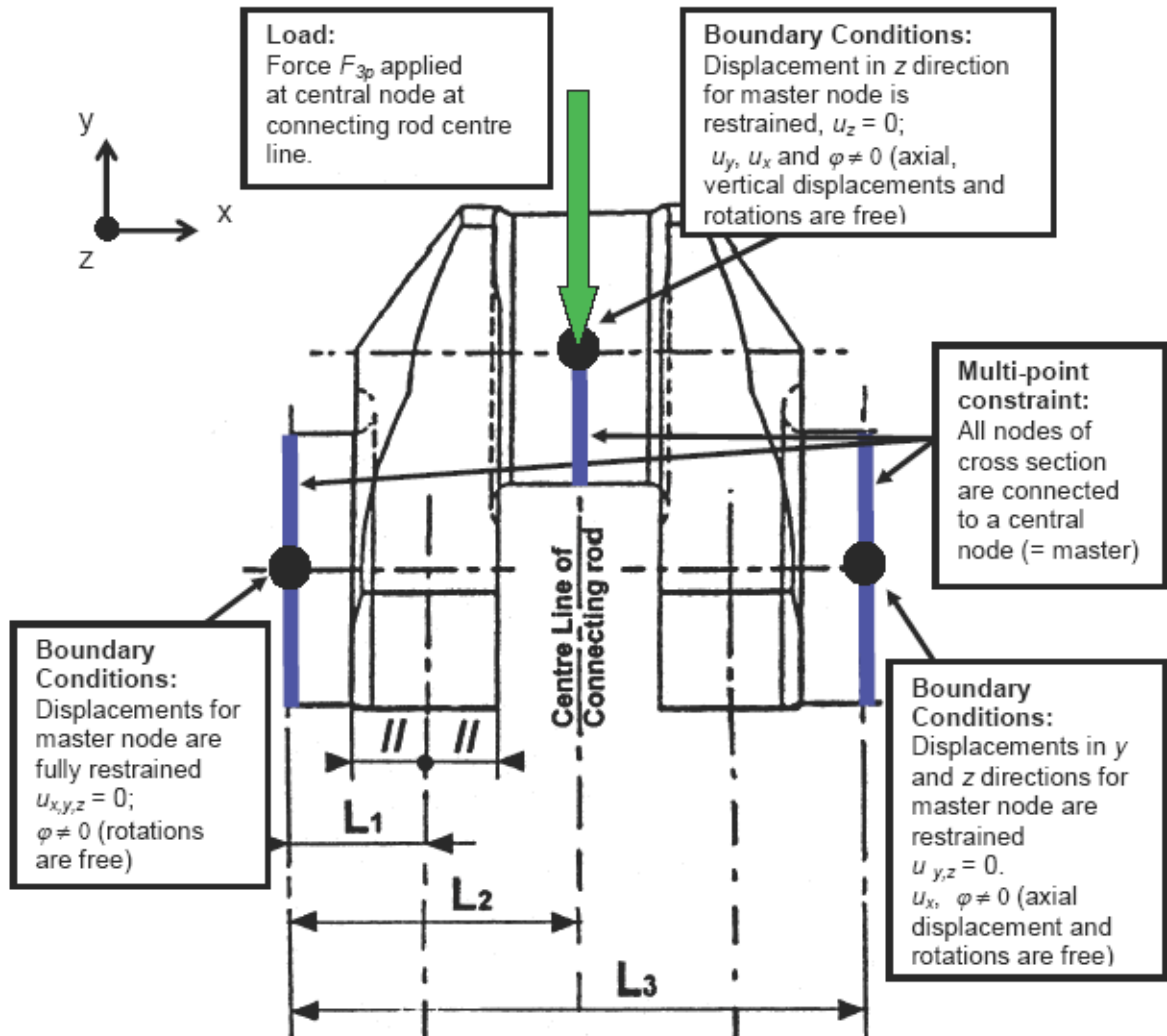


Figure 3.3. Boundary and load conditions for the 3-point bending load case of an inline engine.

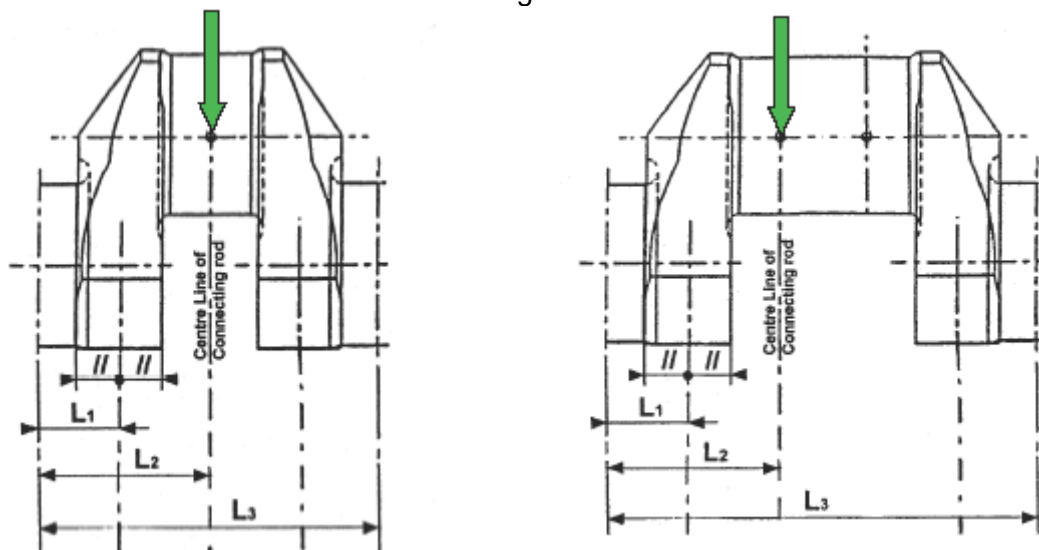


Figure 3.4 Load applications for in-line and V-type engines.

M53 (cont)

The maximum equivalent von Mises stress σ_{3P} in the journal fillet is evaluated. The SCF in the journal fillet can be determined in two ways as shown below.

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:

σ_{3P} as found by the FE calculation.

σ_{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.

β_B as determined in paragraph 3.2.

$\sigma_{Q3P} = Q_{3P} / (B.W)$ 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

$$\beta_{BQ} = \frac{\sigma_{3P}}{\sigma_{N3P}}$$

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:

$$\sigma_{BG} = \pm |\beta_{BQ} \cdot \sigma_{BFN}|$$

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.

M53
(cont)**Appendix IV****Guidance for Evaluation of Fatigue Tests**

Contents

1. Introduction

- 1.1. Small specimen testing
- 1.2. Full-size crank throw testing

2. Evaluation of test results

- 2.1. Principles
- 2.2. Staircase method
- 2.3. Modified staircase method
- 2.4. Calculation of sample mean and standard deviation
- 2.5. Confidence interval for mean fatigue limit
- 2.6. Confidence interval for standard deviation

3. Small specimen testing

- 3.1. Determination of bending fatigue strength
- 3.2. Determination of torsional fatigue strength
- 3.3. Other test positions
- 3.4. Correlation of test results

4. Full size testing

- 4.1. Hydraulic pulsation
- 4.2. Resonance tester
- 4.3. Use of results and crankshaft acceptability

5. Use of existing results for similar crankshafts

M53

(cont)

1. Introduction

Fatigue testing can be divided into two main groups; testing of small specimens and full-size crank throws. Testing can be made using the staircase method or a modified version thereof which is presented in this document. Other statistical evaluation methods may also be applied.

1.1. Small specimen testing

For crankshafts without any fillet surface treatment, the fatigue strength can be determined by testing small specimens taken from a full-size crank throw. When other areas in the vicinity of the fillets are surface treated introducing residual stresses in the fillets, this approach cannot be applied.

One advantage of this approach is the rather high number of specimens which can be then manufactured. Another advantage is that the tests can be made with different stress ratios (R-ratios) and/or different modes e.g. axial, bending and torsion, with or without a notch. This is required for evaluation of the material data to be used with critical plane criteria.

1.2. Full-size crank throw testing

For crankshafts with surface treatment the fatigue strength can only be determined through testing of full size crank throws. For cost reasons, this usually means a low number of crank throws. The load can be applied by hydraulic actuators in a 3- or 4- point bending arrangement, or by an exciter in a resonance test rig. The latter is frequently used, although it usually limits the stress ratio to $R = -1$.

2. Evaluation of test results**2.1. Principles**

Prior to fatigue testing the crankshaft must be tested as required by quality control procedures, e.g. for chemical composition, mechanical properties, surface hardness, hardness depth and extension, fillet surface finish, etc.

The test samples should be prepared so as to represent the “lower end” of the acceptance range e.g. for induction hardened crankshafts this means the lower range of acceptable hardness depth, the shortest extension through a fillet, etc. Otherwise the mean value test results should be corrected with a confidence interval: a 90% confidence interval may be used both for the sample mean and the standard deviation.

The test results, when applied in M53, shall be evaluated to represent the mean fatigue strength, with or without taking into consideration the 90% confidence interval as mentioned above. The standard deviation should be considered by taking the 90% confidence into account. Subsequently the result to be used as the fatigue strength is then the mean fatigue strength minus one standard deviation.

If the evaluation aims to find a relationship between (static) mechanical properties and the fatigue strength, the relation must be based on the real (measured) mechanical properties, not on the specified minimum properties.

The calculation technique presented in Chapter 2.4 was developed for the original staircase method. However, since there is no similar method dedicated to the modified staircase method the same is applied for both.

M53

(cont)

2.2. Staircase method

In the original staircase method, the first specimen is subjected to a stress corresponding to the expected average fatigue strength. If the specimen survives 10^7 cycles, it is discarded and the next specimen is subjected to a stress that is one increment above the previous, i.e. a survivor is always followed by the next using a stress one increment above the previous. The increment should be selected to correspond to the expected level of the standard deviation.

When a specimen fails prior to reaching 10^7 cycles, the obtained number of cycles is noted and the next specimen is subjected to a stress that is one increment below the previous. With this approach, the sum of failures and run-outs is equal to the number of specimens.

This original staircase method is only suitable when a high number of specimens are available. Through simulations it has been found that the use of about 25 specimens in a staircase test leads to a sufficient accuracy in the result.

2.3. Modified staircase method

When a limited number of specimens are available, it is advisable to apply the modified staircase method. Here the first specimen is subjected to a stress level that is most likely well below the average fatigue strength. When this specimen has survived 10^7 cycles, this **same** specimen is subjected to a stress level one increment above the previous. The increment should be selected to correspond to the expected level of the standard deviation. This is continued with the same specimen until failure.

Then the number of cycles is recorded and the next specimen is subjected to a stress that is at least 2 increments below the level where the previous specimen failed.

With this approach, the number of failures usually equals the number of specimens. The number of run-outs, counted as the highest level where 10^7 cycles were reached, also equals the number of specimens.

The acquired result of a modified staircase method should be used with care, since some results available indicate that testing a runout on a higher test level, especially at high mean stresses, tends to increase the fatigue limit. However, this "training effect" is less pronounced for high strength steels (e.g. UTS > 800 MPa).

If the confidence calculation is desired or necessary, the minimum number of test specimens is 3.

2.4. Calculation of sample mean and standard deviation

A hypothetical example of tests for 5 crank throws is presented further in the subsequent text. When using the modified staircase method and the evaluation method of Dixon and Mood, the number of samples will be 10, meaning 5 run-outs and 5 failures, i.e.:

Number of samples, $n=10$

Furthermore, the method distinguishes between

Less frequent event is failures $C=1$
Less frequent event is run-outs $C=2$

The method uses only the less frequent occurrence in the test results, i.e. if there are more failures than run-outs, then the number of run-outs is used, and vice versa.

M53

(cont)

In the modified staircase method, the number of run-outs and failures are usually equal. However, the testing can be unsuccessful, e.g. the number of run-outs can be less than the number of failures if a specimen with 2 increments below the previous failure level goes directly to failure. On the other hand, if this unexpected premature failure occurs after a rather high number of cycles, it is possible to define the level below this as a run-out.

Dixon and Mood's approach, derived from the maximum likelihood theory, which also may be applied here, especially on tests with few samples, presented some simple approximate equations for calculating the sample mean and the standard deviation from the outcome of the staircase test. The sample mean can be calculated as follows:

$$\overline{S}_a = S_{a0} + d \cdot \left(\frac{A}{F} - \frac{1}{2} \right) \quad \text{when } C=1$$

$$\overline{S}_a = S_{a0} + d \cdot \left(\frac{A}{F} + \frac{1}{2} \right) \quad \text{when } C=2$$

The standard deviation can be found by

$$s = 1.62 \cdot d \cdot \left(\frac{F \cdot B - A^2}{F^2} + 0.029 \right)$$

where:

S_{a0} is the lowest stress level for the less frequent occurrence

d is the stress increment

$$F = \sum fi$$

$$A = \sum i \cdot fi$$

$$B = \sum i^2 \cdot fi$$

i is the stress level numbering

fi is the number of samples at stress level i

M53

(cont)

The formula for the standard deviation is an approximation and can be used when

$$\frac{B \cdot F - A^2}{F^2} > 0.3 \quad \text{and} \quad 0.5 \cdot s < d < 1.5 \cdot s$$

If any of these two conditions are not fulfilled, a new staircase test should be considered or the standard deviation should be taken quite large in order to be on the safe side.

If increment d is greatly higher than the standard deviation s , the procedure leads to a lower standard deviation and a slightly higher sample mean, both compared to values calculated when the difference between the increment and the standard deviation is relatively small. Respectively, if increment d is much less than the standard deviation s , the procedure leads to a higher standard deviation and a slightly lower sample mean.

2.5. Confidence interval for mean fatigue limit

If the staircase fatigue test is repeated, the sample mean and the standard deviation will most likely be different from the previous test. Therefore, it is necessary to assure with a given confidence that the repeated test values will be above the chosen fatigue limit by using a confidence interval for the sample mean.

The confidence interval for the sample mean value with unknown variance is known to be distributed according to the t -distribution (also called *student's t-distribution*) which is a distribution symmetric around the average.

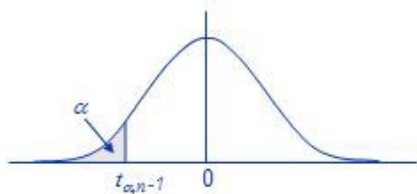


Figure 2.1. Student's t -distribution

The confidence level normally used for the sample mean is 90 %, meaning that 90 % of sample means from repeated tests will be above the value calculated with the chosen confidence level. The figure shows the t -value for $(1 - \alpha) \cdot 100\%$ confidence interval for the sample mean.

If S_a is the empirical mean and s is the empirical standard deviation over a series of n samples, in which the variable values are normally distributed with an unknown sample mean and unknown variance, the $(1 - \alpha) \cdot 100\%$ confidence interval for the mean is:

$$P\left(S_a - t_{\alpha, n-1} \cdot \frac{s}{\sqrt{n}} < S_{aX\%}\right) = 1 - \alpha$$

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(cont)

The resulting confidence interval is symmetric around the empirical mean of the sample values, and the lower endpoint can be found as:

$$S_{aX\%} = S_a - t_{\alpha, n-1} \cdot \frac{s}{\sqrt{n}}$$

which is the mean fatigue limit (population value) to be used to obtain the reduced fatigue limit where the limits for the probability of failure are taken into consideration.

2.6. Confidence interval for standard deviation

The confidence interval for the variance of a normal random variable is known to possess a chi-square distribution with $n - 1$ degrees of freedom.

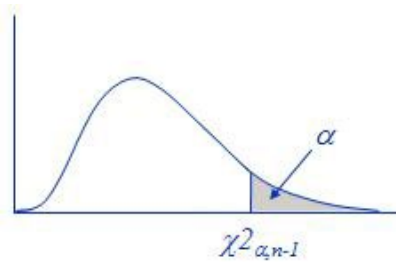


Figure 2.2. Chi-square distribution

The confidence level on the standard deviation is used to ensure that the standard deviations for repeated tests are below an upper limit obtained from the fatigue test standard deviation with a confidence level. The figure shows the chi-square for $(1 - \alpha) \cdot 100\%$ confidence interval for the variance.

An assumed fatigue test value from n samples is a normal random variable with a variance of σ^2 and has an empirical variance s^2 . Then a $(1 - \alpha) \cdot 100\%$ confidence interval for the variance is:

$$P\left(\frac{(n-1)s^2}{\sigma^2} < \chi^2_{\alpha, n-1}\right) = 1 - \alpha$$

A $(1 - \alpha) \cdot 100\%$ confidence interval for the standard deviation is obtained by the square root of the upper limit of the confidence interval for the variance and can be found by

$$S_{X\%} = \sqrt{\frac{n-1}{\chi^2_{\alpha, n-1}}} \cdot s$$

This standard deviation (population value) is to be used to obtain the fatigue limit, where the limits for the probability of failure are taken into consideration.

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3. Small specimen testing

In this connection, a small specimen is considered to be one of the specimens taken from a crank throw. Since the specimens shall be representative for the fillet fatigue strength, they should be taken out close to the fillets, as shown in Figure 3.1.

It should be made certain that the principal stress direction in the specimen testing is equivalent to the full-size crank throw. The verification is recommended to be done by utilising the finite element method.

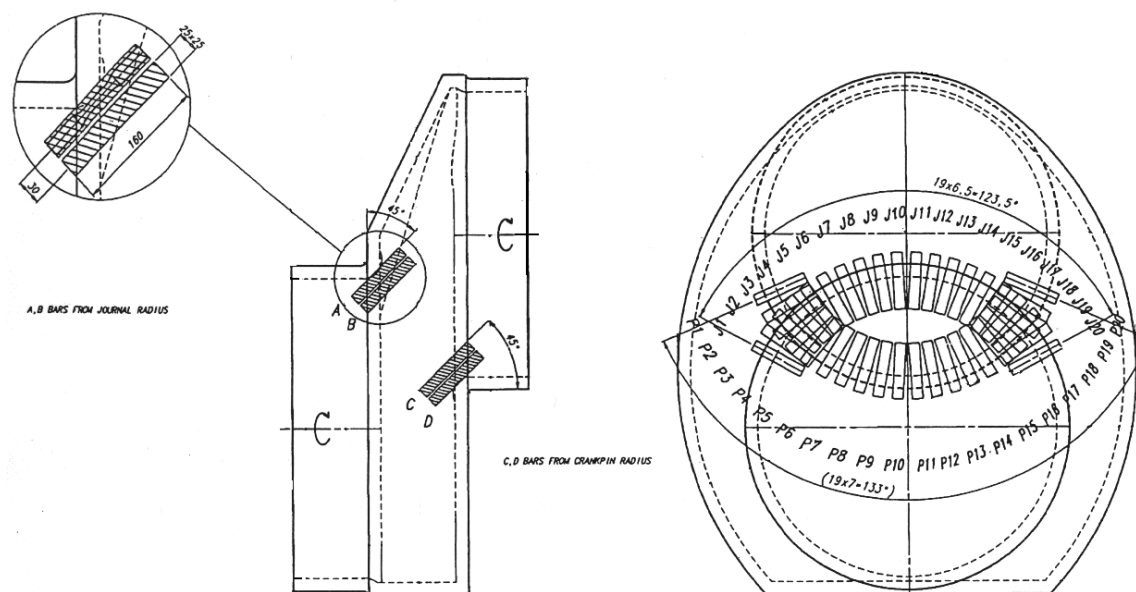


Figure 3.1. Specimen locations in a crank throw

The (static) mechanical properties are to be determined as stipulated by the quality control procedures.

3.1. Determination of bending fatigue strength

It is advisable to use un-notched specimens in order to avoid uncertainties related to the stress gradient influence. Push-pull testing method (stress ratio $R = -1$) is preferred, but especially for the purpose of critical plane criteria other stress ratios and methods may be added.

In order to ensure principal stress direction in push-pull testing to represent the full-size crank throw principal stress direction and when no further information is available, the specimen shall be taken in 45 degrees angle as shown in Figure 3.1.

- A. If the objective of the testing is to document the influence of high cleanliness, test samples taken from positions approximately 120 degrees in a circumferential direction may be used. See Figure 3.1.
- B. If the objective of the testing is to document the influence of continuous grain flow (cgf) forging, the specimens should be restricted to the vicinity of the crank plane.

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3.2. Determination of torsional fatigue strength

- A. If the specimens are subjected to torsional testing, the selection of samples should follow the same guidelines as for bending above. The stress gradient influence has to be considered in the evaluation.
- B. If the specimens are tested in push-pull and no further information is available, the samples should be taken out at an angle of 45 degrees to the crank plane in order to ensure collinearity of the principal stress direction between the specimen and the full-size crank throw. When taking the specimen at a distance from the (crank) middle plane of the crankshaft along the fillet, this plane rotates around the pin centre point making it possible to resample the fracture direction due to torsion (the results are to be converted into the pertinent torsional values).

3.3. Other test positions

If the test purpose is to find fatigue properties and the crankshaft is forged in a manner likely to lead to cgf, the specimens may also be taken longitudinally from a prolonged shaft piece where specimens for mechanical testing are usually taken. The condition is that this prolonged shaft piece is heat treated as a part of the crankshaft and that the size is so as to result in a similar quenching rate as the crank throw.

When using test results from a prolonged shaft piece, it must be considered how well the grain flow in that shaft piece is representative for the crank fillets.

3.4. Correlation of test results

The fatigue strength achieved by specimen testing shall be converted to correspond to the full-size crankshaft fatigue strength with an appropriate method (size effect).

When using the bending fatigue properties from tests mentioned in this section, it should be kept in mind that successful continuous grain flow (cgf) forging leading to elevated values compared to other (non cgf) forging, will normally not lead to a torsional fatigue strength improvement of the same magnitude.

In such cases it is advised to either carry out also torsional testing or to make a conservative assessment of the torsional fatigue strength, e.g. by using no credit for cgf. This approach is applicable when using the Gough Pollard criterion. However, this approach is not recognised when using the von Mises or a multi-axial criterion such as Findley.

If the found ratio between bending and torsion fatigue differs significantly from $\sqrt{3}$, one should consider replacing the use of the von Mises criterion with the Gough Pollard criterion. Also, if critical plane criteria are used, it must be kept in mind that cgf makes the material inhomogeneous in terms of fatigue strength, meaning that the material parameters differ with the directions of the planes.

Any addition of influence factors must be made with caution. If for example a certain addition for clean steel is documented, it may not necessarily be fully combined with a K -factor for cgf. Direct testing of samples from a clean and cgf forged crank is preferred.

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4. Full size testing**4.1. Hydraulic pulsation**

A hydraulic test rig can be arranged for testing a crankshaft in 3-point or 4-point bending as well as in torsion. This allows for testing with any R -ratio.

Although the applied load should be verified by strain gauge measurements on plain shaft sections for the initiation of the test, it is not necessarily used during the test for controlling load. It is also pertinent to check fillet stresses with strain gauge chains.

Furthermore, it is important that the test rig provides boundary conditions as defined in Appendix III (section 3.1 to 3.3).

The (static) mechanical properties are to be determined as stipulated by the quality control procedures.

4.2. Resonance tester

A rig for bending fatigue normally works with an R -ratio of -1. Due to operation close to resonance, the energy consumption is moderate. Moreover, the frequency is usually relatively high, meaning that 10^7 cycles can be reached within some days. Figure 4.1 shows a layout of the testing arrangement.

The applied load should be verified by strain gauge measurements on plain shaft sections. It is also pertinent to check fillet stresses with strain gauge chains.

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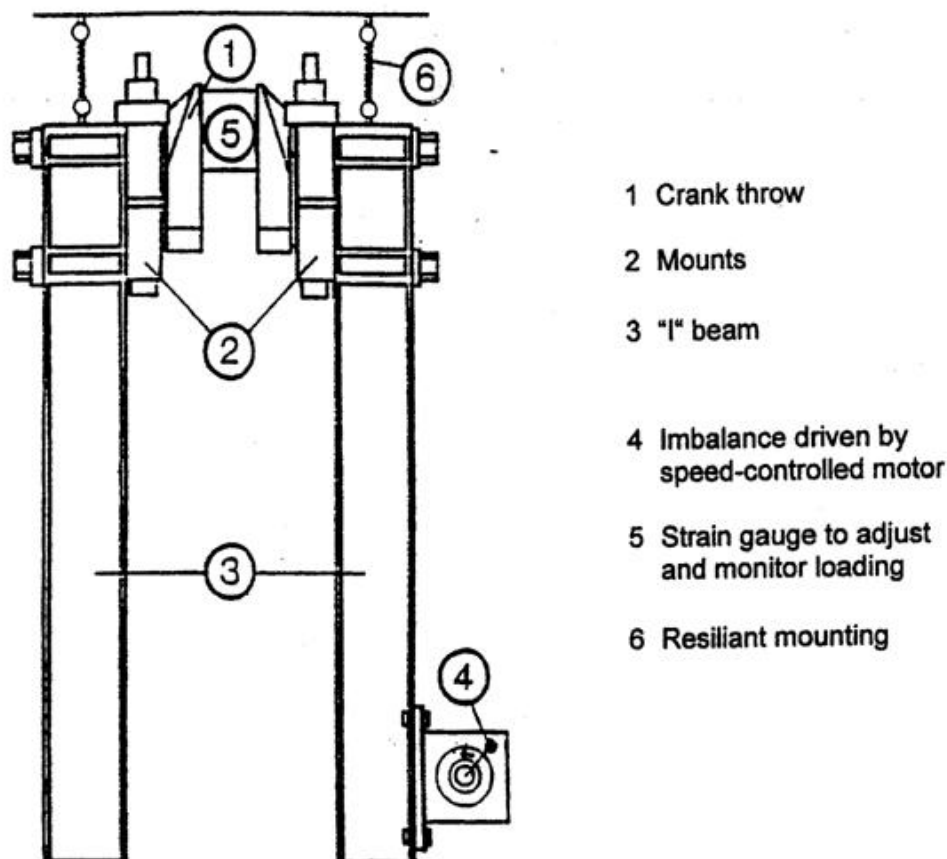


Figure 4.1. An example of testing arrangement of the resonance tester for bending loading

Clamping around the journals must be arranged in a way that prevents severe fretting which could lead to a failure under the edges of the clamps. If some distance between the clamps and the journal fillets is provided, the loading is consistent with 4-point bending and thus representative for the journal fillets also.

In an engine, the crankpin fillets normally operate with an R -ratio slightly above -1 and the journal fillets slightly below -1. If found necessary, it is possible to introduce a mean load (deviate from $R = -1$) by means of a spring preload.

A rig for torsion fatigue can also be arranged as shown in Figure 4.2. When a crank throw is subjected to torsion, the twist of the crankpin makes the journals move sideways. If one single crank throw is tested in a torsion resonance test rig, the journals with their clamped-on weights will vibrate heavily sideways.

This sideways movement of the clamped-on weights can be reduced by having two crank throws, especially if the cranks are almost in the same direction. However, the journal in the middle will move more.

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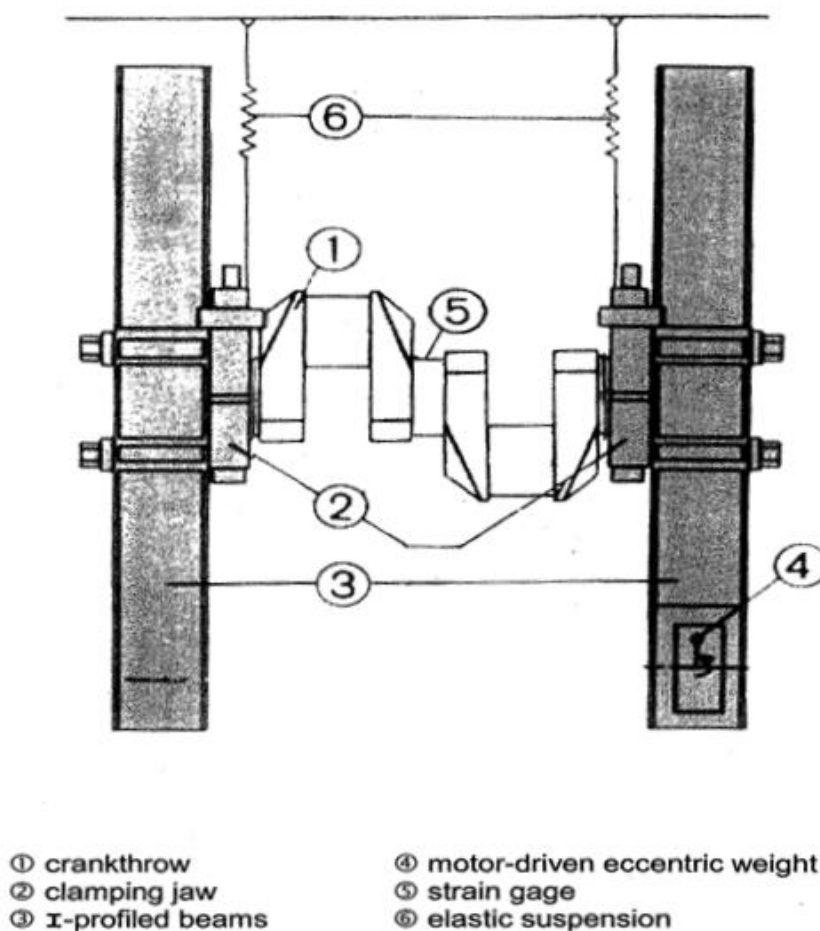


Figure 4.2. An example of testing arrangement of the resonance tester for torsion loading with double crank throw section

Since sideways movements can cause some bending stresses, the plain portions of the crankpins should also be provided with strain gauges arranged to measure any possible bending that could have an influence on the test results.

Similarly, to the bending case the applied load shall be verified by strain gauge measurements on plain shaft sections. It is also pertinent to check fillet stresses with strain gauge chains as well.

4.3. Use of results and crankshaft acceptability

In order to combine tested bending and torsion fatigue strength results in calculation of crankshaft acceptability (see M53.7), the Gough-Pollard approach and the maximum principal equivalent stress formulation can be applied for the following cases:

At the crankpin fillet:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BH} + \sigma_{add}}{\sigma_{DWCT}} \right)^2 + \left(\frac{\tau_H}{\tau_{DWCT}} \right)^2} \right)^{-1}$$

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(cont)

where:

σ_{DWCT} fatigue strength by bending testing

τ_{DWCT} fatigue strength by torsion testing

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

Related to crankpin oil bore:

$$Q = \frac{\sigma_{DWOT}}{\sigma_v}; \quad \sigma_v = \frac{1}{3} * \sigma_{BO} * \left[1 + 2 * \sqrt{1 + \frac{9}{4} * \left(\frac{\sigma_{TO}}{\sigma_{BO}} \right)^2} \right]$$

where:

σ_{DWOT} fatigue strength by means of largest principal stress from torsion testing

At the journal fillet:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BG} + \sigma_{add}}{\sigma_{DWJT}} \right)^2 + \left(\frac{\tau_G}{\tau_{DWJT}} \right)^2} \right)^{-1}$$

where:

σ_{DWJT} fatigue strength by bending testing

τ_{DWJT} fatigue strength by torsion testing

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

In case increase in fatigue strength due to the surface treatment is considered to be similar between the above cases, it is sufficient to test only the most critical location according to the calculation where the surface treatment had not been taken into account.

5. Use of existing results for similar crankshafts

For fillets or oil bores without surface treatment, the fatigue properties found by testing may be used for similar crankshaft designs providing:

- **Material:**
 - Similar material type
 - Cleanliness on the same or better level
 - The same mechanical properties can be granted (size versus hardenability)
- **Geometry:**
 - Difference in the size effect of stress gradient is insignificant or it is considered

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- Principal stress direction is equivalent. See Chapter 3.
- **Manufacturing:**
 - Similar manufacturing process

Induction hardened or gas nitrited crankshafts will suffer fatigue either at the surface or at the transition to the core. The surface fatigue strength as determined by fatigue tests of full size cranks, may be used on an equal or similar design as the tested crankshaft when the fatigue initiation occurred at the surface. With the similar design, it is meant that a similar material type and surface hardness are used and the fillet radius and hardening depth are within approximately $\pm 30\%$ of the tested crankshaft.

Fatigue initiation in the transition zone can be either subsurface, i.e. below the hard layer, or at the surface where the hardening ends. The fatigue strength at the transition to the core can be determined by fatigue tests as described above, provided that the fatigue initiation occurred at the transition to the core. Tests made with the core material only will not be representative since the tension residual stresses at the transition are lacking.

It has to be noted also what some recent research has shown: The fatigue limit can decrease in the very high cycle domain with subsurface crack initiation due to trapped hydrogen that accumulates through diffusion around some internal defect functioning as an initiation point. In these cases, it would be appropriate to reduce the fatigue limit by some percent per decade of cycles beyond 10^7 . Based on a publication by Yukitaka Murakami "Metal Fatigue: Effects of Small Defects and Non-metallic Inclusions" the reduction is suggested to be 5 % per decade especially when the hydrogen content is considered to be high.

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Appendix V**Guidance for Calculation of Surface Treated Fillets and Oil Bore Outlets**

Contents

1. Introduction
2. Definition of surface treatment
 - 2.1. Surface treatment methods
3. Calculation principles
 - 3.1. Evaluation of local fillet stresses
 - 3.2. Evaluation of oil bore stresses
 - 3.3. Acceptability criteria
4. Induction hardening
 - 4.1. Local fatigue strength
5. Nitriding
 - 5.1. Local fatigue strength
6. Cold forming
 - 6.1. Stroke peening by means of a ball
 - 6.1.1. Use of existing results for similar crankshafts
 - 6.2. Cold rolling
 - 6.2.1. Use of existing results for similar crankshafts

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1. Introduction

This appendix deals with surface treated fillets and oil bore outlets. The various treatments are explained and some empirical formulae are given for calculation purposes. Conservative empiricism has been applied intentionally, in order to be on the safe side from a calculation standpoint.

Please note that measurements or more specific knowledge should be used if available. However, in the case of a wide scatter (e.g. for residual stresses) the values should be chosen from the end of the range that would be on the safe side for calculation purposes.

2. Definition of surface treatment

‘Surface treatment’ is a term covering treatments such as thermal, chemical or mechanical operations, leading to inhomogeneous material properties – such as hardness, chemistry or residual stresses – from the surface to the core.

2.1. Surface treatment methods

The following list covers possible treatment methods and how they influence the properties that are decisive for the fatigue strength.

Table 2.1. Surface treatment methods and the characteristics they affect.

Treatment method	Affecting
•Induction hardening	Hardness and residual stresses
•Nitriding	Chemistry, hardness and residual stresses
•Case hardening	Chemistry, hardness and residual stresses
•Die quenching (no temper)	Hardness and residual stresses
•Cold rolling	Residual stresses
•Stroke peening	Residual stresses
•Shot peening	Residual stresses
•Laser peening	Residual stresses
•Ball coining	Residual stresses

It is important to note that since only induction hardening, nitriding, cold rolling and stroke peening are considered relevant for marine engines, other methods as well as combination of two or more of the above are not dealt with in this document. In addition, die quenching can be considered in the same way as induction hardening.

3. Calculation principles

The basic principle is that the alternating working stresses shall be below the local fatigue strength (including the effect of surface treatment) wherein non-propagating cracks may occur, see also section 6.1 for details. This is then divided by a certain safety factor. This applies through the entire fillet or oil bore contour as well as below the surface to a depth below the treatment-affected zone – i.e. to cover the depth all the way to the core.

Consideration of the local fatigue strength shall include the influence of the local hardness, residual stress and mean working stress. The influence of the ‘giga-cycle effect’, especially for initiation of subsurface cracks, should be covered by the choice of safety margin.

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It is of vital importance that the extension of hardening/peening in an area with concentrated stresses be duly considered. Any transition where the hardening/peening is ended is likely to have considerable tensile residual stresses.

This forms a 'weak spot' and is important if it coincides with an area of high stresses.

Alternating and mean working stresses must be known for the entire area of the stress concentration as well as to a depth of about 1.2 times the depth of the treatment. The following figure indicates this principle in the case of induction hardening. The base axis is either the depth (perpendicular to the surface) or along the fillet contour.

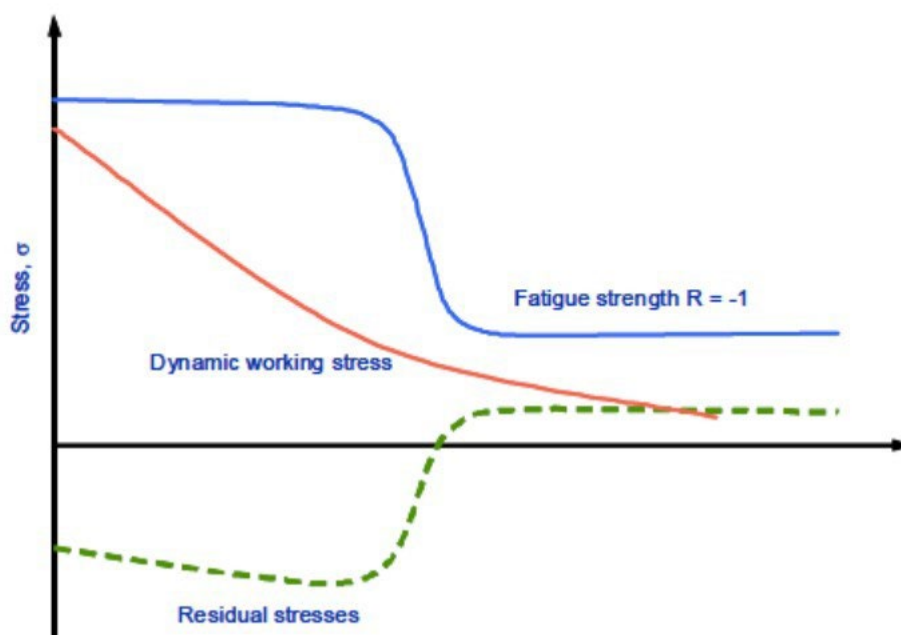


Figure 3.1. Stresses as functions of depth, general principles

The acceptability criterion should be applied stepwise from the surface to the core as well as from the point of maximum stress concentration along the fillet surface contour to the web.

3.1. Evaluation of local fillet stresses

It is necessary to have knowledge of the stresses along the fillet contour as well as in the subsurface to a depth somewhat beyond the hardened layer. Normally this will be found via FEA as described in Appendix III. However, the element size in the subsurface range will have to be the same size as at the surface. For crankpin hardening only the small element size will have to be continued along the surface to the hard layer.

If no FEA is available, a simplified approach may be used. This can be based on the empirically determined stress concentration factors (SCFs), as in M53.3 if within its validity range, and a relative stress gradient inversely proportional to the fillet radius.

Bending and torsional stresses must be addressed separately. The combination of these is addressed by the acceptability criterion.

The subsurface transition-zone stresses, with the minimum hardening depth, can be determined by means of local stress concentration factors along an axis perpendicular to the fillet surface. These functions $\alpha_{B-local}$ and $\alpha_{T-local}$ have different shapes due to the different stress gradients.

The SCFs α_B and α_T are valid at the surface. The local $\alpha_{B-local}$ and $\alpha_{T-local}$ drop with increasing depth. The relative stress gradients at the surface depend on the kind of stress raiser, but for

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crankpin fillets they can be simplified to $2/R_H$ in bending and $1/R_H$ in torsion. The journal fillets are handled analogously by using R_G and D_G . The nominal stresses are assumed to be linear from the surface to a midpoint in the web between the crankpin fillet and the journal fillet for bending and to the crankpin or journal centre for torsion.

The local SCFs are then functions of depth t according to Equation 3.1 as shown in Figure 3.2 for bending and respectively for torsion in Equation 3.2 and Figure 3.3.

$$\alpha_{B-local} = (\alpha_B - 1) \cdot e^{\frac{-2 \cdot t}{R_H}} + 1 - \left(\frac{2 \cdot t}{\sqrt{W^2 + S^2}} \right)^{\frac{0.6}{\sqrt{\alpha_B}}} \quad (3.1)$$

$$\alpha_{T-local} = (\alpha_T - 1) \cdot e^{\frac{-t}{R_H}} + 1 - \left(\frac{2 \cdot t}{D} \right)^{\frac{1}{\sqrt{\alpha_T}}} \quad (3.2)$$

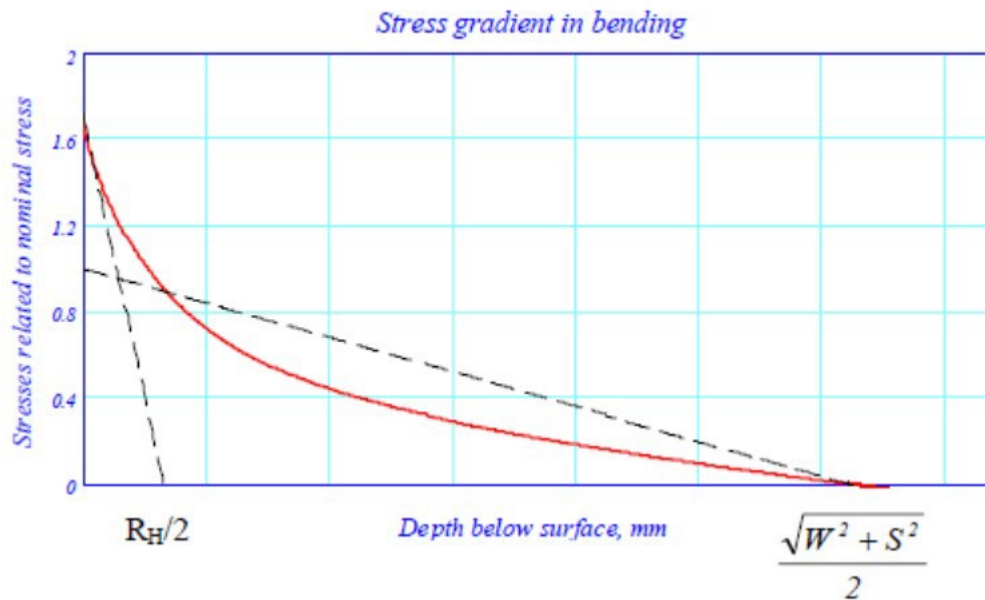


Figure 3.2. Bending SCF in the crankpin fillet as a function of depth. The corresponding SCF for the journal fillet can be found by replacing R_H with R_G

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(cont)



Figure 3.3. Torsional SCF in the crankpin fillet as a function of depth. The corresponding SCF for the journal fillet can be found by replacing R_H with R_G and D with D_G

If the pin is hardened only and the end of the hardened zone is closer to the fillet than three times the maximum hardness depth, FEA should be used to determine the actual stresses in the transition zone.

3.2. Evaluation of oil bore stresses

Stresses in the oil bores can be determined also by FEA. The element size should be less than $1/8$ of the oil bore diameter D_o and the element mesh quality criteria should be followed as prescribed in Appendix III. The fine element mesh should continue well beyond a radial depth corresponding to the hardening depth.

The loads to be applied in the FEA are the torque – see Appendix III item 3.1 – and the bending moment, with four-point bending as in Appendix III item 3.2.

If no FEA is available, a simplified approach may be used. This can be based on the empirically determined SCF from M53.3 if within its applicability range. Bending and torsional stresses at the point of peak stresses are combined as in M53.5.

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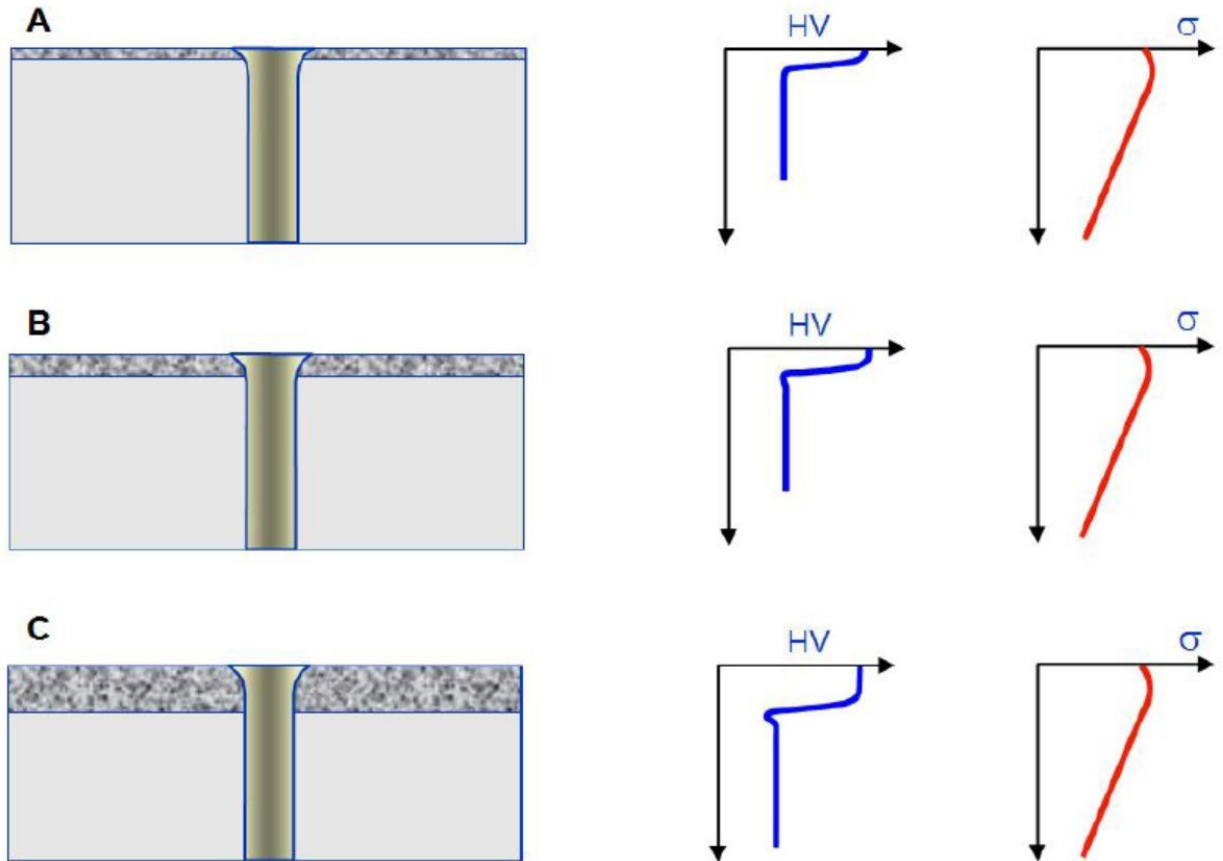


Figure 3.4. Stresses and hardness in induction hardened oil holes

Figure 3.4 indicates a local drop of the hardness in the transition zone between a hard and soft material. Whether this drop occurs depends also on the tempering temperature after quenching in the QT process.

The peak stress in the bore occurs at the end of the edge rounding. Within this zone the stress drops almost linearly to the centre of the pin. As can be seen from Figure 3.4, for shallow (A) and intermediate (B) hardening, the transition point practically coincides with the point of maximal stresses. For deep hardening the transition point comes outside of the point of peak stress and the local stress can be assessed as a portion $(1-2tH/D)$ of the peak stresses where tH is the hardening depth.

The subsurface transition-zone stresses (using the minimum hardening depth) can be determined by means of local stress concentration factors along an axis perpendicular to the oil bore surface. These functions $\gamma_{B-local}$ and $\gamma_{T-local}$ have different shapes, because of the different stress gradients.

The stress concentration factors γ_B and γ_T are valid at the surface. The local SCFs $\gamma_{B-local}$ and $\gamma_{T-local}$ drop with increasing depth. The relative stress gradients at the surface depend on the kind of stress raiser, but for crankpin oil bores they can be simplified to $4/D_o$ in bending and $2/D_o$ in torsion. The local SCFs are then functions of the depth t :

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(cont)

$$\gamma_{B-local} = (\gamma_B - 1) \cdot e^{\frac{-4 \cdot t}{D_o}} + 1 \quad (3.3)$$

$$\gamma_{T-local} = (\gamma_T - 1) \cdot e^{\frac{-2 \cdot t}{D_o}} + 1 \quad (3.4)$$

3.3. Acceptability criteria

Acceptance of crankshafts is based on fatigue considerations; M53 compares the equivalent alternating stress and the fatigue strength ratio to an acceptability factor of $Q \geq 1.15$ for oil bore outlets, crankpin fillets and journal fillets. This shall be extended to cover also surface treated areas independent of whether surface or transition zone is examined.

4. Induction hardening

Generally, the hardness specification shall specify the surface hardness range i.e. minimum and maximum values, the minimum and maximum extension in or through the fillet and also the minimum and maximum depth along the fillet contour. The referenced Vickers hardness is considered to be **HV0.5...HV5**.

The induction hardening depth is defined as the depth where the hardness is 80% of the minimum specified surface hardness.

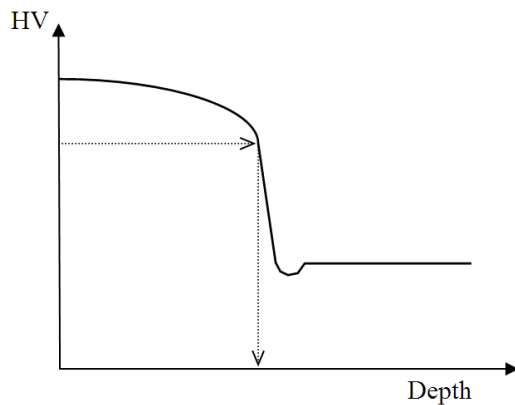


Figure 4.1. Typical hardness as a function of depth. The arrows indicate the defined hardening depth. Note the indicated potential hardness drop at the transition to the core. This can be a weak point as local strength may be reduced and tensile residual stresses may occur.

In the case of crankpin or journal hardening only, the minimum distance to the fillet shall be specified due to the tensile stress at the heat-affected zone as shown in Figure 4.2.

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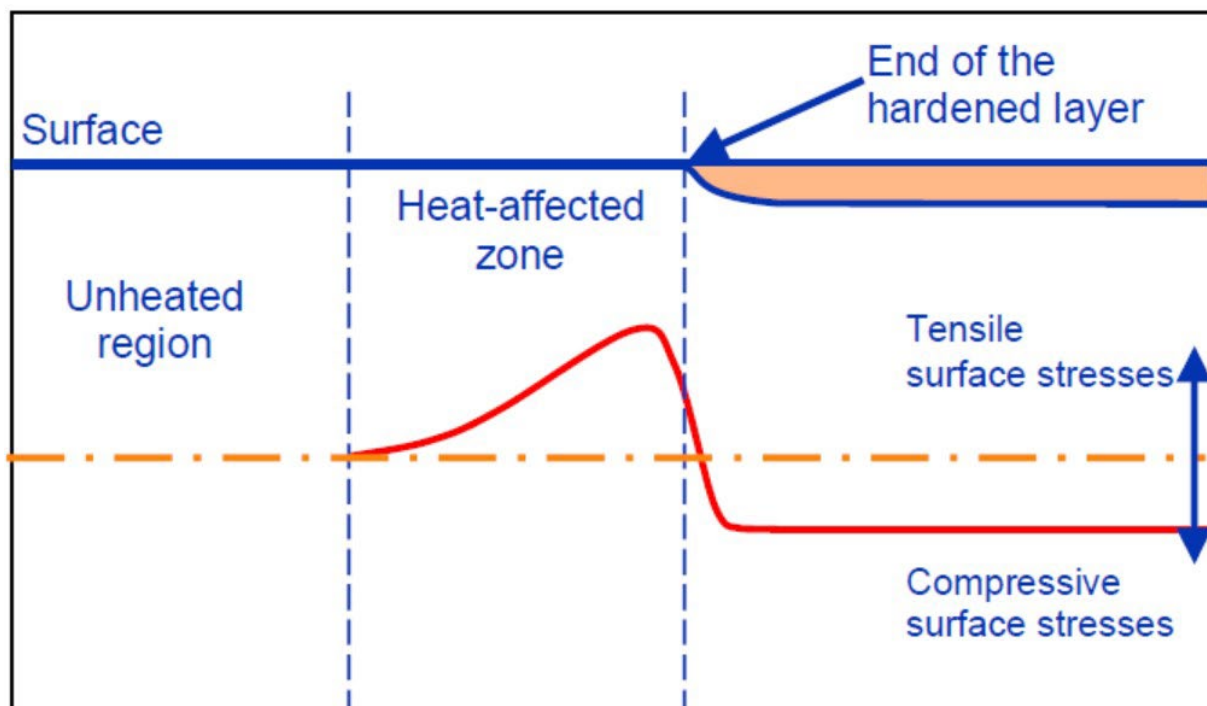


Figure 4.2. Residual stresses along the surface of a pin and fillet

If the hardness-versus-depth profile and residual stresses are not known or specified, one may assume the following:

- The hardness profile consists of two layers (see figure 4.1):
 - Constant hardness from the surface to the transition zone
 - Constant hardness from the transition zone to the core material
- Residual stresses in the hard zone of 200 MPa (compression)
- Transition-zone hardness as 90% of the core hardness unless the local hardness drop is avoided
- Transition-zone maximum residual stresses (von Mises) of 300 MPa tension

If the crankpin or journal hardening ends close to the fillet, the influence of tensile residual stresses has to be considered. If the minimum distance between the end of the hardening and the beginning of the fillet is more than 3 times the maximum hardening depth, the influence may be disregarded.

4.1. Local fatigue strength

Induction-hardened crankshafts will suffer fatigue either at the surface or at the transition to the core. The fatigue strengths, for both the surface and the transition zone, can be determined by fatigue testing of full size cranks as described in Appendix IV. In the case of a transition zone, the initiation of the fatigue can be either subsurface (i.e. below the hard layer) or at the surface where the hardening ends.

Tests made with the core material only will not be representative since the tensile residual stresses at the transition are lacking.

Alternatively, the surface fatigue strength can be determined empirically as follows where HV is the surface Vickers hardness. The Equation 4.1 provides a conservative value, with which

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the fatigue strength is assumed to include the influence of the residual stress. The resulting value is valid for a working stress ratio of $R = -1$:

$$\sigma_{F_{surface}} = 400 + 0.5 \cdot (HV - 400) \quad [MPa] \quad (4.1)$$

It has to be noted also that the mean stress influence of induction-hardened steels may be significantly higher than that for QT steels.

The fatigue strength in the transition zone, without taking into account any possible local hardness drop, shall be determined by the equation introduced in UR M53.6.

For journal and respectively to crankpin fillet applies:

$$\sigma_{F_{transition, cpin}} = \pm K \cdot (0.42 \cdot \sigma_B + 39.3) \cdot \left[0.264 + 1.073 \cdot Y^{-0.2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{X}} \right] \quad (4.2)$$

where:

$$\begin{array}{lll} Y = D_G & \text{and} & X = R_G & \text{for journal fillet} \\ Y = D & \text{and} & X = R_H & \text{for crankpin fillet} \\ Y = D & \text{and} & X = D_o/2 & \text{for oil bore outlet} \end{array}$$

The influence of the residual stress is not included in 4.2.

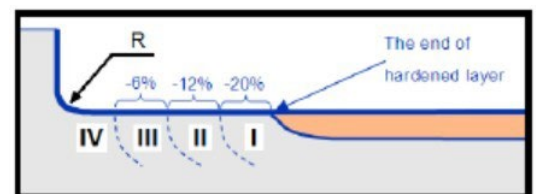
For the purpose of considering subsurface fatigue, below the hard layer, the disadvantage of tensile residual stresses has to be considered by subtracting 20% from the value determined above. This 20% is based on the mean stress influence of alloyed quenched and tempered steel having a residual tensile stress of 300 MPa.

When the residual stresses are known to be lower, also smaller value of subtraction shall be used. For low-strength steels the percentage chosen should be higher.

For the purpose of considering surface fatigue near the end of the hardened zone – i.e. in the heat-affected zone shown in the Figure 4.2 – the influence of the tensile residual stresses can be considered by subtracting a certain percentage, in accordance with Table 4.1, from the value determined by the above formula.

Table 4.1. The influence of tensile residual stresses at a given distance from the end of the hardening towards the fillet

I.	0 to 1.0 of the max. hardening depth:	20%
II.	1.0 to 2.0 of the max. hardening depth:	12%
III.	2.0 to 3.0 of the max. hardening depth:	6%
IV.	3.0 or more of the max. hardening depth:	0%



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5. Nitriding

The hardness specification shall include the surface hardness range (min and max) and the minimum and maximum depth. Only gas nitriding is considered. The referenced Vickers hardness is considered to be **HV0.5**.

The depth of the hardening is defined in different ways in the various standards and the literature. The most practical method to use in this context is to define the nitriding depth t_N as the depth to a hardness of 50 HV above the core hardness.

The hardening profile should be specified all the way to the core. If this is not known, it may be determined empirically via the following formula:

$$HV(t) = HV_{core} + (HV_{surface} - HV_{core}) \cdot \left(\frac{50}{HV_{surface} - HV_{core}} \right)^{\left(\frac{t}{t_N} \right)^2} \quad (5.1)$$

where:

t	=	The local depth
$HV(t)$	=	Hardness at depth t
HV_{core}	=	Core hardness (minimum)
$HV_{surface}$	=	Surface hardness (minimum)
t_N	=	Nitriding depth as defined above (minimum)

5.1. Local fatigue strength

It is important to note that in nitrided crankshaft cases, fatigue is found either at the surface or at the transition to the core. This means that the fatigue strength can be determined by tests as described in Appendix IV.

Alternatively, the surface fatigue strength (principal stress) can be determined empirically and conservatively as follows. This is valid for a surface hardness of 600 HV or greater:

$$\sigma_{F_{surface}} = 450 \text{ MPa} \quad (5.2)$$

Note that this fatigue strength is assumed to include the influence of the surface residual stress and applies for a working stress ratio of $R = -1$.

The fatigue strength in the transition zone can be determined by the equation introduced in UR M53.6. For crankpin and respectively to journal applies:

$$\sigma_{F_{transition, cpin}} = \pm K \cdot (0.42 \cdot \sigma_B + 39.3) \cdot \left[0.264 + 1.073 \cdot Y^{-0.2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{X}} \right] \quad (5.3)$$

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(cont)

where:

$$\begin{array}{lll}
 Y = D_G & \text{and} & X = R_G & \text{for journal fillet} \\
 Y = D & \text{and} & X = R_H & \text{for crankpin fillet} \\
 Y = D & \text{and} & X = D_o/2 & \text{for oil bore outlet}
 \end{array}$$

Note that this fatigue strength is **not** assumed to include the influence of the residual stresses.

In contrast to induction-hardening the nitrited components have no such distinct transition to the core. Although the compressive residual stresses at the surface are high, the balancing tensile stresses in the core are moderate because of the shallow depth. For the purpose of analysis of subsurface fatigue the disadvantage of tensile residual stresses in and below the transition zone may be even disregarded in view of this smooth contour of a nitriding hardness profile.

Although in principle the calculation should be carried out along the entire hardness profile, it can be limited to a simplified approach of examining the surface and an artificial transition point. This artificial transition point can be taken at the depth where the local hardness is approximately 20 HV above the core hardness. In such a case, the properties of the core material should be used. This means that the stresses at the transition to the core can be found by using the local SCF formulae mentioned earlier when inserting $t=1.2t_N$.

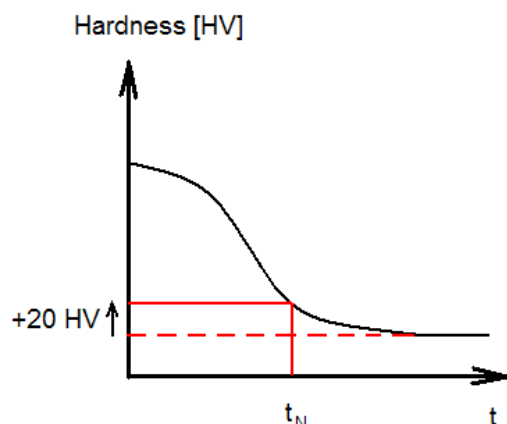


Figure 5.1. Sketch of the location for the artificial transition point in the depth direction

6. Cold forming

The advantage of stroke peening or cold rolling of fillets is the compressive residual stresses introduced in the high-loaded area. Even though surface residual stresses can be determined by X-ray diffraction technique and subsurface residual stresses can be determined through neutron diffraction, the local fatigue strength is virtually non-assessable on that basis since suitable and reliable correlation formulae are hardly known.

Therefore, the fatigue strength has to be determined by fatigue testing; see also Appendix IV. Such testing is normally carried out as four-point bending, with a working stress ratio of $R = -1$. From these results, the bending fatigue strength – surface- or subsurface-initiated depending on the manner of failure – can be determined and expressed as the representative fatigue strength for applied bending in the fillet.

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In comparison to bending, the torsion fatigue strength in the fillet may differ considerably from the ratio $\sqrt{3}$ (utilized by the von Mises criterion). The forming-affected depth that is sufficient to prevent subsurface fatigue in bending, may still allow subsurface fatigue in torsion. Another possible reason for the difference in bending and torsion could be the extension of the highly stressed area.

The results obtained in a full-size crank test can be applied for another crank size provided that the base material (alloyed Q+T) is of the similar type and that the forming is done so as to obtain the similar level of compressive residual stresses at the surface as well as through the depth. This means that both the extension and the depth of the cold forming must be proportional to the fillet radius.

6.1. Stroke peening by means of a ball

The fatigue strength obtained can be documented by means of full size crank tests or by empirical methods if applied on the safe side. If both bending and torsion fatigue strengths have been investigated and differ from the ratio $\sqrt{3}$, the von Mises criterion should be excluded.

If only bending fatigue strength has been investigated, the torsional fatigue strength should be assessed conservatively. If the bending fatigue strength is concluded to be x% above the fatigue strength of the non-peened material, the torsional fatigue strength should not be assumed to be more than 2/3 of x% above that of the non-peened material.

As a result of the stroke peening process the maximum of the compressive residual stress is found in the subsurface area. Therefore, depending on the fatigue testing load and the stress gradient, it is possible to have higher working stresses at the surface in comparison to the local fatigue strength of the surface. Because of this phenomenon small cracks may appear during the fatigue testing, which will not be able to propagate in further load cycles and/or with further slight increases of the testing load because of the profile of the compressive residual stress. Put simply, the high compressive residual stresses below the surface 'arrest' small surface cracks.

This is illustrated in Figure 6.1 as gradient load 2.

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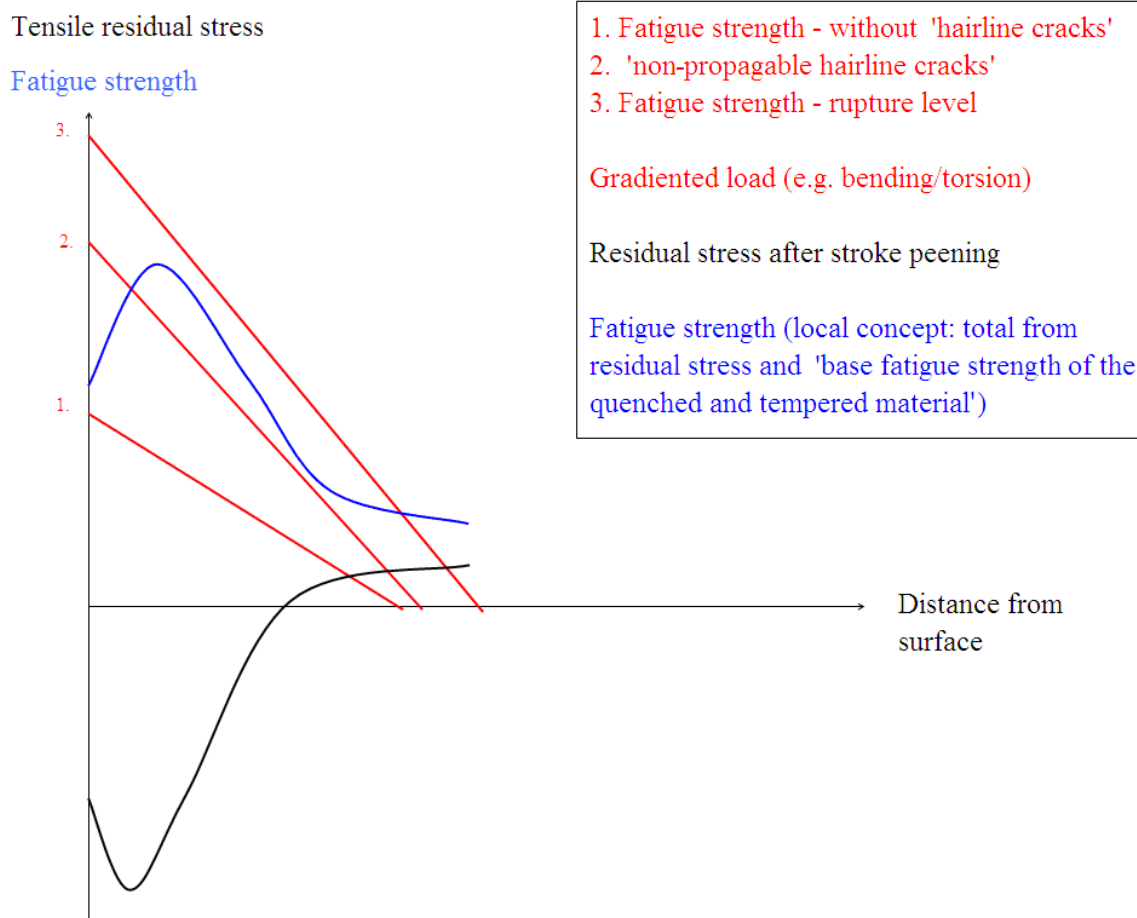


Figure 6.1. Working and residual stresses below the stroke-peened surface.
Straight lines 1...3 represent different possible load stress gradients.

In fatigue testing with full-size crankshafts these small “hairline cracks” should not be considered to be the failure crack. The crack that is technically the fatigue crack leading to failure, and that therefore shuts off the test-bench, should be considered for determination of the failure load level. This also applies if induction-hardened fillets are stroke-peened.

In order to improve the fatigue strength of induction-hardened fillets it is possible to apply the stroke peening process in the crankshafts' fillets after they have been induction-hardened and tempered to the required surface hardness. If this is done, it might be necessary to adapt the stroke peening force to the hardness of the surface layer and not to the tensile strength of the base material. The effect on the fatigue strength of induction hardening and stroke peening the fillets shall be determined by a full-size crankshaft test.

6.1.1. Use of existing results for similar crankshafts

The increase in fatigue strength, which is achieved by applying stroke peening, may be utilized in another similar crankshaft if all of the following criteria are fulfilled:

- Ball size relative to fillet radius within $\pm 10\%$ in comparison to the tested crankshaft
- At least the same circumferential extension of the stroke peening

M53 (cont)

- Angular extension of the fillet contour relative to fillet radius within $\pm 15\%$ in comparison to the tested crankshaft and located to cover the stress concentration during engine operation
- Similar base material, e.g. alloyed quenched and tempered
- Forward feed of ball of the same proportion of the radius
- Force applied to ball proportional to base material hardness (if different)
- Force applied to ball proportional to square of ball radius

6.2. Cold rolling

The fatigue strength can be obtained by means of full size crank tests or by empirical methods, if these are applied so as to be on the safe side. If both, bending and torsion fatigue strengths have been investigated, and differ from the ratio $\sqrt{3}$, the von Mises criterion should be excluded.

If only bending fatigue strength has been investigated, the torsional fatigue strength should be assessed conservatively. If the bending fatigue strength is concluded to be $x\%$ above the fatigue strength of the non-rolled material, the torsional fatigue strength should not be assumed to be more than $2/3$ of $x\%$ above that of the non-rolled material.

6.2.1. Use of existing results for similar crankshafts

The increase in fatigue strength, which is achieved applying cold rolling, may be utilized in another similar crankshaft if all of the following criteria are fulfilled:

- At least the same circumferential extension of cold rolling
- Angular extension of the fillet contour relative to fillet radius within $\pm 15\%$ in comparison to the tested crankshaft and located to cover the stress concentration during engine operation
- Similar base material, e.g. alloyed quenched and tempered
- Roller force to be calculated so as to achieve at least the same relative (to fillet radius) depth of treatment

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Appendix VI

Guidance for Calculation of Stress Concentration Factors in the Oil Bore Outlets of crankshafts through utilisation of the 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 and assessment of stress
 - 3.1. Torsion
 - 3.2. Bending

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(cont)

1. General

The objective of the analysis described in this document is to substitute the analytical calculation of the stress concentration factor (SCF) at the oil bore outlet with suitable finite element method (FEM) calculated figures. The former method is based on empirical formulae developed from strain gauge readings or photo-elasticity measurements of various round bars. Because use of these formulae beyond any of the validity ranges can lead to erroneous results in either direction, the FEM-based method is highly recommended.

The SCF calculated according to the rules set forth in this document is defined as the ratio of FEM-calculated stresses to nominal stresses calculated analytically. In use in connection with the present method in UR M53, principal stresses shall be calculated.

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

It is advisable to check the element accuracy of the FE solver in use, e.g. by modelling a simple geometry and comparing the FEM-obtained stresses with the analytical solution.

A boundary element method (BEM) approach may be used instead of FEM.

2. Model requirements

The basic recommendations and assumptions for building of the FE-model are presented in Subsection 2.1. The final FE-model must meet one of the criteria in Subsection 2.3.

2.1. Element mesh recommendations

For the mesh quality criteria to be met, construction of the FE model for the evaluation of stress concentration factors according to the following recommendations is advised:

- The model consists of one complete crank, from the main bearing centre line to the opposite side's main bearing centre line.
- The following element types are used in the vicinity of the outlets:
 - 10-node tetrahedral elements
 - 8-node hexahedral elements
 - 20-node hexahedral elements
- The following mesh properties for the oil bore outlet are used:
 - Maximum element size $a = r / 4$ through the entire outlet fillet as well as in the bore direction (if 8-node hexahedral elements are used, even smaller elements are required for meeting of the quality criterion)
 - Recommended manner for element size in the fillet depth direction
 - First layer's thickness equal to element size of ***a***
 - Second layer's thickness equal to element size of ***2a***
 - Third -layer thickness equal to element size of ***3a***
- In general, the rest of the crank should be suitable for numeric stability of the solver
- Drillings and holes for weight reduction have to be modelled

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Submodeling may be used as long as the software requirements are fulfilled.

2.2. Material

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

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

2.3. Element mesh quality criteria

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

2.3.1. Principal -stresses criterion

The quality of the mesh should be assured through checking of the stress component normal to the surface of the oil bore outlet radius. With principal stresses σ_1 , σ_2 and σ_3 the following criterion must be met:

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

2.3.2. Averaged/unaveraged -stresses criterion

The averaged/unaveraged –stresses criterion is based on observation of the discontinuity of stress results over elements at the fillet for the calculation of the SCF:

- Unaveraged nodal stress results calculated from each element connected to a node i should differ less than 5 % from the 100 % averaged nodal stress results at this node i at the location examined.

3. Load cases and assessment of stress

For substitution of the analytically determined SCF in UR M53, calculation shall be performed for the following load cases.

3.1. Torsion

The structure is loaded in pure torsion. The surface warp at the end faces of the model is suppressed.

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

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

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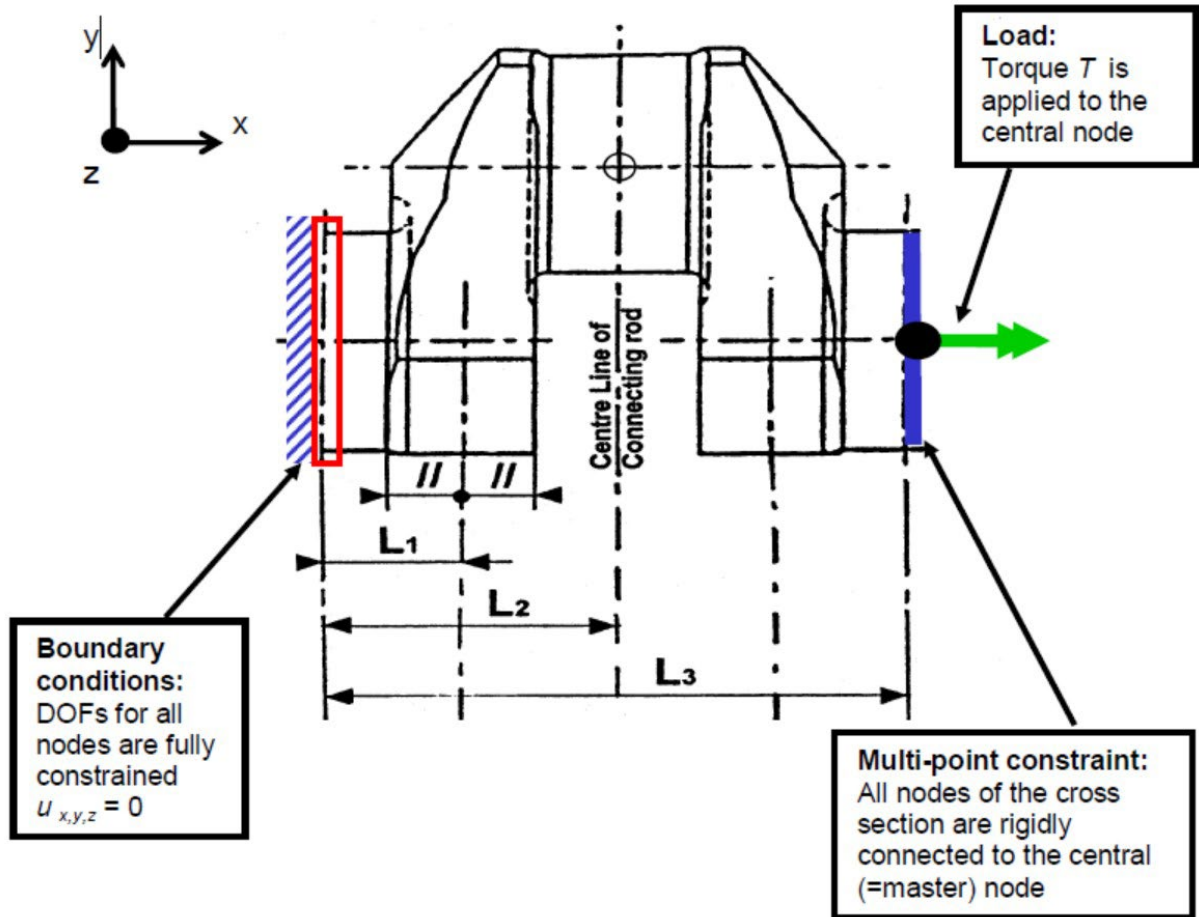


Figure 3.1 Boundary and load conditions for the torsion load case

For all nodes in an oil bore outlet, the principal stresses are obtained and the maximum value is taken for subsequent calculation of the SCF:

$$\gamma_T = \frac{\max(|\sigma_1|, |\sigma_2|, |\sigma_3|)}{\tau_N}$$

where the nominal torsion stress τ_N referred to the crankpin is evaluated per M53.2.2.2 with torque T :

$$\tau_N = \frac{T}{W_P}$$

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3.2. Bending

The structure is loaded in pure bending. The surface warp at the end faces of the model is suppressed.

The bending moment is applied to the central node on the crankshaft axis. This node acts as the master node, with six degrees of freedom, and is connected rigidly to all nodes of the end face.

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

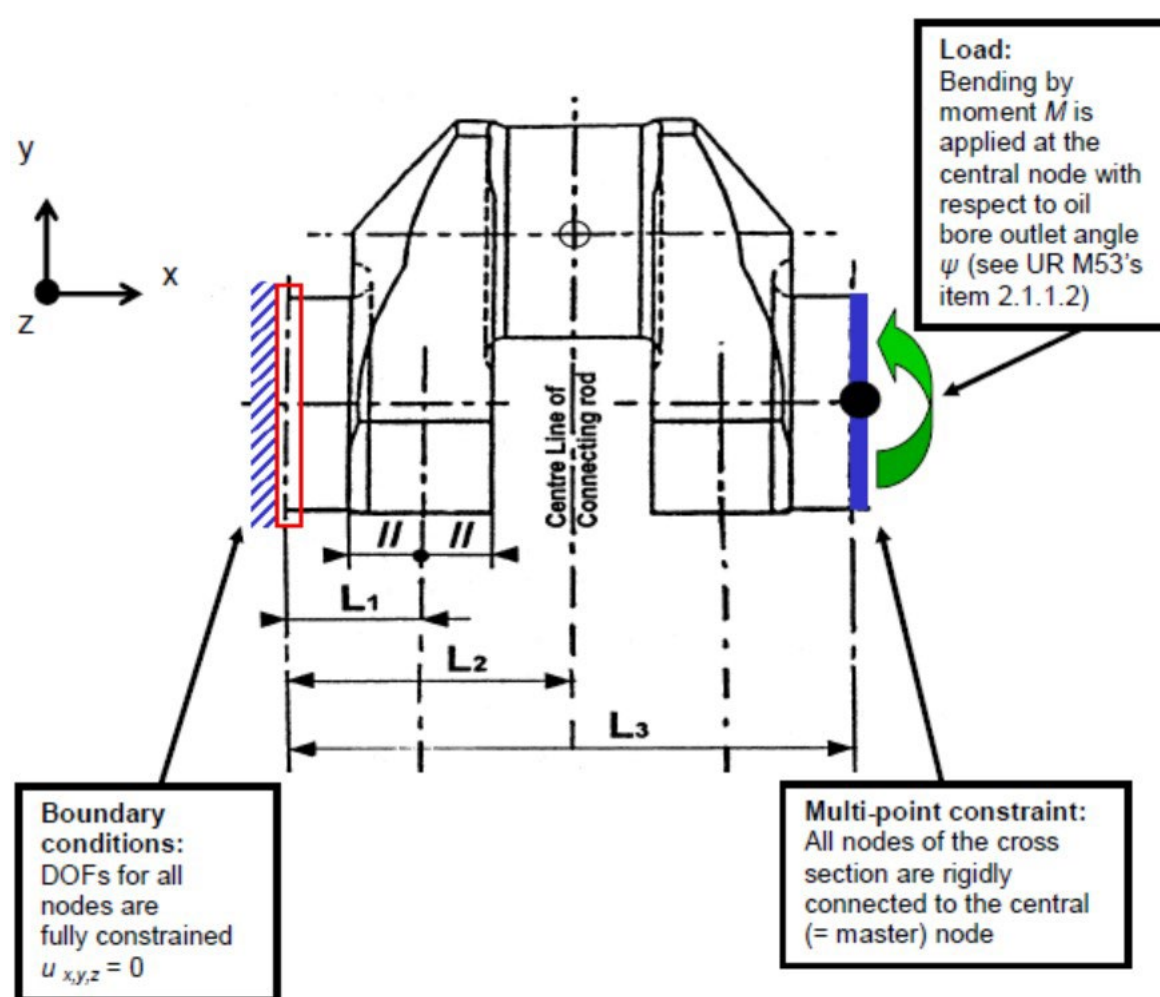


Figure 3.2. Boundary and load conditions for the pure bending load case

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For all nodes in the oil bore outlet, principal stresses are obtained and the maximum value is taken for subsequent calculation of the SCF:

$$\gamma_B = \frac{\max(|\sigma_1|, |\sigma_2|, |\sigma_3|)}{\sigma_N}$$

where the nominal bending stress σ_N referred to the crankpin is calculated per M53.2.1.2.2 with bending moment M :

$$\sigma_N = \frac{M}{W_e}$$

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M54 Deleted

(1986)
(Rev 1
1997)



M55 ~~Planned maintenance scheme (PMS) for machinery~~

(1988)

Deleted in May 2001



M56

(1990)
(Rev.1
1994/
Corr.
1996)
(Rev.2
Oct 2013)
(Rev.3 Oct
2015)
(Rev.4
Feb 2021)
(Corr.1
Oct 2021)
(Corr. 2
Mar 2023)

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 series 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.

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.
3. Rev.4 of this UR is to be uniformly implemented by IACS Societies from 1 July 2022 to any marine gear subject to approval and to any Type Approved marine gear from the date of the first renewal after 1 July 2022. For a marine gear approved prior to 1 July 2022 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.4 may be waived.

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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.

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.

a	centre distance	mm
b	common face width	mm
$b_{1,2}$	face width of pinion, wheel	mm
d	reference diameter	mm
$d_{1,2}$	reference diameter of pinion, wheel	mm
$d_{a1,2}$	tip diameter of pinion, wheel	mm
$d_{b1,2}$	base diameter of pinion, wheel	mm
$d_{f1,2}$	root diameter of pinion, wheel	mm
$d_{w1,2}$	working diameter of pinion, wheel	mm
F_t	nominal tangential load	N
F_{bt}	nominal tangential load on base cylinder in the transverse section	N
h	tooth depth	mm
m_n	normal module	mm
m_t	transverse module	mm
$n_{1,2}$	rotational speed of pinion, wheel	revs/min (rpm)
P	maximum continuous power transmitted by the gear set	kW
$T_{1,2}$	torque in way of pinion, wheel	Nm
u	gear ratio	
v	linear velocity at pitch diameter	m/s

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$x_{1,2}$	addendum modification coefficient of pinion, wheel	
z	number of teeth	
$z_{1,2}$	number of teeth of pinion, wheel	
z_n	virtual number of teeth	
α_n	normal pressure angle at reference cylinder	°
α_t	transverse pressure angle at ref. cylinder	°
α_{tw}	transverse pressure angle at working pitch cylinder	°
β	helix angle at reference cylinder	°
β_b	helix angle at base cylinder	°
ε_α	transverse contact ratio	
ε_β	overlap ratio	
ε_γ	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:

$$u = z_2/z_1 = d_{w2}/d_{w1} = d_2/d_1$$

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.

$$\tan \alpha_t = \frac{\tan \alpha_n}{\cos \beta}$$

$$\tan \beta_b = \tan \beta \cdot \cos \alpha_t$$

$$d_{1,2} = \frac{z_{1,2} m_n}{\cos \beta}$$

$$d_{b1,2} = d_{1,2} \cos \alpha_t$$

$$\left. \begin{aligned} d_{w1} &= \frac{2a}{u+1} \\ d_{w2} &= \frac{2au}{u+1} \end{aligned} \right\} \text{ where } a = 0.5(d_{w1} + d_{w2})$$

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$$z_{n1,2} = \frac{z_{1,2}}{\cos^2 \beta_b \cdot \cos \beta}$$

$$m_t = \frac{m_n}{\cos \beta}$$

$$\text{inv} \alpha = \tan \alpha - \frac{\pi \alpha}{180}; \quad \alpha [^\circ]$$

$$\text{inv} \alpha_{tw} = \text{inv} \alpha_t + 2 \tan \alpha_n \frac{x_1 + x_2}{z_1 + z_2} \quad \text{or} \quad \cos \alpha_{tw} = \frac{m_t (z_1 + z_2)}{2a} \cos \alpha_t$$

$$\varepsilon_\alpha = \frac{0,5 \sqrt{d_{a1}^2 - d_{b1}^2} \pm 0,5 \sqrt{d_{a2}^2 - d_{b2}^2} - a \cdot \sin \alpha_{tw}}{\pi \cdot m_t \cdot \cos \alpha_t}$$

the positive sign is used for external gears, the negative sign for internal gears

$$\varepsilon_\beta = \frac{b \cdot \sin \beta}{\pi \cdot m_n}$$

for double helix, b is to be taken as the width of one helix

$$\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta$$

$$v = \pi \cdot d_{1,2} n_{1,2} / 60 \cdot 10^3$$

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:

$$T_{1,2} = \frac{30 \cdot 10^3 P}{\pi \cdot n_{1,2}}$$

$$F_t = 2000 \cdot T_{1,2} / d_{1,2}$$

M56.1.6 General influence factors

M56.1.6.1 Application factor, K_A ¹⁾

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;

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- 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_V

The load sharing factor, K_V , accounts for the maldistribution of load in multiple path transmissions (dual tandem, epicyclic, double helix, etc.)

K_V 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_V , 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 ($F_t K_A K_V$).

The factor mainly depends on:

- transmission errors (depending on pitch and profile errors);
- masses of pinion and wheel;

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- 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.:

$$\frac{vz_1}{100} \sqrt{\frac{u^2}{1+u^2}} < 10 \text{ m/s}$$

- 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 $\frac{vz_1}{100} \sqrt{\frac{u^2}{1+u^2}} < 3 \text{ m/s}$, 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 6336-1:2019.

a) For spur gears and for helical gears with overlap ratio $\varepsilon_\beta \geq 1$

$$K_v = 1 + \left(\frac{K_1}{K_A \frac{F_t}{b}} + K_2 \right) \cdot \frac{vz_1}{100} K_3 \sqrt{\frac{u^2}{1+u^2}}$$

If $K_A F_t / b$ 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

	K_1 ISO accuracy grades ²⁾					
	3	4	5	6	7	8
spur gears	2.1	3.9	7.5	14.9	26.8	39.1
helical gears	1.9	3.5	6.7	13.3	23.9	34.8

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:

$$\text{If } \frac{vz_1}{100} \sqrt{\frac{u^2}{1+u^2}} \leq 0.2 \text{ then } K_3 = 2.0$$

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$$\text{If } \frac{vz_1}{100} \sqrt{\frac{u^2}{1+u^2}} > 0.2 \quad \text{then} \quad K_3 = 2.071 - 0.357 \cdot \frac{vz_1}{100} \sqrt{\frac{u^2}{1+u^2}}$$

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 1328-1:2013. 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 6336-1:2019.

Alternative methods acceptable to the Society may be applied.

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- a) In case the hardest contact is at the end of the face width $K_{F\beta}$ is given by the following equations:

$$K_{F\beta} = K_{H\beta}^N$$

$$N = \frac{(b/h)^2}{1 + (b/h) + (b/h)^2}$$

(b/h) = face width/tooth height ratio, the minimum of b_1/h_1 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_γ , 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 6336-1:2019.

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 σ_H must be equal to or less than the permissible contact stress σ_{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:

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σ_{H0} = basic value of contact stress for pinion and wheel

$$\sigma_{H0} = Z_B \cdot Z_H \cdot Z_E \cdot Z_\varepsilon \cdot Z_\beta \sqrt{\frac{F_t}{d_1 \cdot b} \frac{(u+1)}{u}} \quad \text{for pinion}$$

$$\sigma_{H0} = Z_D \cdot Z_H \cdot Z_E \cdot Z_\varepsilon \cdot Z_\beta \sqrt{\frac{F_t}{d_1 \cdot b} \frac{(u+1)}{u}} \quad \text{for wheel}$$

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_ε = contact ratio factor (see clause 2.6)

Z_β = helix angle factor (see clause 2.7)

F_t = nominal tangential load at reference cylinder in the transverse section (see Part 1)

b = common face width

d_1 = reference diameter of pinion

u = gear ratio
(for external gears u is positive, for internal gears u is negative)

Regarding factors K_A , K_V , K_H , $K_{H\alpha}$ and $K_{H\beta}$, see Part 1.

M56.2.2.2 Permissible contact stress

The permissible contact stress σ_{HP} is to be evaluated separately for pinion and wheel:

$$\sigma_{HP} = \frac{\sigma_{Hlim} \cdot Z_N}{S_H} \cdot Z_L \cdot Z_V \cdot Z_R \cdot Z_X$$

where:

σ_{Hlim} = endurance limit for contact stress (see clause 2.8)

Z_N = life factor for contact stress (see clause 2.9)

Z_L = lubrication factor (see clause 2.10)

Z_V = velocity factor (see clause 2.10)

Z_R = roughness factor (see clause 2.10)

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Z_W = hardness ratio factor (see clause 2.11)

Z_X = size factor for contact stress (see clause 2.12)

S_H = 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, $\varepsilon_\beta=0$

$Z_B = M_1$ or 1 whichever is the larger value

$Z_D = M_2$ or 1 whichever is the larger value

$$M_1 = \frac{\tan \alpha_{tw}}{\sqrt{\left(\sqrt{\frac{d_{a1}^2}{d_{b1}^2} - 1} - \frac{2\pi}{z_1}\right) \left(\sqrt{\frac{d_{a2}^2}{d_{b2}^2} - 1} - (\varepsilon_\alpha - 1) \frac{2\pi}{z_2}\right)}}$$

$$M_2 = \frac{\tan \alpha_{tw}}{\sqrt{\left(\sqrt{\frac{d_{a2}^2}{d_{b2}^2} - 1} - \frac{2\pi}{z_2}\right) \left(\sqrt{\frac{d_{a1}^2}{d_{b1}^2} - 1} - (\varepsilon_\alpha - 1) \frac{2\pi}{z_1}\right)}}$$

For helical gears when $\varepsilon_\beta \geq 1$

$$\begin{aligned} Z_B &= 1 \\ Z_D &= 1 \end{aligned}$$

For helical gears when $\varepsilon_\beta < 1$ 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 $\varepsilon_\beta \geq 1$.

Thus:

$$Z_B = M_1 - \varepsilon_\beta (M_1 - 1) \text{ and } Z_B \geq 1$$

$$Z_D = M_2 - \varepsilon_\beta (M_2 - 1) \text{ and } Z_D \geq 1$$

For internal gears, Z_D shall be taken as equal to 1.

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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:

$$Z_H = \sqrt{\frac{2 \cos \beta_b}{\cos^2 \alpha_t \tan \alpha_{tw}}}$$

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 ν (Poisson's ratio) on the contact stress.

The elasticity factor, Z_E , for steel gears ($E = 206\,000 \text{ N/mm}^2$, $\nu = 0.3$) is equal to:

$$Z_E = 189.8 \sqrt{\text{N/mm}^2}$$

In other cases, reference is to be made to the reference standard ISO 6336-2:2019.

M56.2.6 Contact ratio factor, Z_ϵ

The contact ratio factor, Z_ϵ , 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_ϵ , is to be calculated as follows:

Spur gears:

$$Z_\epsilon = \sqrt{\frac{4 - \epsilon_\alpha}{3}}$$

Helical gears:

- for $\epsilon_\beta < 1$

$$Z_\epsilon = \sqrt{\frac{4 - \epsilon_\alpha (1 - \epsilon_\beta) + \frac{\epsilon_\beta}{\epsilon_\alpha}}{3}}$$

- for $\epsilon_\beta \geq 1$

$$Z_\epsilon = \sqrt{\frac{1}{\epsilon_\alpha}}$$

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M56.2.7 Helix angle factor, Z_β

The helix angle factor, Z_β , 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_β is dependent only on the helix angle.

The helix angle factor, Z_β , is to be calculated as follows:

$$Z_\beta = \sqrt{\frac{1}{\cos \beta}}$$

Where β is the reference helix angle.

M56.2.8 Endurance limit for contact stress, σ_{Hlim}

For a given material, σ_{Hlim} is the limit of repeated contact stress which can be permanently endured. The value of σ_{Hlim} can be regarded as the level of contact stress which the material will endure without pitting for at least 5×10^7 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 σ_{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 σ_{Hlim} , is to be determined, in general, making reference to values indicated in the standard ISO 6336-5:2016, 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;
- influence factors (Z_R , Z_V , Z_L , Z_W , Z_X).

The life factor, Z_N , is to be determined according to Method B outlined in the reference standard ISO 6336-2:2019.

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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:

$$Z_L = C_{ZL} + \frac{4(1 - C_{ZL})}{\left(1.2 + \frac{134}{v_{40}}\right)^2}$$

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:

v_{40} = nominal kinematic viscosity of the oil at 40°C, mm²/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:

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$$C_{ZV} = C_{ZL} + 0.02$$

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 6336-2:2019).

$$R_{z10} = R_z \sqrt[3]{\frac{10}{\rho_{red}}}$$

relative radius of curvature:

$$\rho_{red} = \frac{\rho_1 \cdot \rho_2}{\rho_1 + \rho_2}$$

Wherein:

$$\rho_{1,2} = 0.5 \cdot d_{b1,2} \cdot \tan \alpha_{tw}$$

(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

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$$\begin{aligned} \text{If } HB < 130 \quad Z_W &= 1.2 \cdot \left(\frac{3}{R_{zH}} \right)^{0.15} \\ \text{If } 130 \leq HB \leq 470 \quad Z_W &= \left(1.2 - \frac{HB - 130}{1700} \right) \cdot \left(\frac{3}{R_{zH}} \right)^{0.15} \\ \text{If } HB > 470 \quad Z_W &= \left(\frac{3}{R_{zH}} \right)^{0.15} \end{aligned}$$

Where:

HB = Brinell hardness of the tooth flanks of the softer gear of the pair

R_{zH} = equivalent roughness, μm

$$R_{zH} = \frac{R_{z1} \cdot (10 / \rho_{red})^{0.33} \cdot (R_{z1} / R_{z2})^{0.66}}{(v \cdot v_{40} / 1500)^{0.33}}$$

ρ_{red} = 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.

$$\begin{aligned} \text{If } HB_1 / HB_2 < 1.2 \quad Z_W &= 1 \\ \text{If } 1.2 \leq HB_1 / HB_2 \leq 1.7 \quad Z_W &= 1 + \left(0.00898 \frac{HB_1}{HB_2} - 0.00829 \right) \cdot (u - 1) \\ \text{If } HB_1 / HB_2 > 1.7 \quad Z_W &= 1 + 0.00698 \cdot (u - 1) \end{aligned}$$

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 case depth relative to tooth size and radius of relative curvature $Z_X = 1$. When the case depth is relatively shallow then a smaller value of Z_X should be chosen.

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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 σ_F and the permissible root stress σ_{FP} shall be calculated separately for the pinion and the wheel.

σ_F must not exceed σ_{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 6336-3:2019.

M56.3.2 Basic equations

M56.3.2.1 Tooth root bending stress for pinion and wheel

$$\sigma_F = \frac{F_t}{bm_n} Y_F Y_S Y_\beta Y_B Y_{DT} K_A K_\gamma K_v K_{F\alpha} K_{F\beta} \leq \sigma_{FP}$$

where:

Y_F	= tooth form factor	(see clause 3.3)
Y_S	= stress correction factor	(see clause 3.4)
Y_β	= helix angle factor	(see clause 3.5)
Y_B	= rim thickness factor	(see clause 3.6)
Y_{DT}	= deep tooth factor	(see clause 3.7)
$F_t, K_A, K_\gamma, K_v, K_{F\alpha}, K_{F\beta}$		(see Part 1)
b		(see Part 1, clause 1.4)
m_n		(see Part 1, clause 1.3)

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M56.3.2.2 Permissible tooth root bending stress for pinion and wheel

$$\sigma_{FP} = \frac{\sigma_{FE} Y_d Y_N}{S_F} Y_{\delta_{relT}} Y_{R_{relT}} Y_X$$

where:

- σ_{FE} = bending endurance limit
- Y_d = design factor
- Y_N = life factor
- $Y_{\delta_{relT}}$ = relative notch sensitivity factor
- $Y_{R_{relT}}$ = 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:

$$Y_F = \frac{6 \frac{h_F}{m_n} \cos \alpha_{Fen}}{\left(\frac{s_{Fn}}{m_n} \right)^2 \cos \alpha_n}$$

Where:

- h_F = bending moment arm for tooth root bending stress
for application of load at the outer point of single tooth
pair contact mm
- s_{Fn} = tooth root normal chord in the critical section mm
- α_{Fen} = pressure angle at the outer point of single tooth pair
contact in the normal section °

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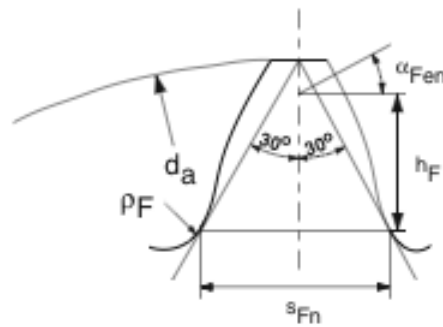


Fig. 3.1 Dimensions of h_F , s_{Fn} and α_{Fen} for external gear

For the calculation of h_F , s_{Fn} and α_{Fen} , the procedure outlined in the reference standard ISO 6336-3:2019 (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: $1 \leq q_s \leq 8$):

$$Y_S = (1.2 + 0.13L) q_s^{\left(\frac{1}{1.21 + 2.3/L}\right)}$$

Where:

$$q_s = \frac{s_{Fn}}{2\rho_F}$$

q_s = notch parameter,

ρ_F = root fillet radius in the critical section, mm

L = s_{Fn} / h_F

For h_F and s_{Fn} see clause 3.1

For the calculation of ρ_F the procedure outlined in the reference standard ISO 6336-3:2019 is to be used.

M56.3.5 Helix angle factor, Y_β

The helix angle factor, Y_β , 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.

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The helix angle factor, Y_β is to be calculated as follows:

$$Y_\beta = 1 - \varepsilon_\beta \frac{\beta}{120}$$

where:

β = reference helix angle in degrees.

The value 1.0 is substituted for ε_β 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:

$$\text{if } s_R / h \geq 1.2 \quad Y_B = 1$$

$$\text{if } 0.5 < s_R / h < 1.2 \quad Y_B = 1.6 \cdot \ln \left(2.242 \frac{h}{s_R} \right)$$

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.

b) for internal gears:

$$\text{if } s_R / m_n \geq 3.5 \quad Y_B = 1$$

$$\text{if } 1.75 < s_R / m_n < 3.5 \quad Y_B = 1.15 \cdot \ln \left(8.324 \frac{m_n}{s_R} \right)$$

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 $2.05 \leq \varepsilon_{an} \leq 2.5$, where:

$$\varepsilon_{an} = \frac{\varepsilon_a}{\cos^2 \beta_b}$$

Factor Y_{DT} is to be determined as follows:

if ISO accuracy grade ≤ 4 and $\varepsilon_{an} > 2.5$

$$Y_{DT} = 0.7$$

if ISO accuracy grade ≤ 4 and $2.05 < \varepsilon_{an} \leq 2.5$

$$Y_{DT} = 2.366 - 0.666 \cdot \varepsilon_{an}$$

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in all other cases

$$Y_{DT} = 1.0$$

M56.3.8 Bending endurance limit, σ_{FE}

For a given material, σ_{FE} is the local tooth root stress which can be permanently endured.

According to the reference standard ISO 6336-5:2016 the number of 3×10^6 cycles is regarded as the beginning of the endurance limit.

σ_{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 σ_{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, σ_{FE} is to be determined, in general, making reference to values indicated in the reference standard ISO 6336-5:2016, 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 σ_{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 ($Y_{\delta relT}$, Y_{RrelT} , Y_X).

The life factor, Y_N , is to be determined according to Method B outlined in the reference standard ISO 6336-3:2019.

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M56.3.11 Relative notch sensitivity factor, $Y_{\delta rel T}$

The relative notch sensitivity factor, $Y_{\delta rel T}$, 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, $Y_{\delta rel T}$, is to be determined as follows:

$$Y_{\delta rel T} = \frac{1 + \sqrt{0.2\rho'(1 + 2q_s)}}{1 + \sqrt{1.2\rho'}}$$

where:

q_s = notch parameter (see clause 3.4)

ρ' = slip-layer thickness, mm, from the following table

Material	ρ' , mm
case hardened steels, flame or induction hardened steels	0.0030
through-hardened steels ¹⁾ , yield point R_e =	500 N/mm ²
	600 N/mm ²
	800 N/mm ²
	1000 N/mm ²
nitrided steels	0.1005
¹⁾ The given values of ρ' can be interpolated for values of R_e not stated above	

M56.3.12 Relative surface factor, $Y_{Rrel T}$

The relative surface factor, $Y_{Rrel T}$, 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, $Y_{Rrel T}$ is to be determined as follows:

$R_z < 1$	$1 \leq R_z \leq 40$	Material
1.120	$1.674 - 0.529(R_z + 1)^{0.1}$	case hardened steels, through - hardened steels ($\sigma_B \geq 800$ N/mm ²)
1.070	$5.306 - 4.203(R_z + 1)^{0.01}$	normalised steels ($\sigma_B < 800$ N/mm ²)
1.025	$4.299 - 3.259(R_z + 1)^{0.0058}$	nitrided steels

Where:

R_z = mean peak-to-valley roughness of tooth root fillets, μm

σ_B = tensile strength, N/mm²

The method applied here is only valid when scratches or similar defects deeper than $2R_z$ are not present.

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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:

$$R_a = CLA = AA = R_z / 6$$

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:

$Y_X = 1.00$	for $m_n \leq 5$	generally
$Y_X = 1.03 - 0.06 m_n$	for $5 < m_n < 30$	normalised and through-hardened steels
$Y_X = 0.85$	for $m_n \geq 30$	
$Y_X = 1.05 - 0.010 m_n$	for $5 < m_n < 25$	surface hardened steels
$Y_X = 0.80$	for $m_n \geq 25$	

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.

End of Document

M57 Use of ammonia as a refrigerant

(1993)

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.

End of Document

M58 Charge air coolers

(1994)

Deleted Feb 2015, replaced by UR M72.

End of Document

M59 **Control and Safety Systems for Dual Fuel Diesel Engines**

(1996)

Deleted June 2019

End of
Document

M60

(1997)
(Rev.1
Nov 2021)

Control and Safety of Gas Turbines for Marine Propulsion Use

1 Governor and Over speed protective devices

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.

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.

2 Miscellaneous automatic safety devices

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 (FMEA).

Unless the FMEA required by this UR proves otherwise, the shutdown functions for gas turbines are to be provided in accordance with Table 1 of this UR in addition to the general monitoring and safety system functions given by the Classification Societies.

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

Note:

- 1. Rev.1 of this UR is to be uniformly implemented by IACS Societies for vessels contracted for construction on or after 1 January 2023.
- 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.

M60
(cont)

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

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.

2.5 Hand trip gear for shutting off the fuel in an emergency is to be provided at the manoeuvring station.

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.

3 Alarming devices

3.1 Although in principle alarming devices listed in Table 1 are to be provided, they can be added or omitted, taking into account the result of FMEA specified in item 2.1.

3.2 Suitable alarms are to be operated by the activation of shutdown devices.

M60

(cont)

Table 1 List of alarm and shutdown

Monitoring parameter	Alarm	Shutdown
Turbine speed	high	x
Lubricating oil pressure	low*	x
Lubricating oil pressure of reduction gear	low*	x
Differential pressure across lubricating oil filter	high	
Lubricating oil temperature	high	
Oil fuel supply pressure	low	
Oil fuel temperature	high	
Cooling medium temperature	high	
Bearing temperature	high	
Flame and ignition Failure	x	x
Automatic starting Failure	x	
Vibration	high*	x
Axial displacement of rotor	high	x
Exhaust gas temperature	high*	x
Vacuum pressure at the compressor inlet	high*	x
Loss of control system	x	
Footnotes: 1) Alarms marked with “*” are to be activated at the suitable setting points prior to arriving the critical condition for the activation of shutdown devices.		

End of
Document

M61

(Dec 2003)
(Rev.1
Feb 2022)
(Rev.2
Aug 2023)

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. The capacity of one of the said independently driven compressors or the combined capacity of independently driven compressors shall not be 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. 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.

Note:

1. Rev.1 of this Unified Requirement is to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 January 2023.
2. Rev.2 of this Unified Requirement is to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 January 2025.
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.

M61
(cont)**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.

End of Document

M62 Rooms for emergency fire pumps in cargo ships

(Feb 2002)

Deleted June 2014, converted to Rec 135.

End of Document

M63

(Jan 2005)
(Rev.1
Jan 2023)

Alarms and safeguards for emergency reciprocating I.C. engines

1. Field of application

These requirements apply to reciprocating I.C. engines, which use distillate marine fuels covered by ISO 8217:2017, 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 reciprocating I.C. engines and are to remain operational in the event of failure of the alarm and safety systems.

Note:

1. Rev.1 of this Unified Requirement is to be uniformly implemented by IACS Societies on ships constructed on or after 1 January 2024.

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(cont)

Table 1

Parameter	Alarm activation	Shutdown with alarm
Fuel oil leakage from high pressure pipes (fuel injection pipes and common rails)	x	
Lubricating oil temperature ¹	high	
Lubricating oil pressure	low	
Activation of oil mist detection arrangements (or activation of the temperature monitoring systems or equivalent devices of: - the engine main and crank bearing oil outlet; or - the engine main and crank bearing) ²	x	
Pressure or flow of cooling water ¹	low	
Temperature of cooling water (or cooling air)	high	
Overspeed activated ¹		x

Note:

- 1 for engines having a power of or more than 220 kW.
- 2 for engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.

End of
Document

M64 Design of integrated cargo and ballast systems on tankers

(April
2003)
(Rev.1
July
2004)

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.

END

M65
(Feb 2004)
(Rev.1
July
2004)

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.

END

M66 Type Testing Procedure for Crankcase Explosion Relief Valves

(Jan 2005)
(Corr.1
Nov 2005)
(Rev.1
Oct 2006)
(Corr.1
Mar 2007)
(Rev.2
Sept 2007)
(Corr.1
Oct 2007)
(Rev.3
Jan 2008)
(Rev.4
Feb 2021)
(Corr.1
Oct 2021)

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.

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) Rev.4 of this UR is to be uniformly implemented by IACS Societies on ships for which the date of contract for construction is on or after 1 July 2022.

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2. Recognised Standards

- 2.1 ISO 16852:2016
- 2.2 ISO/IEC 17025:2017
- 2.3 ISO 12100:2010
- 2.4 VDI 3673-1:2002
- 2.5 IMO MSC/Circ.677 as amended by MSC/Circ.1009 and MSC.1/Circ.1324

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 17025:2017, 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 $\pm 0.1\%$.
 - 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.

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- 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 1150cm^2 of free area, would require a test vessel with a volume of 10m^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 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 $9.5\% \pm 0.5\%$. 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.

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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.

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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:

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- 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.

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$$(a) \quad \frac{n_1}{n_2} = \sqrt{\frac{S_1}{S_2}}$$

$$(b) \quad \frac{A_1}{A_2} = \frac{S_1}{S_2}$$

Where:

n_1 = 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 = 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 = free area of quenching device for a valve with a relief area equal to S_1

A_2 = free area of quenching device for a valve with a relief area equal to S_2

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

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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.

End of Document

M67 Type Testing Procedure for Crankcase Oil Mist Detection and Alarm Equipment

(Jan
2005)
(Corr.1
Nov
2005)
(Rev.1
Oct
2006)
(Corr.1
Oct
2007)
(Rev.2
Feb
2015)

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.

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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 $\pm 10\%$ 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.

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- (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 $\pm 10\%$.
- 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.

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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.

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8.1.1.2 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.

8.1.1.3 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.

8.1.1.4 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.

8.1.1.5 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.

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

8.1.2 For type approval by a classification society the testing is to be witnessed by authorised personnel from the classification society.

8.1.3 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.

8.1.4 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:

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- 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;

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(cont'd)

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.

End of Document

M68 Dimensions of propulsion shafts and their permissible torsional vibration stresses

(Feb 2005)
(Corr.1
Mar 2012)
(Corr.2
Nov 2012)
(Rev.1
Aug 2014)
(Rev.2
Apr 2015)
(Rev.3
Feb 2021)

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.
6. Rev.3 of UR M68 is to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 July 2022.

M68 (cont)

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 (σ_B) of 500 N/mm². Otherwise materials having a specified minimum ultimate tensile strength (σ_B) of 400 N/mm² may be used.

For use in the following formulae in this UR, σ_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:

$$d = F.k. \sqrt[3]{\frac{p}{n_0} \cdot \frac{1}{1 - \frac{d_i^4}{d_o^4}} \cdot \frac{560}{\sigma_B + 160}}$$

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 ≤0.40d_o, the expression

$$1 - \frac{d_i^4}{d_o^4} \text{ may be taken as } 1.0$$

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

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(cont)

k = factor for the particular shaft design features, see M68.6

n_0 = 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)

σ_B = 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 $(\tau_{\max} - \tau_{\min})/2$ 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:

$$\pm \tau_C = \frac{\sigma_B + 160}{18} \cdot C_K \cdot C_D \cdot (3 - 2\lambda^2) \quad \text{for } \lambda < 0.9$$

$$\pm \tau_C = \frac{\sigma_B + 160}{18} \cdot C_K \cdot C_D \cdot 1.38 \quad \text{for } 0.9 \leq \lambda < 1.05$$

where:

τ_C = permissible stress amplitude in N/mm² due to torsional vibration for continuous operation

σ_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

λ = speed ratio = n/n_0

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(cont)

n = speed in revolutions per minute under consideration

n_0 = speed in revolutions per minute of shaft at rated power

Where the stress amplitudes exceed the limiting values of τ_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 (τ_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 τ_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 = critical speed in revolutions per minute (resonance speed)

λ_c = speed ratio = 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:

τ_T = permissible stress amplitude in N/mm² due to steady state torsional vibration in a barred speed range.

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(cont)

M68.6 Table of k and c_k factors for different design features (see M68.7.2)

Intermediate shafts with						thrust shafts external to engines		propeller shafts		
integral coupling flange ¹⁾ and straight sections	shrink fit coupling ²⁾	Keyway, tapered connection ^{3) 4)}	Keyway, cylindrical connection ^{3) 4)}	radial hole ⁵⁾	longitudinal slot ⁶⁾	on both sides of thrust collar ¹⁾	in way of bearing when a roller bearing is used	Flange mounted or keyless taper fitted propellers ⁸⁾	Key fitted propellers ⁸⁾	Between forward end of aft most bearing and forward stern tube seal
$k=1.0$	1.0	1.10	1.10	1.10	1.20	1.10	1.10	1.22	1.26	1.15
$c_k=1.0$	1.0	0.60	0.45	0.50	0.30 ⁷⁾	0.85	0.85	0.55	0.55	0.80

Note:

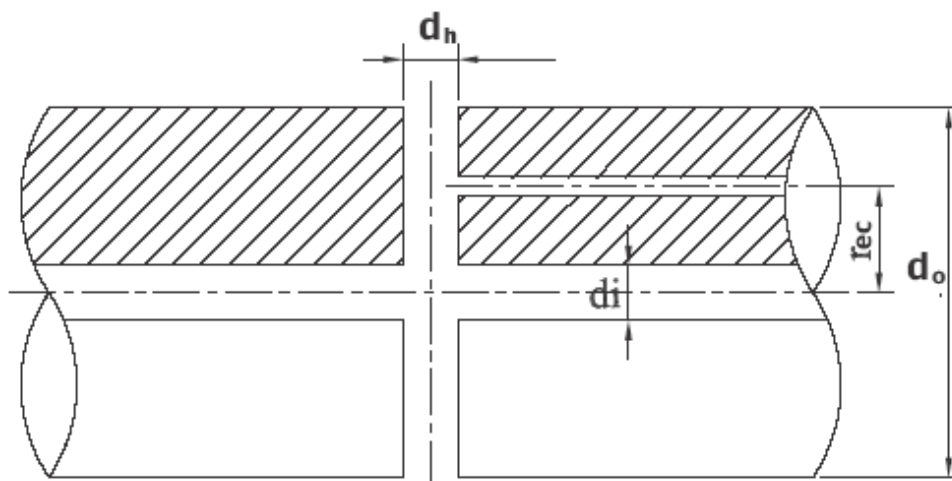
Transitions of diameters are to be designed with either a smooth taper or a blending radius. For guidance, a blending radius equal to the change in diameter is recommended.

Footnotes

- 1) Fillet radius is not to be less than $0.08d$.
- 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 $0.2d_o$ 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_h) not to exceed $0.3d_o$.
The intersection between a radial and an eccentric (r_{ec}) axial bore (see below) is not covered by this UR.

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(cont)



- 6) Subject to limitations as slot length (l)/outside diameter < 0.8 and inner diameter (d_i)/outside diameter < 0.7 and slot width (e)/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:

$$c_K = 1.45/\text{scf}$$

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.

M68 (cont)

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 $0.08d_o$ (geometric stress concentration of approximately 1.45).

$$C_K = \frac{1.45}{scf} \quad \text{and} \quad k = \left[\frac{scf}{1.45} \right]^x$$

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):

$$scf = \alpha_{t(hole)} + 0.8 \cdot \frac{(l - e)/d}{\sqrt{\left(1 - \frac{d_i}{d}\right) \cdot \frac{e}{d}}}$$

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.

$\alpha_{t(hole)}$ represents the stress concentration of radial holes (in this context e = hole diameter) and can be determined as:

$$\alpha_{t(hole)} = 2.3 - 3 \cdot \frac{e}{d} + 15 \cdot \left(\frac{e}{d}\right)^2 + 10 \cdot \left(\frac{e}{d}\right)^2 \cdot \left(\frac{d_i}{d}\right)^2$$

or simplified to $\alpha_{t(hole)} = 2.3$

M68 Appendix I

(cont)

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 τ_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 β 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 <0.2µm Ra with the absence of localised machining marks verified by visual examination at low magnification (x20) as required by Section 8.4 of ISO 1352:2011.

Test procedures are to be in accordance with Section 10 of ISO 1352:2011.

Table 1 **Test condition**

Loading type	Torsion
Stress ratio	R=-1
Load waveform	Constant-amplitude sinusoidal
Evaluation	S-N curve
Number of cycles for test termination	1 x 10 ⁷ cycles

2.2 Acceptance criteria

Measured high-cycle torsional fatigue strength τ_{C1} and low-cycle torsional fatigue strength τ_{C2} are to be equal to or greater than the values given by the following formulae:

$$\tau_{C1} \geq \tau_{C,\lambda=0} = \frac{\sigma_B + 160}{6} \cdot C_K \cdot C_D$$

$$\tau_{C2} \geq 1.7 \cdot \frac{1}{\sqrt{C_K}} \tau_{C1}$$

M68**(cont)**

where

 C_K = factor for the particular shaft design features, see M68.7

scf = stress concentration factor, see M68.7.3 (For unnotched specimen, 1.0.)

 C_D = size factor, see M68.5 σ_B = specified minimum tensile strength in N/mm² 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 4967:2013 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

Inclusion group	Series	Limiting chart diagram index <i>I</i>
Type A	Fine	1
	Thick	1
Type B	Fine	1.5
	Thick	1
Type C	Fine	1
	Thick	1
Type D	Fine	1
	Thick	1
Type DS	-	1

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.

End of Document

M69

(June 2008)
(Rev.1
Feb 2021)

Qualitative Failure Analysis for Propulsion and Steering on Passenger Ships

Deleted in Mar 2022.

End of
Document

M71 Type Testing of I.C. Engines

(Feb
2015)
(Corr.1
June
2016)

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.

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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

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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

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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⁾

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- 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.

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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.

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8.5 During all these load points, engine parameters are to be within the specified and approved values.

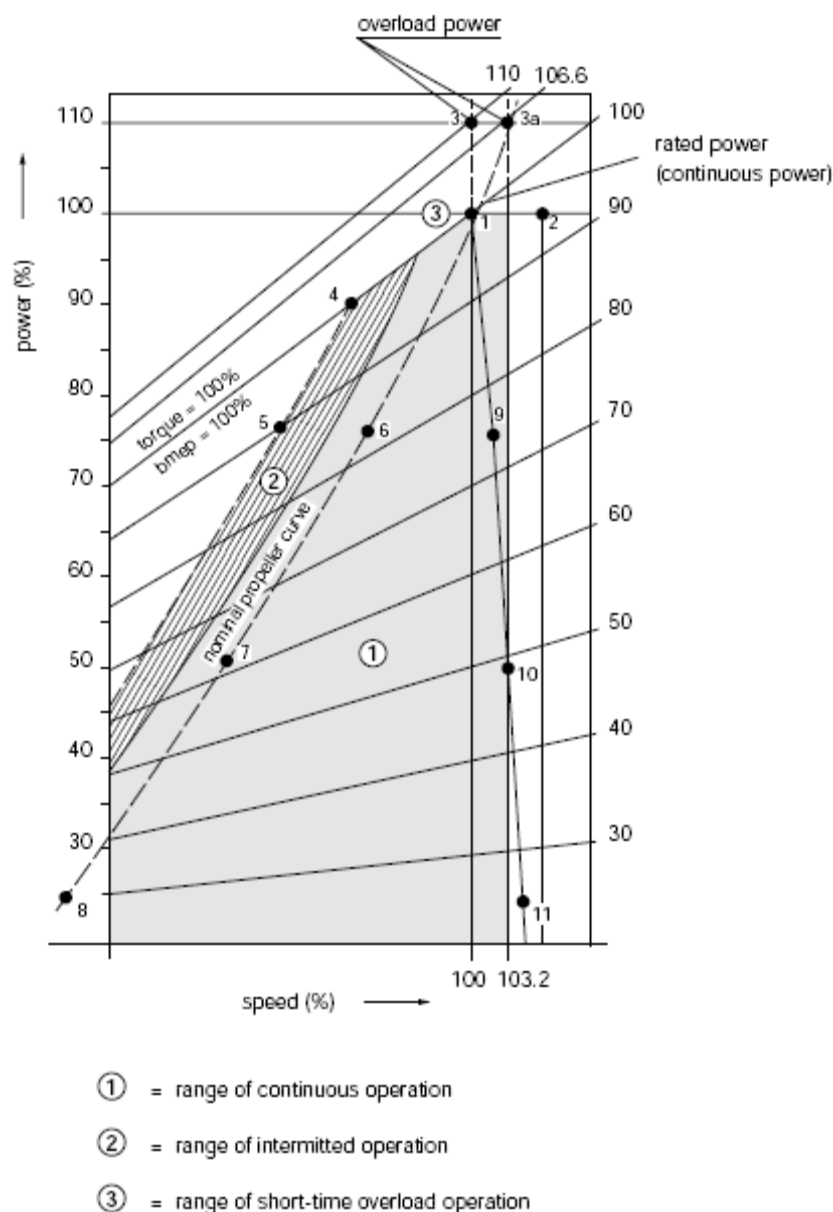


Figure 1 Load points

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.)

M71 (cont)

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

M71
(cont)

- 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.

End of Document

M72 Certification of Engine Components

(Feb 2015)
(Corr.1
Aug 2015)
(Rev.1
Mar 2016)
(Rev.2
Jan 2019)
(Rev.3
Apr 2023)

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 finished certified component itself; or
 - on samples taken from earlier stages in the production of the component, when applicable.
- that the inspection and tests were performed in the presence of the Surveyor or in accordance with special agreements, i.e., Alternative Certification Scheme (ACS).

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.
3. Rev.2 of this UR is to be uniformly implemented by IACS Societies to engines with an application for certification dated on or after 1 January 2020.
4. Rev.3 of this UR is to be uniformly implemented by IACS Societies to engines with an application for certification dated on or after 1 July 2024.

M72

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

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

- the test was witnessed by the Society Surveyor; or
- an 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.

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 batch.

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

M72

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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

Symbol	Description
C	chemical composition
CD	crack detection by MPI or DP
CH	crosshead engines
D	cylinder bore diameter (mm)
GJL	gray cast iron
GJS	spheroidal graphite cast iron
GS	cast steel
M	mechanical properties
SC	society certificate
TR	test report
UT	ultrasonic testing
W	work certificate
X	visual examination of accessible surfaces by the Surveyor

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

M72
(cont)

Item	Part ^{4), 5), 6), 7), 8)}	Material properties ¹⁾	Non-destructive examination ²⁾	Hydraulic testing ³⁾	Dimensional inspection, including surface condition	Visual inspection (surveyor)	Applicable to engines:	Component certificate
1	Welded bedplate	W(C+M)	W(UT+CD)			fit-up + post-welding	All	SC
2	Bearing transverse girders GS	W(C+M)	W(UT+CD)			X	All	SC
3	Welded frame box	W(C+M)	W(UT+CD)			fit-up + post-welding	All	SC
4	Cylinder block GJL			W ¹⁰⁾			>400 kW/cyl	
5	Cylinder block GJS			W ¹⁰⁾			>400 kW/cyl	
6	Welded cylinder frames	W(C+M)	W(UT+CD)			fit-up + post-welding	CH	SC
7	Engine block GJL			W ¹⁰⁾			>400 kW/cyl	
8	Engine block GJS	W(M)		W ¹⁰⁾			>400 kW/cyl	
9	Cylinder liner	W(C+M)		W ¹⁰⁾			D>300mm	
10	Cylinder head GJL			W			D>300mm	
11	Cylinder head GJS			W			D>300mm	
12	Cylinder head GS	W(C+M)	W(UT+CD)	W		X	D>300mm	SC
13	Forged cylinder head	W(C+M)	W(UT+CD)	W		X	D>300mm	SC
14	Piston crown GS	W(C+M)	W(UT+CD)			X	D>400mm	SC
15	Forged piston crown	W(C+M)	W(UT+CD)			X	D>400mm	SC
16	Crankshaft: made in one piece	SC(C+M)	W(UT+CD)		W	Random, of fillets and oil bores	All	SC
17	Semi-built Crankshaft (Crankthrow, forged main journal and journals with flange)	SC(C+M)	W(UT+CD)		W	Random, of fillets and shrink fittings	All	SC

M72
 (cont)

Item	Part ^{4), 5), 6), 7), 8)}	Material properties ¹⁾	Non-destructive examination ²⁾	Hydraulic testing ³⁾	Dimensional inspection, including surface condition	Visual inspection (surveyor)	Applicable to engines:	Component certificate
18	Exhaust gas valve cage			W			CH	
19	Piston rod	SC(C+M)	W(UT+CD)			Random	D>400mm CH	SC
20	Cross head	SC(C+M)	W(UT+CD)			Random	CH	SC
21	Connecting rod with cap	SC(C+M)	W(UT+CD)		W	Random, of all surfaces, in particular those shot peened	All	SC
22	Coupling bolts for crankshaft	SC(C+M)	W(UT+CD)		W	Random, of interference fit	All	SC
23	Bolts and studs for main bearings	W(C+M)	W(UT+CD)				D>300mm	
24	Bolts and studs for cylinder heads	W(C+M)	W(UT+CD)				D>300mm	
25	Bolts and studs for connecting rods	W(C+M)	W(UT+CD)		TR of thread making		D>300mm	
26	Tie rod	W(C+M)	W(UT+CD)		TR of thread making	Random	CH	SC
27	High pressure fuel injection pump body	W(C+M)		W			D>300mm	
		W(C+M)		TR			D≤300mm	
28	High pressure fuel injection valves (only for those not autofretted)			W			D>300mm	
				TR			D≤300mm	
29	High pressure fuel injection pipes including common fuel rail	W(C+M)		W for those that are not autofretted			D>300mm	

M72
 (cont)

Item	Part ^{4), 5), 6), 7), 8)}	Material properties ¹⁾	Non-destructive examination ²⁾	Hydraulic testing ³⁾	Dimensional inspection, including surface condition	Visual inspection (surveyor)	Applicable to engines:	Component certificate
		W(C+M)		TR for those that are not autofretted			D≤300mm	
30	High pressure common servo oil system	W(C+M)		W			D>300mm	
		W(C+M)		TR			D≤300mm	
31	Cooler, both sides ⁹⁾	W(C+M)		W			D>300mm	
32	Accumulator	W(C+M)		W			All engines with accumulators with a capacity of >0,5 l	
33	Piping, pumps, actuators, etc. for hydraulic drive of valves, if applicable	W(C+M)		W			>800 kW/cyl	
34	Engine driven pumps (oil, water, fuel, bilge) other than pumps referred to in item 27 and 33			W			>800 kW/cyl	
35	Bearings for main, crosshead, and crankpin	TR(C)	TR (UT for full contact between base material and bearing metal)		W		>800 kW/cyl	

M72 FOOTNOTES:

- (cont)
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. When certain NDE method on the finished component is impractical (for example UT for items 12/13), the NDE method can be performed at earlier appropriate stages in the production of the component, see M72.1.2.
 3. Hydraulic testing is applied on the water/oil side of the component. Items are to be tested by hydraulic pressure at the pressure equal to 1.5 times the maximum working pressure. High pressure parts of the fuel injection system are to be tested by hydraulic pressure at the pressure equal to 1.5 maximum working pressure or maximum working pressure plus 300 bar, whichever is the less. Where design or testing features may require modification of these test requirements, special consideration may be given.
 4. Material certification requirements for pumps and piping components are dependent on the operating pressure and temperature. Requirements given in this Table apply except where alternative requirements are explicitly given elsewhere in the IACS URs.
 5. For turbochargers, see M73.
 6. Crankcase explosion relief valves are to be type tested in accordance with M66 and documented according to M9.
 7. Oil mist detection systems are to be type tested in accordance with M67 and documented according to M10.
 8. For speed governor and overspeed protective devices, see M3.
 9. Charge air coolers need only be tested on the water side.
 10. Hydraulic testing is also required for those parts filled with cooling water and having the function of containing the water which is in contact with the cylinder or cylinder liner.

End of Document

M73 Turbochargers

(Feb 2015)
(Corr.1
Apr 2016)
(Rev.1
Mar 2022)
(Rev.2
May 2023)

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 new turbocharger type or of a turbocharger type that has undergone substantive modifications in respect of the one previously type approved, or for renewal of an expired type approval certificate.
3. The requirements of UR M73 Rev.1, except for M73.4, are to be uniformly implemented by IACS Societies to turbochargers with the date of application for certification on or after 1 January 2023. Turbochargers with an existing type approval on 1 January 2023 are not required to be re-type approved in accordance with this UR until the current Type Approval reaches its expiry date.

The requirements of M73.4 Rev.1 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 January 2023.

4. The requirements of UR M73 Rev.2, except for M73.4, are to be uniformly implemented by IACS Societies to turbochargers with the date of application for certification on or after 1 July 2024. Turbochargers with an existing type approval on 1 July 2024 are not required to be re-type approved in accordance with this UR until the current Type Approval reaches its expiry date.

The requirements of M73.4 Rev.2 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 2024.

M73 (cont)

1. Scope

1.1 These requirements are applicable for turbochargers regarding 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.

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

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- 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^{*)} 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^{*)}.

^{*)}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}

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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.

**) A generic range means a series of turbocharger which are of the same design, but scaled to each other.

3.2.3 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 a temperature which is not lower than the maximum allowable temperature of the turbocharger to be specified by the manufacturer.

3.2.5 Manufacturers are to determine whether cases more critical than those defined in M73.3.2.3. and M73.3.2.4 exist with respect to containment safety. Where such a case is identified, evidence of containment safety shall also be provided for that case.

3.2.56A numerical analysis (simulation) such as Finite Element Method (FEM) 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:

- 1) 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.
- 2) The corresponding numerical simulation for the containment is performed for the same speeds as specified for the containment test.
- 3) 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.
- 4) The design of the turbocharger regarding geometry and kinematics is to be 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.

3.2.7 In cases where a totally new design^{***}) is adopted for a turbocharger for which an application for type approval certification has been requested, new reference containment tests are to be performed.

***) Totally new design means the principal differences between a new turbocharger and previous ones are related to geometry and kinematics. The turbochargers are to be regarded as having a totally new design if the structure and/or material of the turbocharger casings are changed, or any of, but not limited to, the following items is changed from the previous design.

- Maximum permissible exhaust gas temperature
- Number of bearings
- Number of turbine blades
- Number of turbine wheels and/or compressor wheels

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- Direction of inlet air and/or exhaust gas (e.g., axial flow orientation, radial flow orientation)
- Type of the turbocharger drive (e.g., axial turbine type, radial turbine type, mixed flow turbine type)

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 for the low, medium, and high-speed engines 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.

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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; see UR Z26) 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 as a minimum cites the applicable type approval and the ACS, when ACS applies.
- For category B, a work's certificate, which at as 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.

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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.

Pos.	Monitored Parameters	Category of Turbochargers				Notes
		B		C		
		Alarm	Indication	Alarm	Indication	
1	Speed	High ⁽⁴⁾	X ⁽⁴⁾	High ⁽⁴⁾	X ⁽⁴⁾	
2	Exhaust gas at each turbocharger inlet, temperature	high ⁽¹⁾	X ⁽¹⁾	high	X	High temp. alarms for each cylinder at engine is acceptable ⁽²⁾
3	Lub. oil at turbocharger outlet, temperature			high	X	If not forced system, oil temperature near bearings
4	Lub. oil at turbocharger inlet, pressure	low	X	low	X	Only for forced lubrication systems ⁽³⁾

- (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.

End of Document

M74 Ballast Water Management Systems

(Sept 2015)
(Rev.1
May 2016)
(Rev.2
June 2021)

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.

This UR is not applied to ship's ballast water systems including piping valves, pumps, etc. where the BWMS is not fitted.

This UR is to be read in conjunction with IACS UR F45 - Installation of BWMS on-board ships.

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 equipment, all associated piping arrangements as specified by the manufacturer, control and monitoring equipment and sampling facilities. The categorization of BWMS technologies is given in Table 1. Applicability of the requirements for each BWMS technology is in accordance with Table 2.

Notes:

1. This UR is to be uniformly implemented by IACS Societies for BWMS:
 - i) For existing ships, where an application for approval for the plans of BWMS is made on or after 1 January 2017; or
 - ii) For new 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) For existing ships, where an application for approval for the plans of BWMS is made on or after 1 January 2017; or
 - ii) For new 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.
4. Rev.2 of this UR is to be uniformly implemented by IACS Societies for BWMS:
 - i) For existing ships, where an application for approval for the plans of BWMS is made on or after 1 July 2022; or
 - ii) For new ships contracted for construction on or after 1 July 2022.

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Table 1 - Categorization of BWMS technologies

BWMS's Technology category (informative Annex II should be referred to) →		1	2	3a	3b	3c	4	5	6	7a	7b	8
		In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO ₂ or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N ₂ from a N ₂ Generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-tank de-oxygenation with Inert Gas Generator	In-line full flow electrolysis	In-line side stream electrolysis (2)	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without Discharge treatment tank	In-line side-stream ozone injection with gas/liquid separation tank and Discharge water treatment tank	In-tank pasteurization and de-oxygenation with N ₂ generator
Characteristics ↓												
Des-infection when ballasting	Making use of active substance		X			In-tank technology: No treatment when ballasting or de-ballasting	X	X	X	X	X	In-tank technology: No treatment when ballasting or de-ballasting
	Full flow of ballast water is passing through the BWMS	X	X	X	X		X				X	
	Only a small part of ballast water is passing through the BWMS to generate the active substance							X				
After-treatment when de-ballasting	Full flow of ballast water is passing through the BWMS	X									X	
	Injection of neutralizer						X	X	X	X	X	
	Not required by the Type Approval Certificate issued by the Administration		X	X								
Examples of dangerous gas as defined in UR M74 §2.3			(1)	O ₂ N ₂	CO ₂ CO		H ₂ Cl ₂	H ₂ Cl ₂	(1)	O ₂ O ₃ N ₂		O ₂ N ₂
Note: (1) To be investigated on a case by case basis based on the result of the IMO (GESAMP) MEPC report for Basic and Final approval in accordance with the G9 Guideline. (2) In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or de-ballasting)												

Taking into consideration future developments of BWMS technologies, some additional technologies may be considered in this Table 1 by identifying their characteristics in the same manner as for the above BWMS categories 1, 2, 3a, 3b, 3c, 4, 5, 6, 7a, 7b and 8.

2.2 Cargo area of tankers is defined in:

- for tankers to which regulation 1.6.1 of SOLAS Chapter II-2 as amended by IMO resolutions up to MSC.421(98) (hereinafter the same) applies, regulation 3.6 of SOLAS Chapter II-2;
- for chemical tankers, Paragraph 1.3.6 of the IBC Code as amended by IMO resolutions up to MSC.460(101);
- for gas carriers, Paragraph 1.2.7 of the IGC Code as amended by IMO resolutions up to MSC.441(99); and
- for offshore support vessels, Paragraph 1.3.1 of the IMO Resolution A.673(16) as amended by Resolution MSC.236(82) or Paragraph 1.2.7 of the IMO Resolution A.1122(30), as applicable.

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Table 2 - Applicability of the requirements for each BWMS technology

BWMS's Technology category (informative Annex II should be referred to)→	1	2	3a	3b	3c	4	5	6	7a	7b	8
UR M74 requirement ↓	In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO ₂ or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N ₂ from a N ₂ Generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-tank de-oxygenation with Inert Gas Generator	In-line full flow electrolysis	In-line side stream electrolysis	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without Discharge treatment tank	In-line side-stream ozone injection with gas/liquid separation tank and Discharge water treatment tank	In-tank pasteurization and de-oxygenation with N ₂ generator
1. and 2.	x	x	x	x	x	x	x	x	x	x	x
3.1.1 to 3.1.4	x	x	x	x	x	x	x	x	x	x	x
3.1.5			x	x	x						x
3.1.6	x	x	x	x	x	x	x	x	x	x	x
3.1.7			x	x	x						x
3.1.8				x						x	
3.1.9	x	x	x	x	x	x	x	x	x	x	x
3.2.1.1				x	x				x	x	
3.2.1.2						x	x	x			
3.2.2	x	x	x	x		x	x	x	x	x	
3.2.3	x	x	x	x	x	x	x	x	x	x	x
3.2.4	x	x	x	x		x	x	x	x	x	
3.3.1.1		x	x			x	x	x	x	x	x
3.3.1.2			x	x	x				x	x	x
3.3.1.3									x	x	
3.3.1.4						x	x	x	x	x	
3.3.1.5						x	x	x			
3.3.1.6			x	x	x				x	x	x
3.3.2.1 to 3.3.2.4		x	x	x	x	x	x	x	x	x	x
3.3.2.5			x			x	x	x	x	x	x
3.3.2.6			x						x	x	x
3.3.2.7			x			x	x	x	x	x	x
3.3.3		x				x	x	x	x	x	
3.3.4						x	x	x	x	x	

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2.3 Dangerous gas means any gas which may develop an atmosphere being hazardous to the crew and/or the ship due to flammability, explosivity, toxicity, asphyxiation, corrosivity or reactivity and for which due consideration of the hazards is required, e.g. hydrogen (H₂), hydrocarbon gas, oxygen (O₂), carbon dioxide (CO₂), carbon monoxide (CO), ozone (O₃), chlorine (Cl₂) and chlorine dioxide (ClO₂), etc.

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.

2.5 Hazardous area is defined in IEC 60092-502:1999 and 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 electrical apparatus. When a gas atmosphere is present, the following hazards may also be present: toxicity, asphyxiation, corrosivity and reactivity.

2.6 Non-hazardous area means an area which is not a hazardous area as defined in above 2.5.

3. Installation

3.1 General requirements

3.1.1 All valves, piping fittings and flanges are to comply with the relevant requirements of IACS 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. For new installation or retrofit to existing ships, under normal operating conditions of ballasting and de-ballasting given in the Ballast Water Management Plan (BWMP) the adequacy of the generating plant capacity installed on the vessel is to be demonstrated by an electrical load analysis.

For retrofit installation to existing ships, a revised electrical load analysis with preferential trips of non-essential services can be accepted.

3.1.3 The BWMS is to be operated in accordance with the requirements specified in the Type Approval Certificate (TAC) issued by the Flag Administration. BWMS should be operated within its Treatment Rated Capacity (TRC) as per the TAC. This may require limiting of ship's ballast pump flowrates.

The arrangement of the bypasses or overrides of the BWMS is to be consistent with the approved Operation Maintenance and Safety Manual by the Flag Administration's Type Approval.

In case the maximum capacity of the ballast pump(s) exceeds the maximum treatment rated Capacity (TRC) of the BWMS specified in the TAC issued by the Flag Administration, there should be a limitation on the BWMP giving a maximum allowable flow rate for operating the ballast pump(s) that shall not exceed the maximum TRC of the BWMS.

3.1.4 BWMS should be subject to design review by the Classification Society to verify the compliance of the BWMS's manufacturer package with the Classification Rules. Manufacturers of the BWMS may apply for this design review at the type approval process.

In general, monitoring functions of BWMS belongs to system category I under the application of the UR E22 Rev. 2. However, in case a by-pass valve is integrated in the valve remote

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control system, the by-pass valve belongs to the system category II Ballast transfer remote control system.

The BWMS's components are required to be inspected and certified by the Classification Society at the manufactory (Society Certificate (SC) as defined in UR M72) including pressure vessels, piping class I or II, filters, switchboards, etc.

3.1.5 Where a vacuum or overpressure may occur in the ballast piping or in the ballast piping or in the ballast tanks due to the height difference or injection of inert gas or nitrogen (N₂), a suitable protection device is to be provided (i.e. P/V valves, P/V breakers, P/V breather valves or pressure safety relief valve or high/low pressure alarms).

The pressure and vacuum settings of the protection device should not exceed the design pressure of the ballast piping (BWMS categories 3a and 3b) or ballast tank (BWMS categories 3a, 3b and 3c), as relevant.

For BWMS categories 3a, 3b and 3c, the inert gas or nitrogen product enriched air from the inert gas system and from the protection devices installed on the ballast tanks (i.e. P/V valves, P/V breakers or P/V breather valves) are to be discharged to a safe location^{*(1)} & ⁽²⁾ on the open deck.

When the concerned ballast tanks are hazardous areas, an extension of hazardous area is to be considered at the outlet of the protection devices: with reference to IEC 60092-502:1999 §4.2.2.9 the areas on open deck, or semi-enclosed spaces on open deck, within 1.5 m of their outlets are to be categorized hazardous zone 1 and with reference to IEC 60092-502:1999 §4.2.3.1, an additional 1.5 m surrounding the 1.5 m hazardous zone 1 is to be categorized hazardous zone 2. Any source of ignition such as anchor windlass or opening into chain locker should be located outside the hazardous areas.

Footnotes **safe location**^{*(1)} and **safe location**^{*(2)}

Safe location needs to address the specific types of discharges separately.

Signboards or similar warnings at the discharge areas are to be provided.

Safe location^{*(1)}: inert gas or nitrogen product enriched air from:

- in-line (categories 3a and 3b) and in-tank (categories 3c and 8) de-oxygenation BWMS: the protection devices installed on the ballast tanks, nitrogen or inert gas generators, nitrogen buffer tank (if any); or
- in-line ozone injection BWMS (categories 7a and 7b): the oxygen generator;

safe locations on the open deck are:

- not within 3 m of areas traversed by personnel; and
- not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.

Safe location^{*(2)}: oxygen-enriched air from:

- in-line and in-tank de-oxygenation BWMS (categories 3a and 8): the nitrogen generator; or
- in-line ozone injection BWMS (categories 7a and 7b): the protection devices or vents from oxygen generator, compressed oxygen vessel, the ozone generator and ozone destructor devices;

safe locations on the open deck are:

- outside of hazardous area;
- not within 3 m of any source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard;
- not within 3 m of areas traversed by personnel; and
- not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets.

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Where products covered by IEC 60092-502:1999 are stored on-board or generated during operation of the BWMS, the requirements of this standard shall be followed in order to:

- Define hazardous areas and acceptable electrical equipment, and
- Design ventilation systems.

3.1.6 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.

3.1.7 Inert gas systems installed for de-oxygenation BWMS (categories 3a, 3b, 3c and 8) are to be designed in accordance with the following requirements:

3.1.7.1 FSS Code Ch 15 requirements

- 2.1.2, 2.1.3
- 2.2.1.3, 2.2.1.4, 2.2.2.1, 2.2.2.2, 2.2.2.3, 2.2.2.6, 2.2.4.1, 2.2.4.2, 2.2.4.3, 2.2.4.4, 2.2.4.5 except 2.2.4.5.1.3 and 2.2.4.5.3
- 2.3.1.1.2, 2.3.1.2, 2.3.1.4.2, 2.3.1.5, 2.3.1.6, 2.3.2 except 2.3.2.2.1
- 2.4.1.3, 2.4.1.4 and 2.4.2
- For inert gas systems installed for in-tank de-oxygenation BWMS (category 8): 2.2.3.1, 2.2.3.2 except 2.2.3.2.6, 2.2.3.2.7 and 2.2.3.2.10

In general, when applying FSS Code Ch.15 requirements to inert-gas based BWMS, the following modifications are to be considered:

- The terms "cargo tank" and "cargo piping" are to be replaced by "ballast water tank" or "ballast water piping" as relevant.
- The term "cargo control room" is to be replaced by "BWMS control station" as relevant
- Requirements for slop tanks on combination carriers are to be disregarded
- When applying FSS Code / 15.2.2.4.5.1.1, the acceptable oxygen content is to be specified by the manufacturer, 5% oxygen content need not necessarily be applied.

3.1.7.2 IACS UR F20 requirements F20.1.1.1, F20.1.1.3, F20.3.1, F20.3.3, F20.3.7, F20.3.8, F20.4.4, F20.4.5 and F20.4.6. In applying F20.4.6, the terms "cargo tanks" and "cargo piping" are to be understood as "ballast tanks" and "ballast piping" respectively. For de-oxygenation BWMS (categories 3a, 3b, 3c and 8), the requirements in 3.1.7.1 prevail.

3.1.8 When cavitation is the BWMS treatment process (for example by use of pressure vacuum reactor working in combination with a vertical ballast water drop line) or part of the BWMS treatment process (for example by use of "smart pipe" or "special pipe" in BWMS category 7b or by use of "venturi pipe" in BWMS technology 3b) or by use other means, the design and the wall thickness or grade of materials or inside coating or surface treatment of the part of the piping where the cavitation is taking place is to be specifically considered.

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3.1.9 When it is required to have an automatic shutdown of the BWMS for safety reasons, this must be initiated by a safety system independent of the BWM control system.

3.2 Additional requirements for tankers:

3.2.1 Hazardous area classification is to be in accordance with IEC 60092-502:1999 with due consideration of IACS UI SC274.

- .1 BWMS using ozone generators (categories 7a and 7b) and de-oxygenation BWMS using inert gas generator by treated flue gas from main or auxiliary boilers or gas from an oil or gas-fired gas generator (categories 3b and 3c) are to be located outside the cargo area in accordance with FSS Code Ch 15 §2.3.1.1.2.

Note: this requirement does not apply to inert gas generators for which FSS Code Ch 15/2.4.1 and IACS UR F20.3 and F20.4 apply.

- .2 In-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6) can be located inside the hazardous areas with due consideration of the requirement of 3.1.6 but should not be located inside the cargo pump room unless it is demonstrated by the BWMS manufacturer that the additional hazards that could be expected from dangerous liquids and dangerous gases stored or evolved from the BWMS (for example H₂ generation):
 - do not lead to an upgrade of the hazardous area categorization of the cargo pump room,
 - are not reactive with the cargo vapours expected to be present in the cargo pump room,
 - are not reactive with the fire-extinguishing medium provided inside the cargo pump room,
 - are not impacting the performance of the existing fire-fighting systems provided inside the cargo pump room, and
 - are not introducing additional hazards inside the cargo pump room such as toxicity hazards that would not have been prior addressed by suitable counter measures.

Notes:

- 1) In-line full flow electrolysis BWMS (category 4) could be accepted in cargo compressor rooms of liquefied gas carriers and inside cargo pump rooms of oil tankers or chemical tankers if that cargo pump room is located above the cargo tank deck.
- 2) For submerged cargo pumps, the room containing the hydraulic power unit or electric motors is not to be considered as the "cargo pump room".
- 3) Ballast pump rooms and other pump rooms not containing the cargo pumps are not to be considered as the "cargo pump room".

3.2.2 In general, two independent BWMS should be required i.e. one for ballast tanks located within the cargo area and the other one for ballast tanks located outside cargo area. Specific arrangements where only one single In-line BWMS (categories 1, 2, 3a, 3b, 4, 5, 6, 7a and 7b) could be accepted are given in Annex I.

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Note: When the Fore Peak Tank is ballasted with the piping system serving the other ballast tanks within the cargo area in accordance with IACS UR F44, the ballast water of the Fore Peak tank is to be processed by the BWMS processing the ballast water of the other ballast tanks within the cargo area.

3.2.3 Isolation between ballast piping serving the ballast tanks inside and outside of the cargo area is to be in accordance with the following requirements:

3.2.3.1 Interconnection in between the ballast piping serving the ballast tanks located within the cargo area and the ballast piping serving the ballast tanks located outside the cargo area may be accepted if appropriate isolation arrangement is provided in accordance with Annex I is applied.

Note 1: The means of appropriate isolation described in Paragraph 3.2.3.1 is necessary for the interconnection specified in said Paragraph regardless of the diameter of the piping.

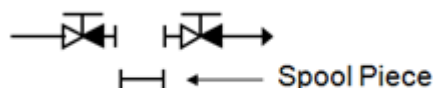
Note 2: As indicated in Annex I, the means of appropriate isolation described in Paragraph 3.2.3.1 is necessary for the interconnection specified in said Paragraph in the case of the active substance piping such as N2 gas piping, inert gas piping, neutralizer piping, fresh water piping for filter cleaning, compressed air piping for remaining water purge and sea water piping for adjusting the salinity etc. At the discretion of the Classification Society and for active substance piping and neutralizer piping (both up to 2 inches) only, alternative isolation arrangements, provided preferably on the open deck, offering enhanced safety and gastightness may be considered for penetration of the bulkhead separating the non-hazardous machinery space from a hazardous area (such as the cargo pump room) at as high an elevation in the machinery space as possible, preferably, just below the main deck. The arrangements are to provide suitable protection measures in addressing the pollution hazards and safety concerns due to the potential migration of hydrocarbon or flammable or toxic liquids or vapours from the hazardous areas.

Note 3: The means of appropriate isolation described in this Paragraph 3.2.3.1 for the interconnection specified in said Paragraph need not be applied to the sampling lines described in Paragraph 3.2.4.

The means of appropriate isolation is to be one of the following :

- .1 Two non-return valves with positive means of closing in series with a spool piece (also mentioned "means of dis-connection" in Annex I), or

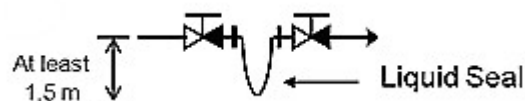
Note: As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the spool piece.



- .2 Two non-return valves with positive means of closing in series with a liquid seal at least 1.5 m in depth, or

Note 1: As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the liquid seal.

Note 2: For ships operating in cold weather conditions, freeze protection should be provided in the water seal. A portable heating system can be accepted for this purpose.

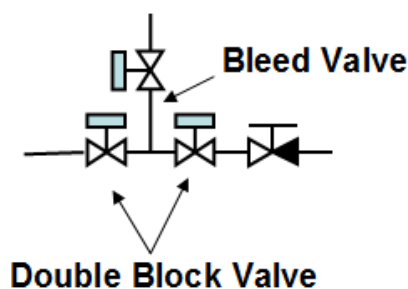


- .3 Automatic double block and bleed valves and a non-return valve with positive means of closing.

Note: As an alternative to positive means of closure, an additional valve having such means of closure may be provided after the non-return valve.

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(cont)



3.2.3.2 The above-mentioned means of appropriate isolation is to be provided on the open deck in the cargo area.

Note: When the Fore Peak Tank is ballasted with the piping system serving the other ballast tanks within the cargo area in accordance with IACS UR F44, the means of appropriate isolation described in Paragraphs 3.2.3.1 and 3.2.3.2 is not required in between the Fore Peak Tank and the common ballast water piping serving the other ballast water tanks within the cargo area.

3.2.4 Sampling lines which are connected to the ballast water piping system serving the tanks in the cargo area and provided for the purpose of the following:

- for any BWMS: ballast water sampling required by the G2 Guideline of the BWM Convention (2004), or
- for BWMS technologies categories 4, 5, 6, 7a and 7b: total residual oxidant (TRO) analysis in closed loop system;

are not to be led into a non-hazardous enclosed space outside the cargo area.

However, the sampling lines may lead into a non-hazardous enclosed space outside the cargo 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 iv) are to be complied.
 - i) In the cabinet, a stop valve is to be installed on each sampling line.
 - 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). Upon an activation of the alarm, all electrical power to the cabinet is to be automatically disconnected.

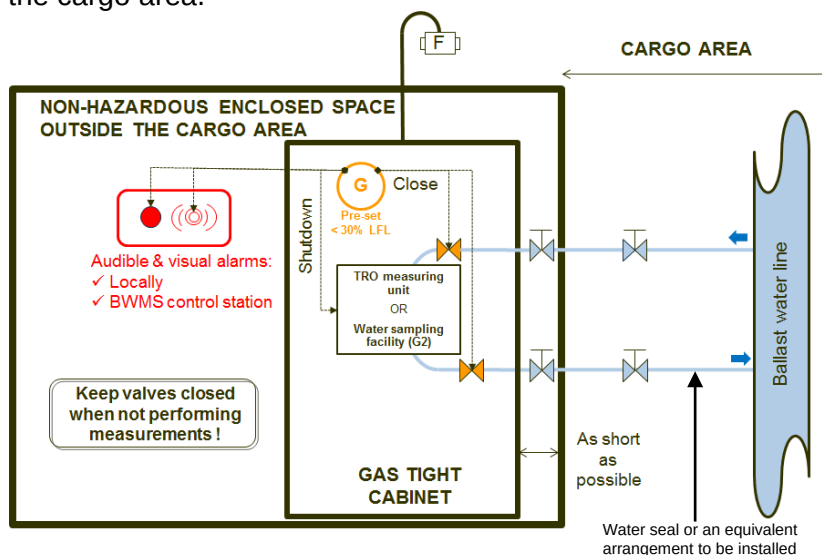
Note: when the electrical equipment is of a certified safety type, the automatic disconnection of power supply is not required.

 - iv) The cabinet is to be vented to a safe location in non-hazardous area on open deck and the vent is to be fitted with a flame arrester.
- .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.

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(cont)

- .3 The cabinet is to be installed as close as possible to the bulkhead facing the cargo area, and the sampling lines located outside the cargo area are to be routed on their shortest ways.
- .4 Stop valves are to be located in the non-hazardous enclosed space outside the cargo area, in both the suction and return lines close to the penetrations through the bulkhead facing the cargo area. 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 stop valve is to be installed on the cargo area for each sampling line (i.e. both the suction and return lines).
- .6 The samples which are extracted from the ballast water piping system serving the tanks within the cargo area are not to be discharged to a tank located outside the cargo area and not to discharge to a piping line supplying the spaces located outside the cargo area.



3.3 Special requirements for BWMS categories 2, 3a, 3b, 3c, 4, 5, 6, 7a, 7b and 8 generating dangerous gas or dealing with dangerous liquids.

3.3.1 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 detectors should be located as close as possible to the BWMS components where the dangerous gas may accumulate.

For flammable gases and explosive atmosphere including but not limited to H_2 , the construction, testing and performance of the gas detection devices is to be in accordance with IEC 60079-29-1:2016, IEC 60079-29-2:2015, IEC 60079-29-3:2014 and/or IEC 60079-29-4:2009, as applicable.

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(cont)

Where other hazards are considered like toxicity, asphyxiation, corrosive and reactivity hazards, a recognized standard acceptable to the Society is to be selected with due consideration of the specific gases to be detected and due consideration of the performance of the detection device with regards to the specific atmosphere where it is used.

- .2 In spaces where inert gas generator systems are fitted (BWMS categories 3b and 3c) or nitrogen generators are fitted (BWMS categories 3a and 8), at least two oxygen sensors shall be positioned at appropriate locations (as required by Paragraph 2.2.4.5.4 of Chapter 15 of the FSS Code as amended by IMO resolutions up to MSC.410(97)) to alarm when the oxygen level falls below 19%. The alarms shall be both audible and visual and shall be activated:

- inside the space;
- at the entry into the space; and
- inside the BWMS control station.

For BWMS categories 7a and 7b, at least two oxygen sensors shall be positioned at appropriate locations in the following spaces:

- spaces where ozone generators are fitted, or
- spaces where ozone destructors are fitted, or
- spaces where ozone piping is routed;

to alarm when the oxygen level raises above 23 %. The alarms shall be both audible and visual and shall be activated at the following locations:

- inside the space; and
- at the entry into the space; and
- inside the BWMS control station.

Automatic shut-down of the BWMS is to be arranged when the oxygen level raises above 25%. Audible and visual alarms independent from those specified in the preceding paragraph are to be activated prior to this shut-down.

- .3 For BWMS categories 7a and 7b, at least one ozone sensor shall be provided at the vicinity of the discharge outlet to the open deck from the ozone destructors addressed in Footnote ^{*(4)} to alarm when the ozone concentration level raises above 0.1 ppm. The alarms shall be both audible and visual and shall be activated in the BWMS control room. In addition, at least two ozone sensors shall be positioned at appropriate location in the following spaces:

For ^{*(4)}, refer to footnotes to Paragraph 3.3.2.3.

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(cont)

- spaces where ozone generators are fitted, or
- spaces where ozone destructors are fitted, or
- spaces where ozone piping is routed;

to alarm when the ozone concentration level raises above 0.1 ppm. The alarms shall be both audible and visual and shall be activated at the following locations:

- inside the space;
- at the entry into the space; and
- inside the BWMS control station.

Automatic shut-down of the BWMS is to be arranged when the ozone concentration measured from one of the two sensors inside the space raises above 0.2 ppm.

- .4 Inside double walled spaces or pipe ducts constructed for the purpose of 3.3.2.1 Note 1), sensors are to be provided for the detection of H₂ leakages (BWMS categories 4, 5 and 6 when relevant) or O₂ leakages (BWMS categories 7a and 7b) or O₃ leakages (BWMS categories 7a and 7b). The sensors are to activate an alarm at the high level settings and automatic shut-down of the BWMS at the high-high level settings described in above 3.3.1.1 to 3.3.1.3.

Note: As an alternative to the sensor for the gas detection, monitored under-pressurization inside the double walled spaces or pipe ducts could be provided with an automatic alarm and shut-down of the BWMS in case of loss of the under-pressurization. The monitoring can be achieved either by monitoring the pressure inside the double walled spaces or pipe ducts or by monitoring the exhaust fan.

- .5 For in-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6): the hydrogen de-gas arrangement (when provided) is to be provided with redundant ventilation fans and redundant monitoring of the ventilation system.

In addition the ventilation fan shall be certified explosion proof and have spark arrestor to avoid ignition sources to enter the ventilation systems whereas remaining H₂ gas may be present in dangerous concentrations.

Audible and visual alarms and automatic shut-down of the BWMS are to be arranged for respectively high and high-high levels of H₂ concentration. The open end of the hydrogen by-product enriched gas relieving device is to be led to a safe location^{*(3)} on open deck.

- .6 The open end of inert gas or nitrogen gas enriched air (BWMS categories 3a, 3b, 3c and 8) or oxygen-enriched air (BWMS categories 3a, 7a, 7b and 8) are to be led to a safe location^{*(1) & (2)} on open deck.

For **safe location**^{*(3)}, refer to footnotes to Paragraph 3.3.2.3.

For **safe location**^{*(1)} and **safe location**^{*(2)}, refer to footnotes to Paragraph 3.1.5.

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(cont)

3.3.2 Where the piping is conveying active substances, by-products or neutralizers that are containing dangerous gas or dangerous liquids as defined respectively in 2.3 and 2.4, the following requirements are to be satisfied:

Notes:

- 1) This requirement is applicable to the injection lines conveying the dangerous gas or dangerous liquids but not applicable to the ballast water lines where the dangerous gas or dangerous liquids are diluted.
- 2) The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) could be used for assessing the hazards that could be expected from the media conveyed by the BWMS piping.

- .1 Irrespective of design pressure and temperature, the piping is to be either of Class I (without special safeguard) or Class II (with special safeguard) as required by IACS UR P2 table 1. The selected materials, the testing of the material, the welding, the non-destructive tests of the welding, the type of connections, the hydrostatic tests and the pressure tests after assembly on-board are to be as required in IACS UR P2. Mechanical joints, where allowed, are to be selected in accordance with IACS UR P2 Table 8.

Notes:

- 1) For piping class II with special safeguards conveying dangerous gas like hydrogen (H₂), oxygen (O₂) or ozone (O₃), the special safeguards are to be either double walled pipes or pipe duct.
- 2) For piping class II with special safeguards conveying dangerous liquids, other special safeguards could be considered like shielding, screening, etc.
- 3) Plastic pipes may be accepted after due assessment of the dangerous gas or dangerous liquids conveyed inside. When plastic pipes are accepted, the requirements of UR P4 apply.

- .2 The length of pipe and the number of connections are to be minimised.

- .3 Inside double walled space or pipe ducts constructed as the special safeguard for the purpose of 3.3.2.1 Note 1) are to be equipped with mechanical exhaust ventilation leading to a safe location^{*(3)} & ⁽⁴⁾ on open deck.

Footnotes **safe location**^{*(3)} and **safe location**^{*(4)}:

Safe location^{*(3)}: hydrogen by-product enriched gas from:

- in-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6): the hydrogen de-gas arrangement (when provided);

safe locations on the open deck are:

- not within 5 m of any source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard;
- not within 3 m of areas traversed by personnel; and
- not within 5 m of air intakes from non-hazardous enclosed spaces.

The areas on open deck, or semi-enclosed spaces on open deck, within 3 m of the outlets are to be categorized hazardous zone 1 plus an additional 1,5 m surrounding the 3 m hazardous zone 1 is to be categorized hazardous zone 2.

Electrical apparatus located in the above hazardous areas zone 1 and zone 2 is to be suitable for at least IIC T1.

Safe location^{*(4)}: For in-line ozone injection BWMS (categories 7a and 7b), vent outlet from O₃ destructor device (ODS) can be considered as oxygen-enriched air provided that:

- the ODS are duplicated; and
- the manufacturer justified that the quantity of consumable (activated carbon) used by the ODS is sufficient for the considered life cycle of the BWMS; and
- ozone detection is arranged in the vicinity of the discharge outlet from the vent outlet of the ODS to alarm the crew in case the ODS is not working.

If one of the above 3 conditions is not fulfilled, the safe location from ODS on open deck are:

- outside of hazardous area;
- not within 3 m of any source of ignition;
- not within 6 m of areas traversed by personnel; and
- not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets.

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- .4 The routing of the piping system is to be kept away from any source of heating, ignition and any other source that could react hazardously with the dangerous gas or liquid conveyed inside. The pipes are to be suitably supported and protected from mechanical damage.
- .5 Pipes carrying acids are to be arranged so as to avoid any projection on crew in case of a leakage.
- .6 H₂ by-product enriched air vent pipes (BWMS categories 4, 5 and 6) or O₂ enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) or O₃ piping (BWMS categories 7a and 7b) shall not be routed through accommodation spaces, services spaces and control stations.
- .7 O₂ enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) shall not be routed through hazardous areas unless it is arranged inside double walled pipes or pipe ducts constructed as the special safeguard for the purpose of 3.3.2.1 Note 1) and provided with suitable gas detection as described in 3.3.1.4 and mechanical exhaust ventilation as described in 3.3.2.3.
- .8 The routing of H₂ by-product enriched air vent pipes (BWMS categories 4, 5 and 6) or O₂ enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) is to be as short and as straight as possible. When necessary, horizontal portions may be arranged with a minimum slope in accordance with the manufacturer's recommendation.

3.3.3 For BWMS using chemical substances or dangerous gas which are stored on-board for either:

- storage or preparation of the active substances (BWMS categories 2 and 6), or
- storage or preparation of the neutralizers (BWMS categories 4, 5, 6, 7a and 7b), or
- recycling the wastes produced by the BWMS (BWMS category 2),

procedures are to be in accordance with the Material Safety Data Sheet and BWM.2/Circ.20 "Guidance to ensure safe handling and storage of chemicals and preparations used to treat ballast water and the development of safety procedures for risks to the ship and crew resulting from the treatment process", and the following measures are to be taken as appropriate:

- .1 The materials, inside coating used for the chemical storage tanks, piping and fittings are to be resistant to such chemicals substances.
- .2 Chemical substances (even if they are not defined as dangerous liquid in the sense of 2.4) and gas storage tanks are to be designed, constructed, tested, inspected, certified and maintained in accordance with:
 - for independent tanks permanently fixed onboard containing dangerous liquids (eg. sulfuric acid H₂SO₄) or dangerous gas (eg. oxygen O₂): the Classification Rules as applicable to pressure vessels
 - for independent tanks permanently fixed onboard not containing dangerous liquid (eg. sodium sulphite, sodium biosulphite or sodium thiosulphate neutralizers) and not containing dangerous gas (eg. nitrogen N₂): the Classification Rules or other industry standard recognized by the Classification Society
 - for portable tanks: the IMDG Code or other industry standard recognized by the Classification Society.

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- .3 When the chemical substances are stored inside integral tanks, the ship's shell plating shall not form any boundary of the tank.
- .4 Dangerous liquids and dangerous gas storage tank air pipes are to be led to a safe location^{*(1) & (2)} on open deck.
- .5 An operation manual containing chemical injection procedures, alarm systems, measures in case of emergency, etc. is to be kept onboard.
- .6 Dangerous liquid storage tanks and their associated components like pumps and filters, are to be provided with spill trays or secondary containment system of sufficient volume to contain potential leakages from tank openings, gauge glasses, pumps, filters and piping fittings.

Further to the safety and/or pollution assessment of the concerned chemical substances, consideration should be provided for segregation of the drains from such spill trays (or secondary containment system) or piping systems from engine room bilge system or from cargo pump room bilge system, as applicable. When necessary, arrangement should be provided within the spill trays (or within the secondary containment system) for the detection of dangerous liquid or dangerous gas as defined respectively in 2.3 and 2.4.

Note: The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) could be used for this assessment.

3.3.4 A risk assessment is to be conducted in a generic manner during the design review mentioned in 3.1.4 and submitted to the Classification Society for approval for the following BWMS categories:

- BWMS category 4: in all cases;
- BWMS category 5: in all cases;
- BWMS category 6: when one of the MSDS indicates that the chemical substance stored on-board is either flammable, toxic, corrosive or reactive;
- BWMS category 7a and 7b: in all cases.

Note: The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) could be used as a reference for this assessment.

- .1 The recommended risk assessment techniques for BWMS and other guidances are listed below but not limited to:
 - FMEA, FMECA, HAZID, HAZOP, etc.
 - ISO 31010 – Risk Assessment Techniques
 - IACS Recommendation Rec. 146
 - Rules of the Classification Society for risk assessment techniques
- .2 The risk assessment should ensure that the package supplied by the BWMS's manufacturer is intrinsically safe and/or provides mitigation measures to the hazards created by the BWMS which have been identified during the design review mentioned in 3.1.4 but that need to be implemented during the installation on-board.

For **safe location**^{*(1)} and **safe location**^{*(2)}, refer to footnotes to Paragraph 3.1.5.

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Annex I - Installation of one single BWMS on tankers

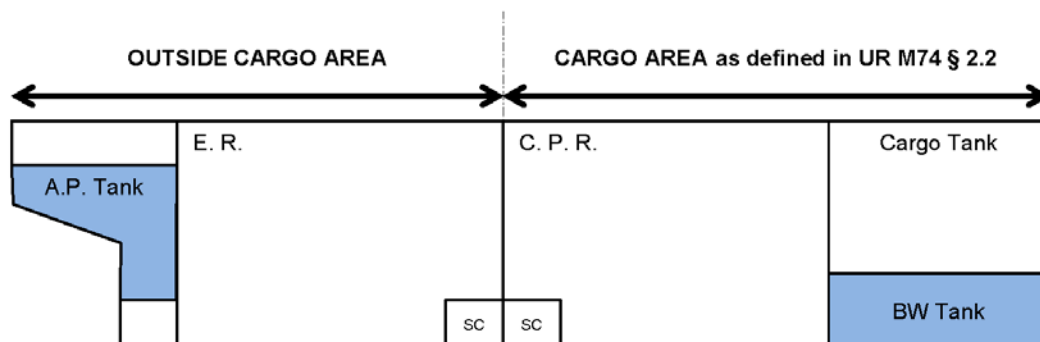
Table 1: In-line BWMS's technologies categorization

Note: This Annex does not cover In-tank technologies categories 3c and 8.

BWMS's Technology category → Characteristics ↓		1	2	3a	3b	4	5	6	7a	7b
Des-infection when ballasting	Making use of active substance	In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO ₂ or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N ₂ from a N ₂ Generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-line full flow electrolysis	In-line side stream electrolysis (3)	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without Discharge treatment tank	In-line side-stream ozone injection with gas/liquid separation tank and Discharge water treatment tank
	Full flow of ballast water is passing through the BWMS	X	X	X	X	X				X
	Only a small part of ballast water is passing through the BWMS to generate the active substance						X			
After-treatment when de-ballasting	Full flow of ballast water is passing through the BWMS	X								X
	Injection of neutralizer					X	X	X	X	X
	Not required by the Type Approval Certificate issued by the Administration		X	X						
Examples of dangerous gas as defined in UR M74 §2.3			(1)	O ₂ N ₂	CO ₂ , CO	H ₂ , Cl ₂	H ₂ , Cl ₂	(1)	O ₂ , O ₃ , N ₂	
Arrangement of one single BWMS	BWMS is located in the outside the cargo area	Not Acceptable	Case 1.2 (2)	Case 1.3a (2)	Case 1.3b	Case 1.4 (2)	Case 1.5	Case 1.6	Case 1.7a	Case 1.7b (2)
Notes: (1) To be investigated on a case by case basis based on the result of the IMO (GESAMP) MEPC report for Basic and Final approval in accordance with the G9 Guideline. (2) Only « Means of dis-connection » as described in 3.2.3.1 are to be applied. (3) In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or deballasting)										

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Pump



BWMS



Additional self-draining filter / hydrocyclone (when not included inside the symbol)



Neutralizer storage tank or neutralizer generator & means of injection



Gas/liquid separation tank



Discharge water treatment tank



Ballast water line



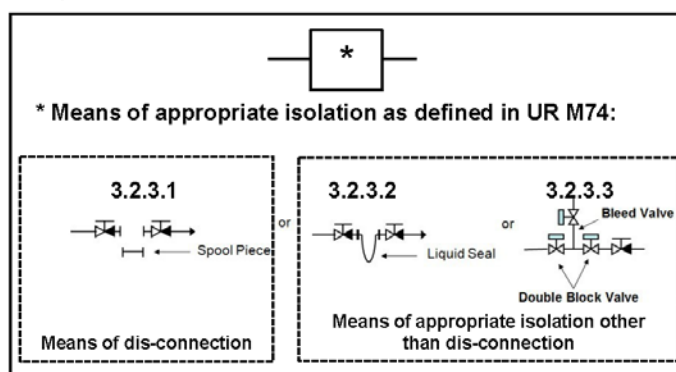
Discharge to the sea



Active substance or IG or N₂ injection line



Neutralizer injection line

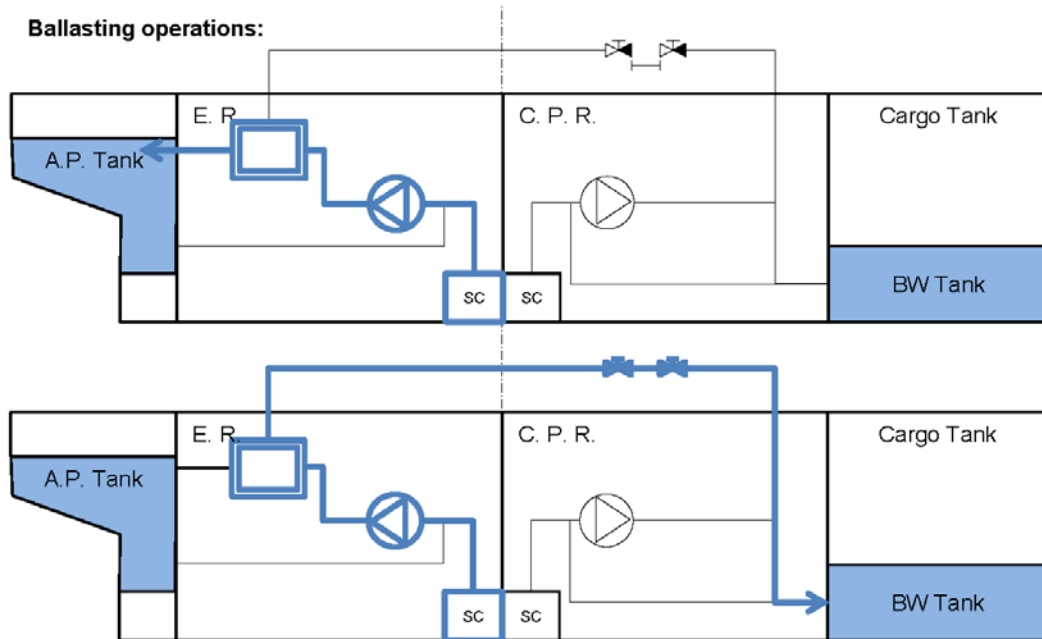
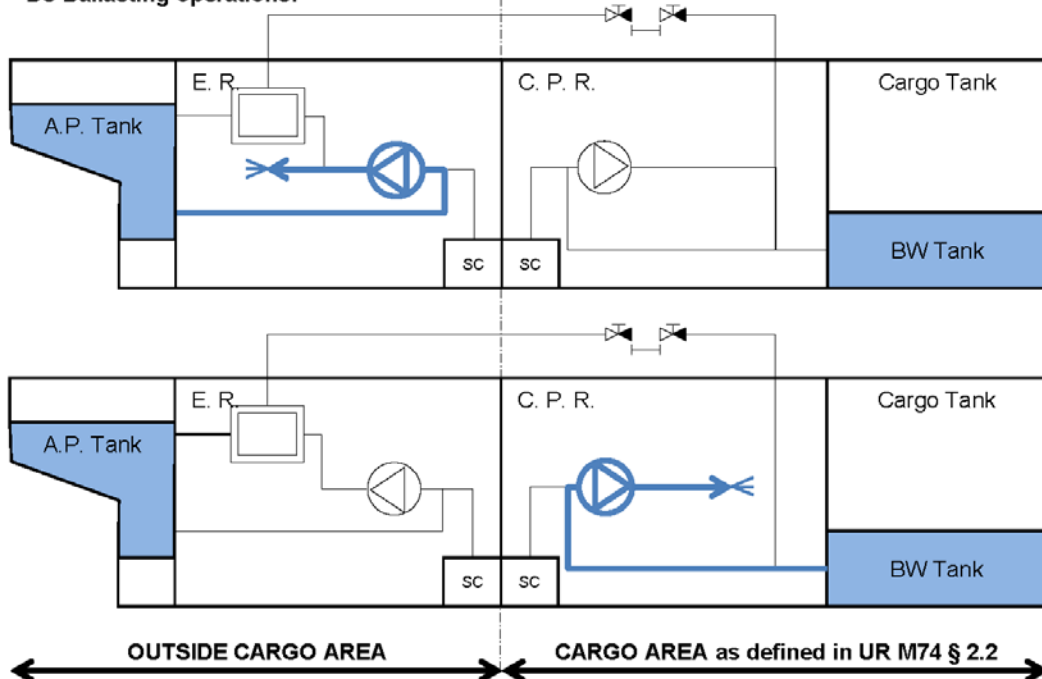


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BWMS installed outside the cargo area

Case 1.2 (Technology category 2, Flocculation); and

Case 1.3a (Technology category 3a De-oxygenation with N₂ Generator)**Ballasting operations:****De-Ballasting operations:**

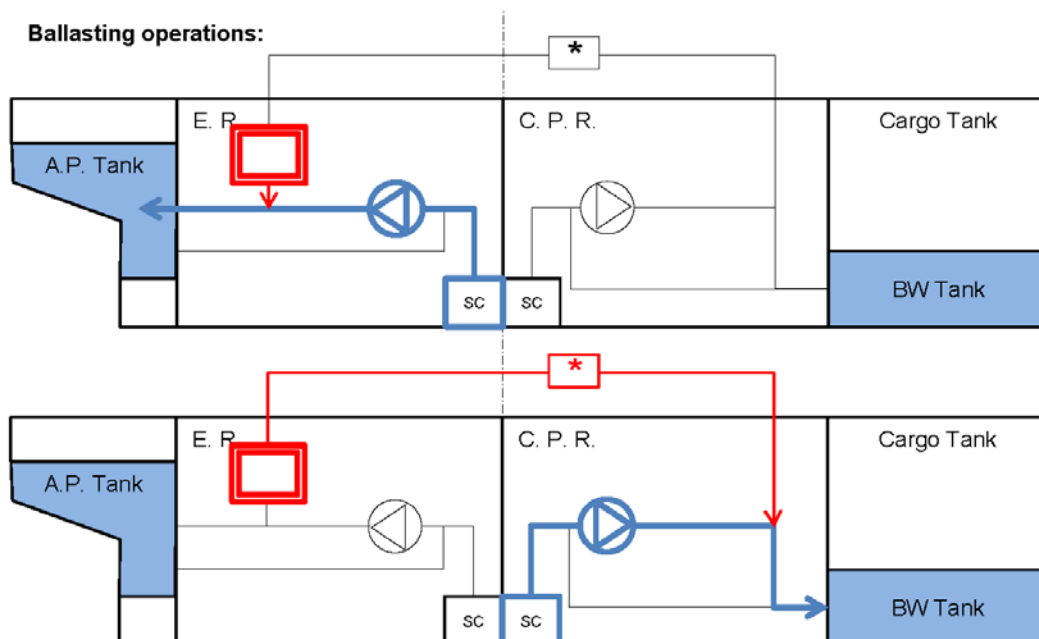
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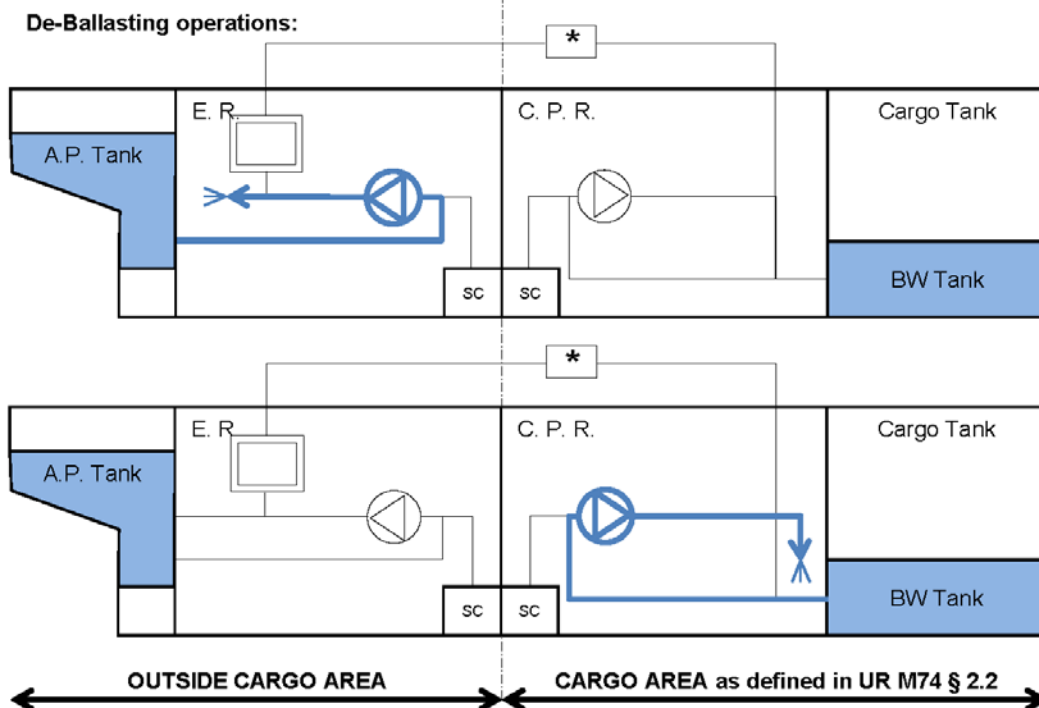
BWMS installed outside the cargo area

Case 1.3b (Technology category 3b, De-oxygenation with Inert Gas Generator):

Ballasting operations:



De-Ballasting operations:



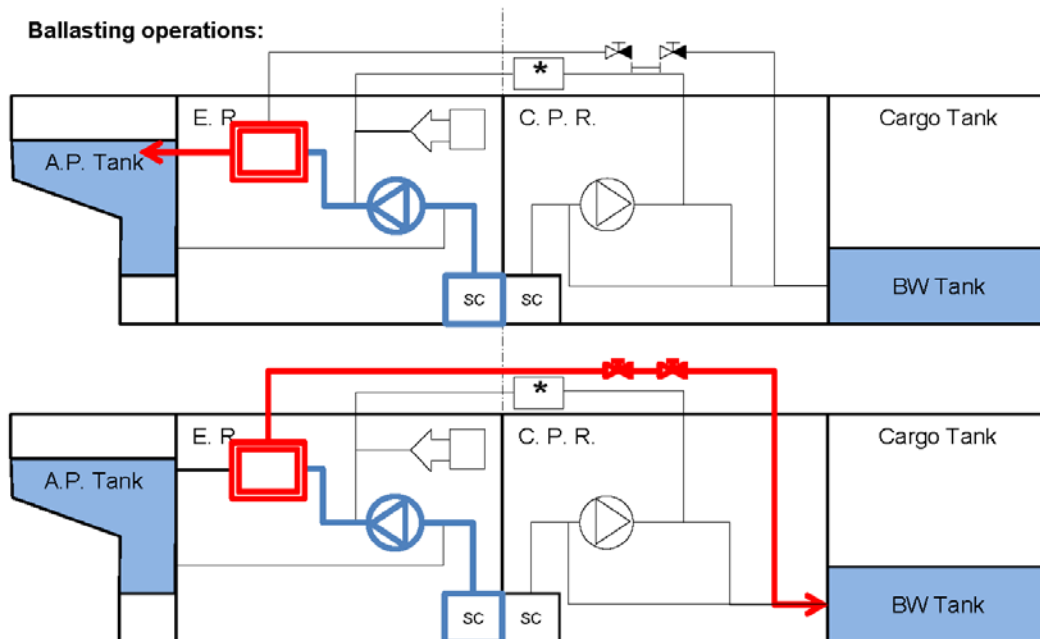
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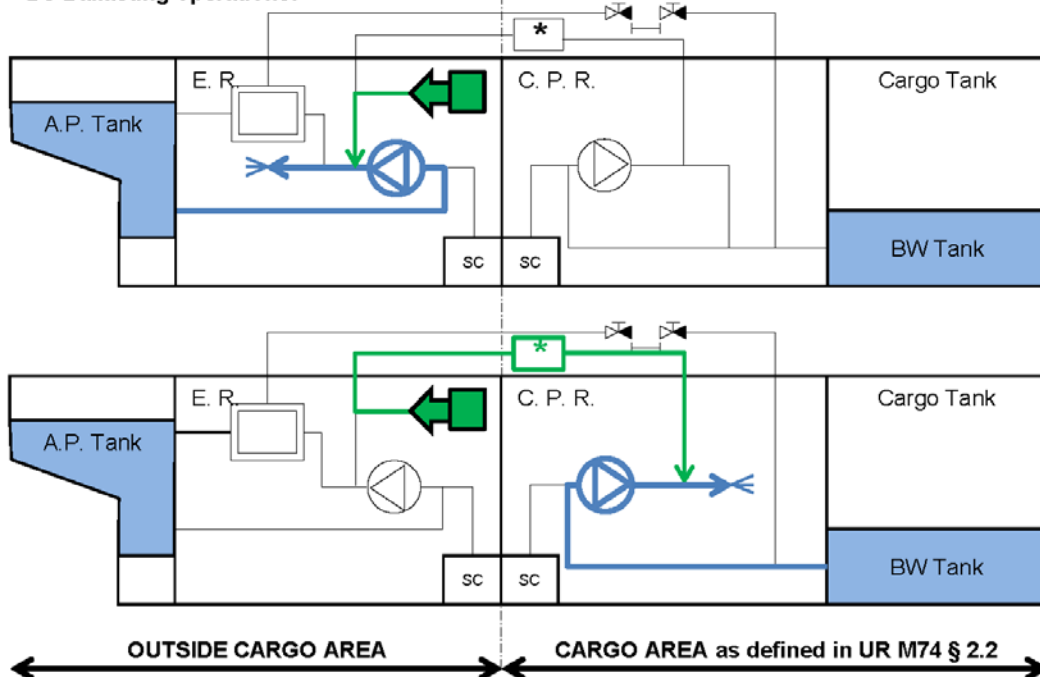
BWMS installed outside the cargo area

Case 1.4 (Technology category 4, Full-flow electrolysis):

Ballasting operations:



De-Ballasting operations:



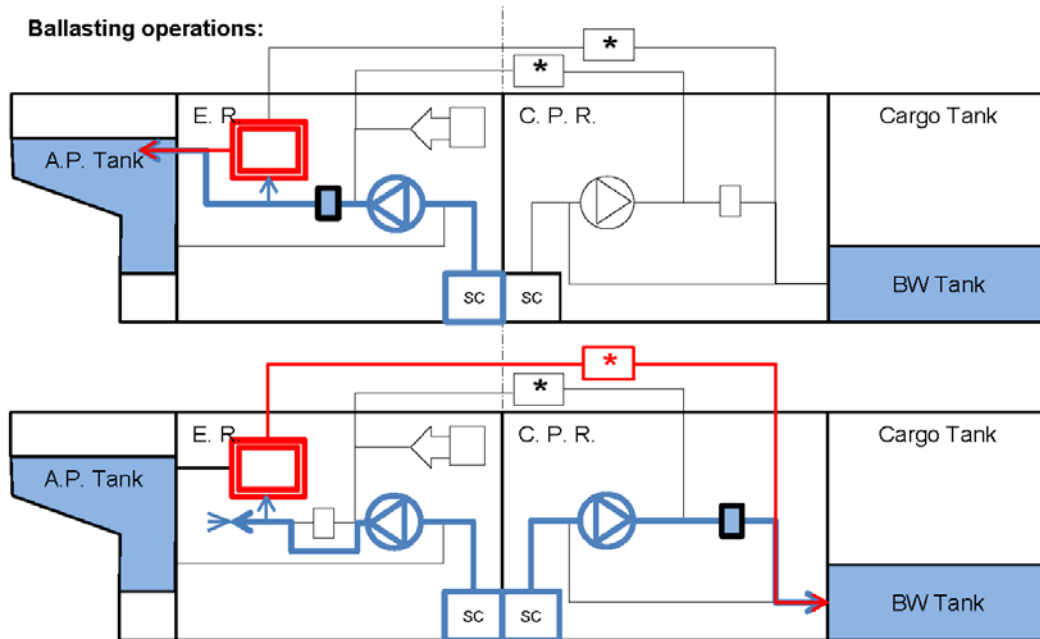
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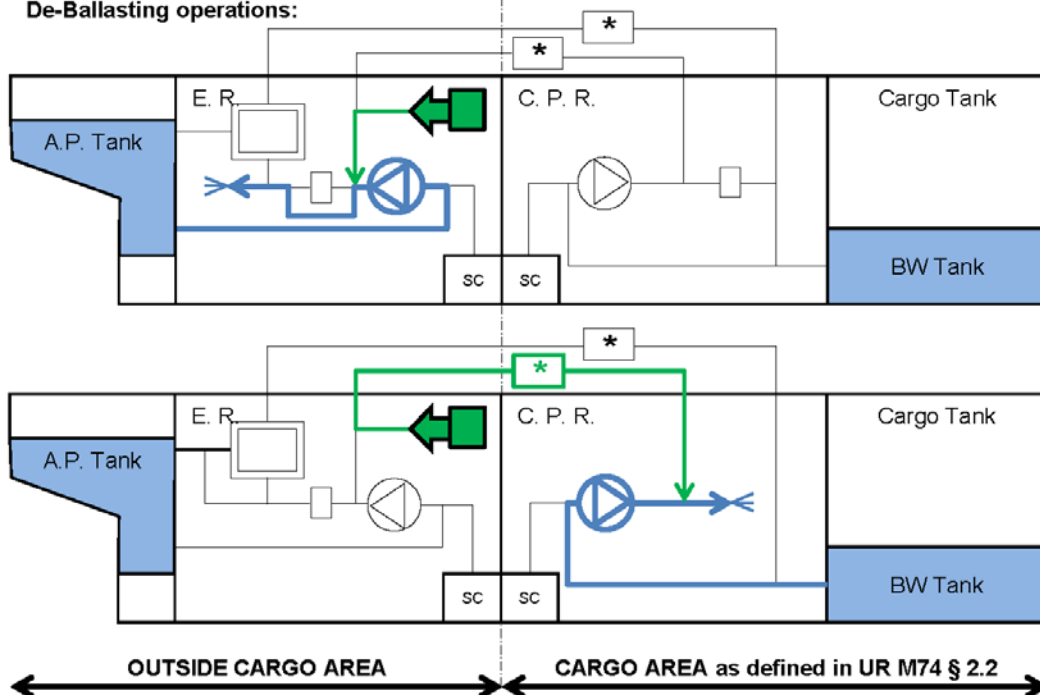
BWMS installed outside the cargo area

Case 1.5 (Technology category 5, Side-stream electrolysis):

Ballasting operations:



De-Ballasting operations:



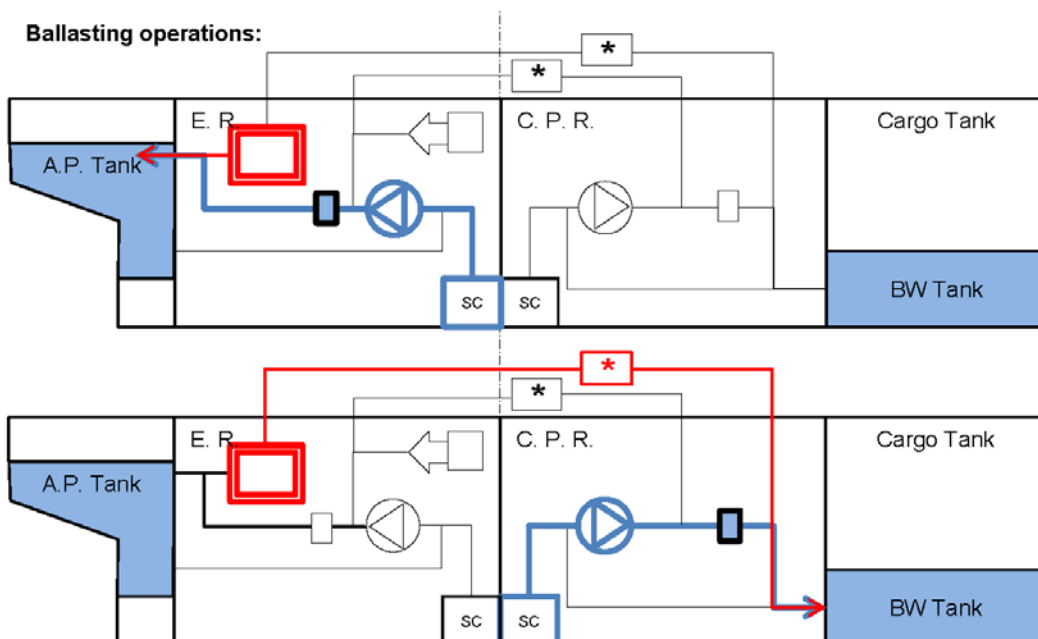
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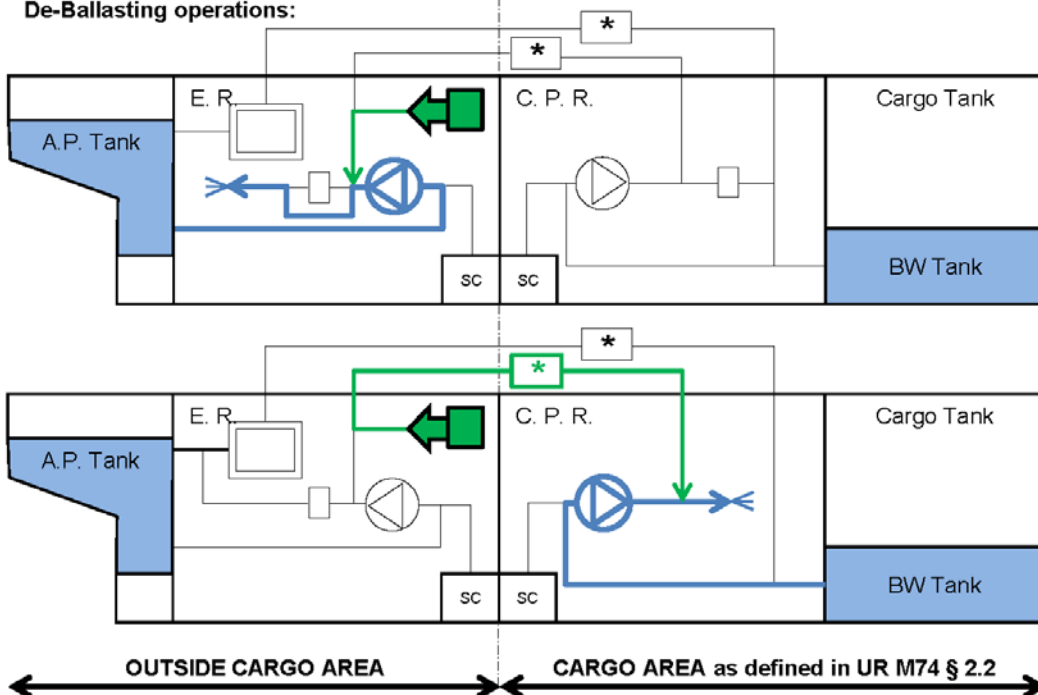
BWMS installed outside the cargo area

Case 1.6 (Technology category 6, Stored chemical injection)

Ballasting operations:

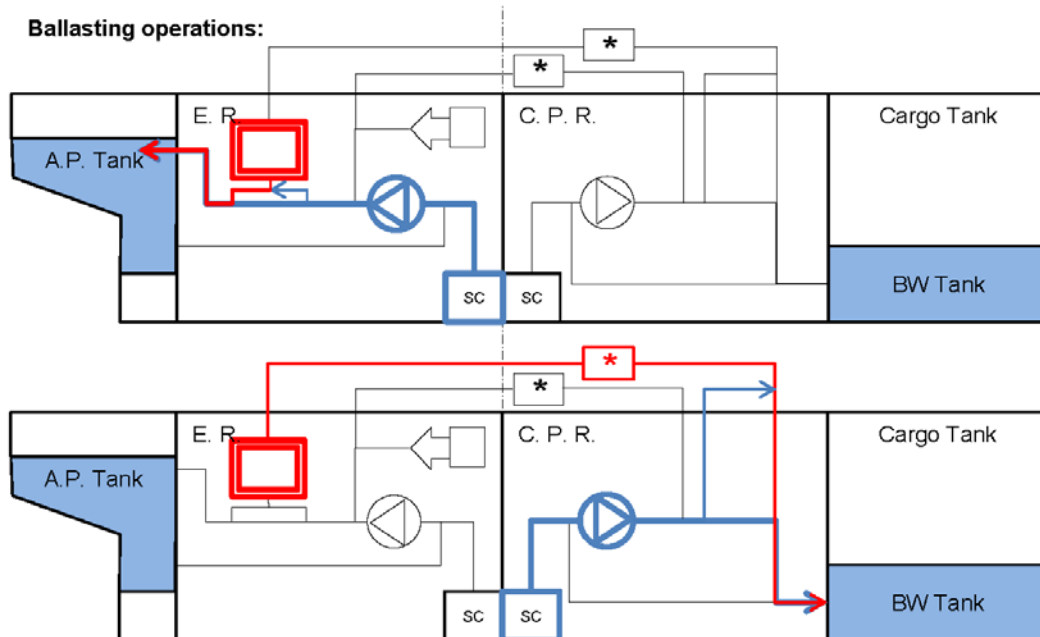
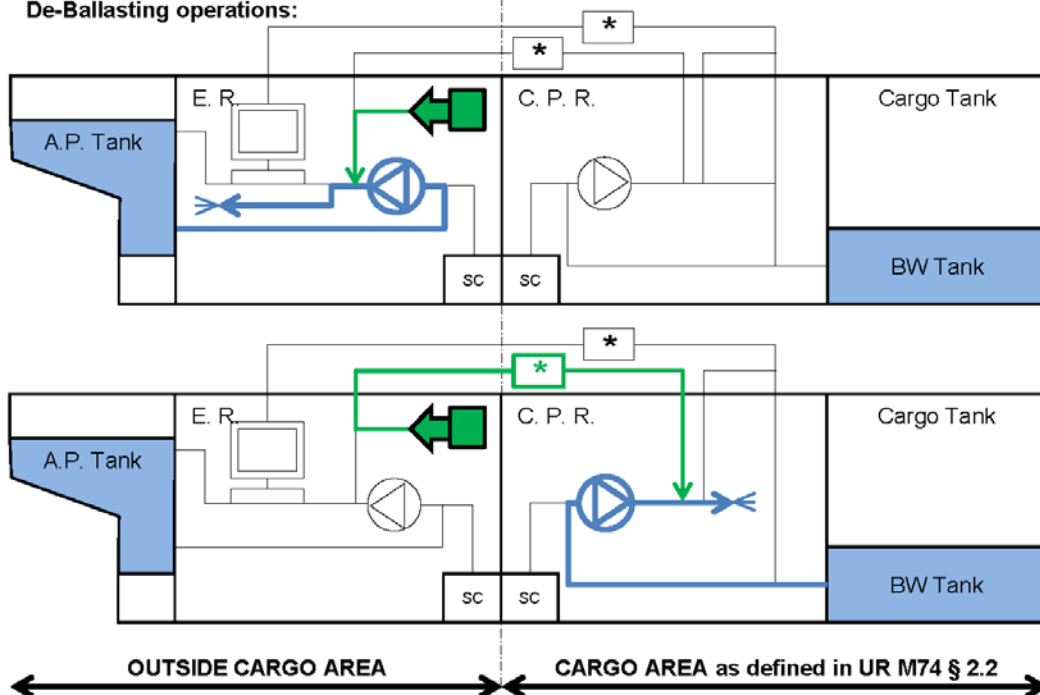


De-Ballasting operations:



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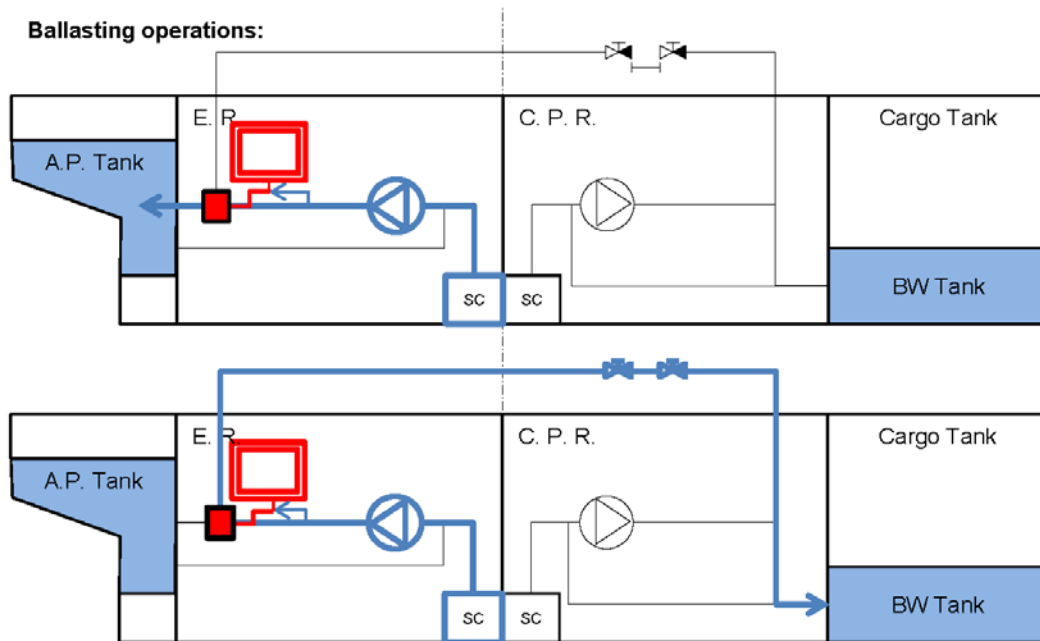
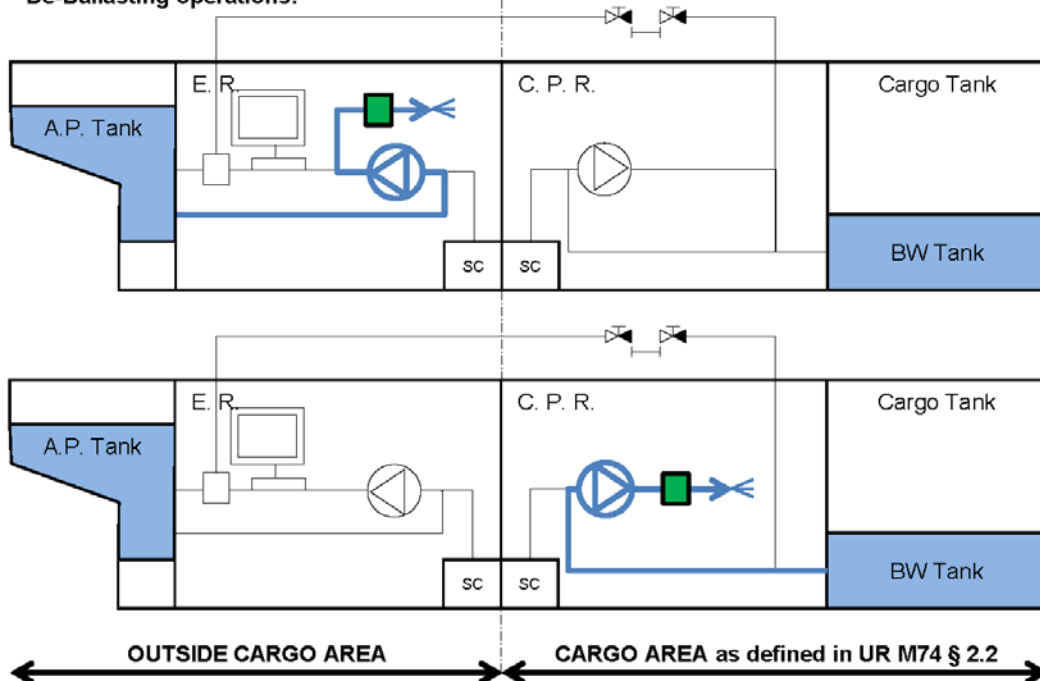
BWMS installed outside the cargo area**Case 1.7a (Technology category 7a, Side-stream ozone injection without gas/liquid separation tank and without discharge water treatment tank):****Ballasting operations:****De-Ballasting operations:**

OUTSIDE CARGO AREA

CARGO AREA as defined in UR M74 § 2.2

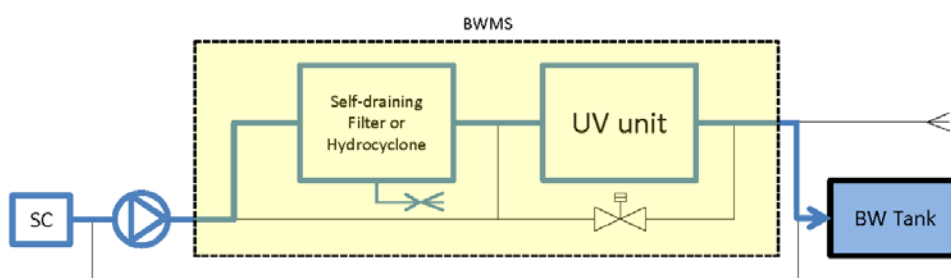
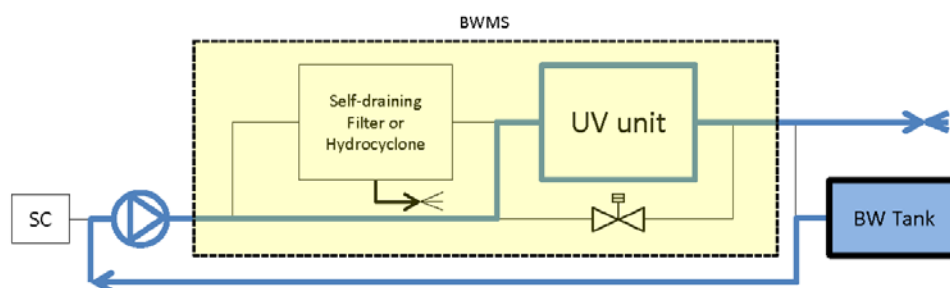
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BWMS installed outside the cargo area**Case 1.7b (Technology category 7b, Side-stream ozone injection with gas/liquid separation tank and discharge water treatment tank):****Ballasting operations:****De-Ballasting operations:**

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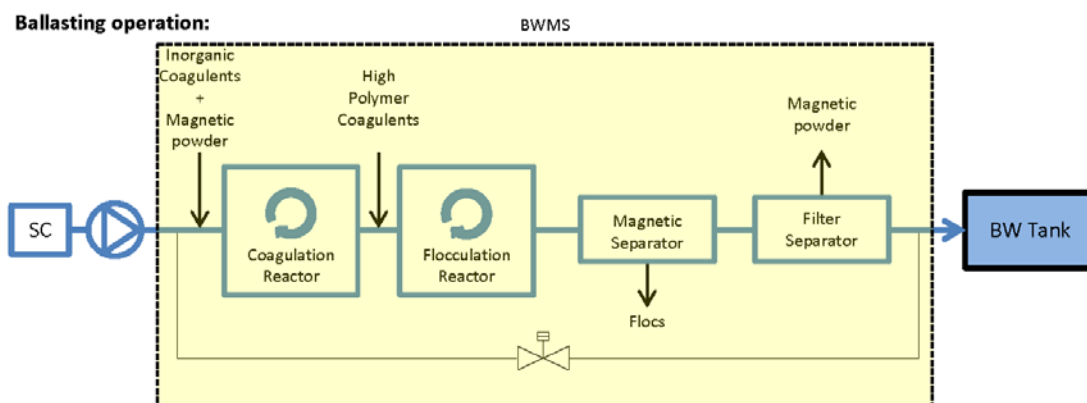
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Annex II (INFORMATIVE)
BWMS Technologies categorization**BWMS Technology Group no. 1****In-Line UV**
including UV + AOT
Including UV+TiO₂)**Ballasting operation:****De-ballasting operation:**

M74

(cont)

BWMS Technology Group no. 2 In-Line Flocculation

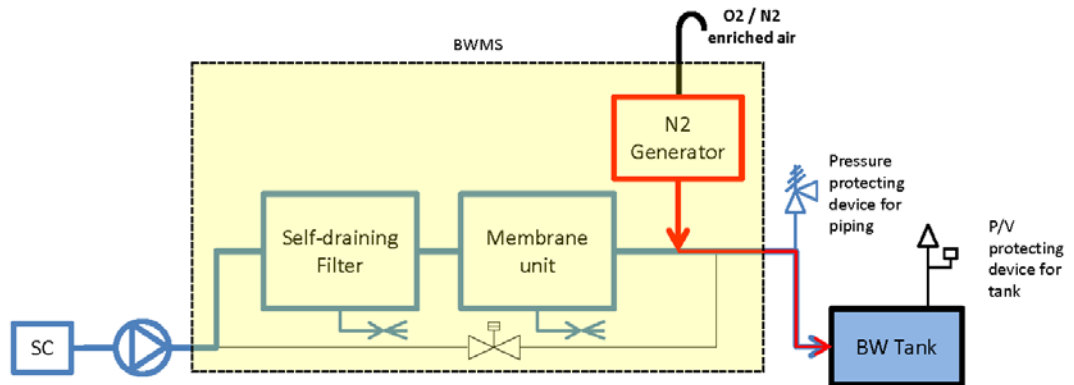


De-ballasting operation: no requirement for after-treatment

M74

(cont)

BWMS Technology Group no. 3a
In-Line membrane separation and de-oxygenation
(injection of N₂ from N₂ Generator)

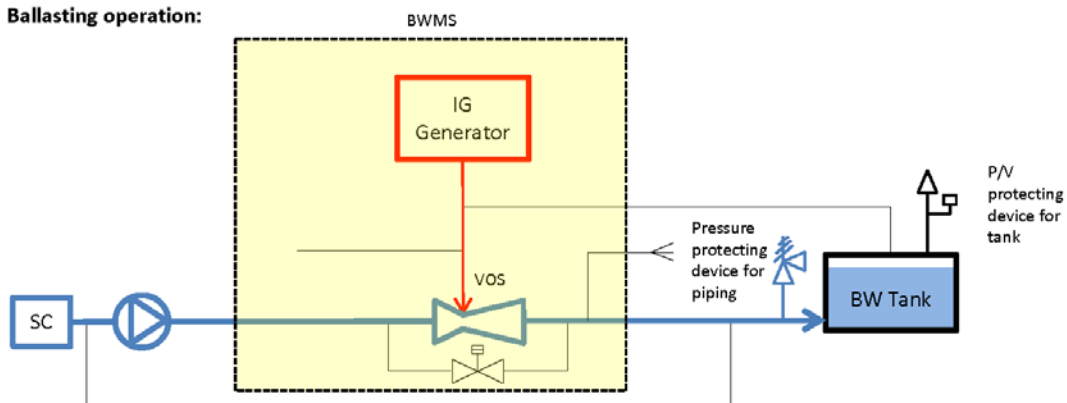
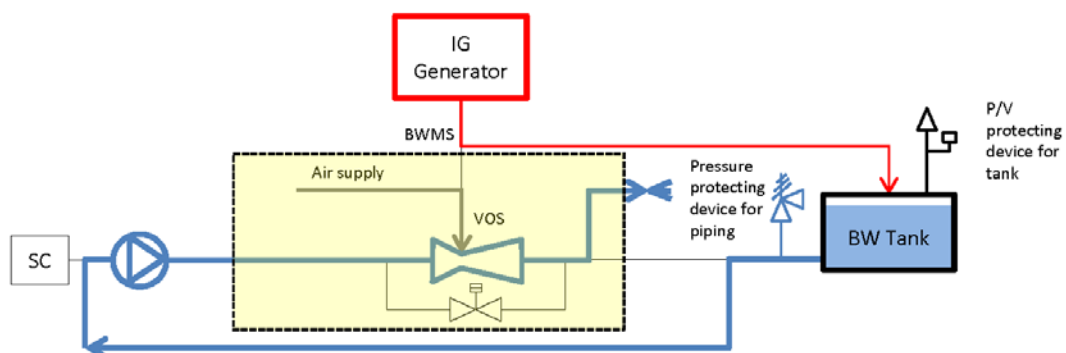
Ballasting operation:**De-ballasting operation: no requirement for after-treatment**

M74

(cont)

BWMS Technology Group no. 3b**In-Line de-oxygenation**

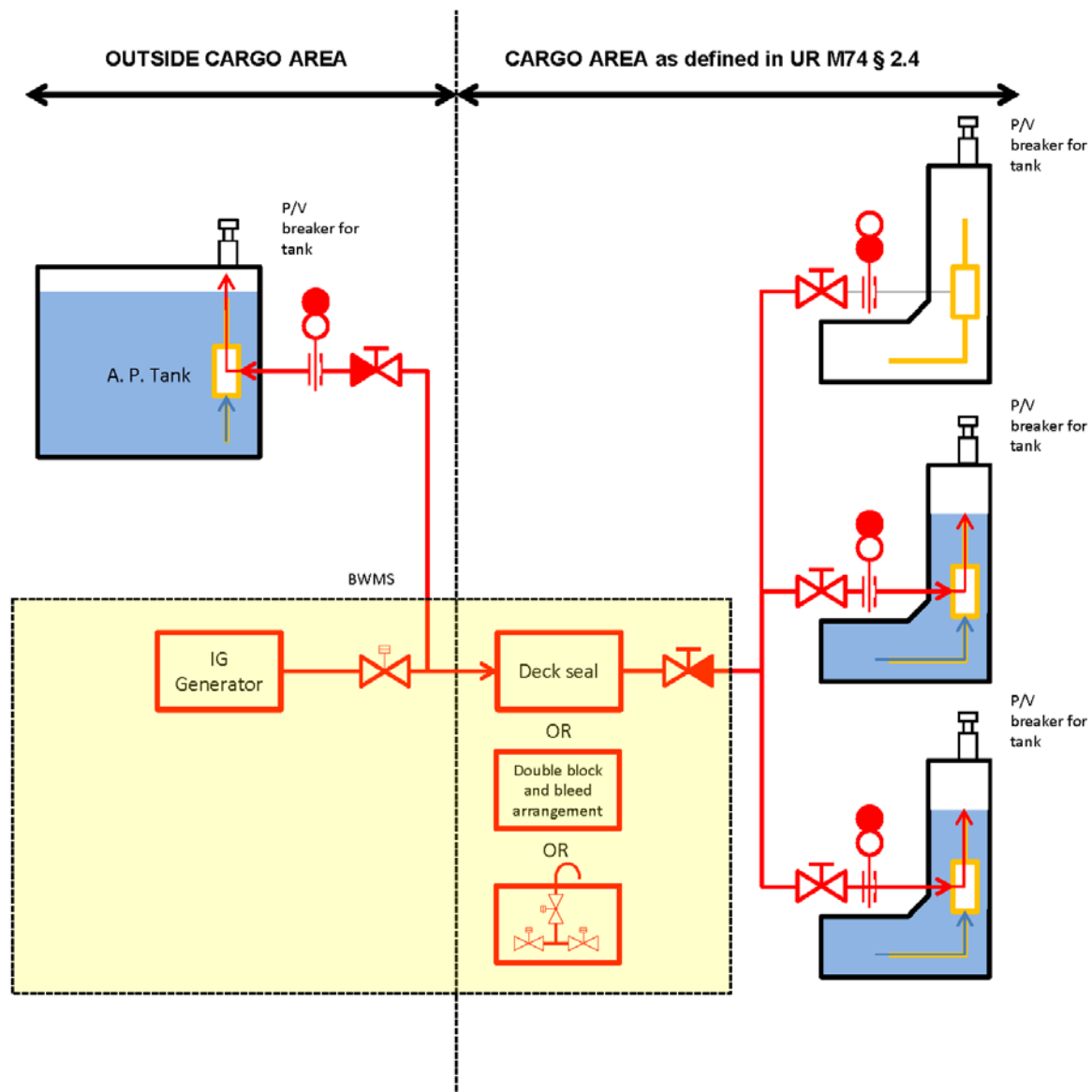
(injection of inert gas from either an oil fired inert gas generator or inert gas from treatment of the flue gas from main or auxiliary boilers)

Ballasting operation:**De-ballasting operation:**

M74

(cont)

BWMS Technology Group no. 3c In-tank de-oxygenation with IGG

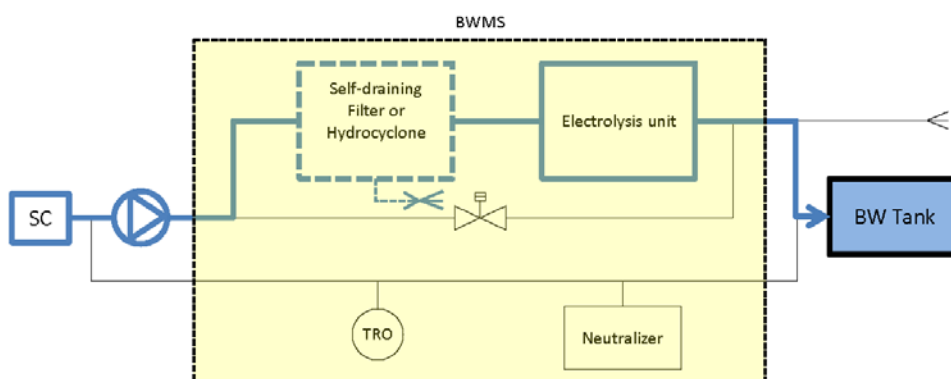


M74

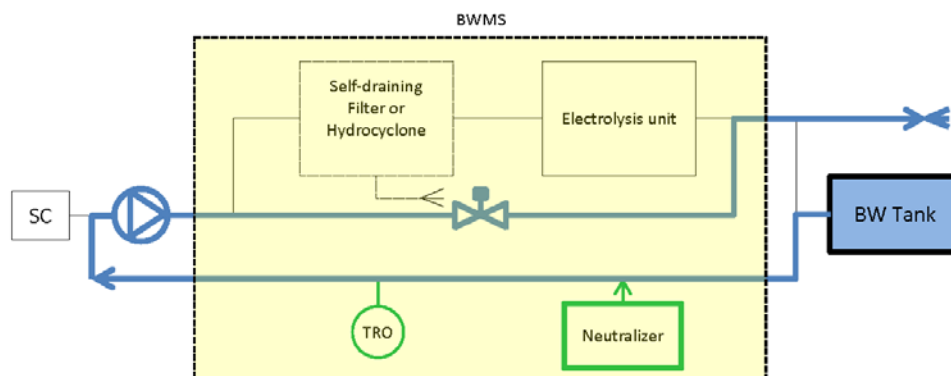
(cont)

BWMS Technology Group no. 4 In-Line Full flow electrolysis

Ballasting operation:



De-ballasting operation:



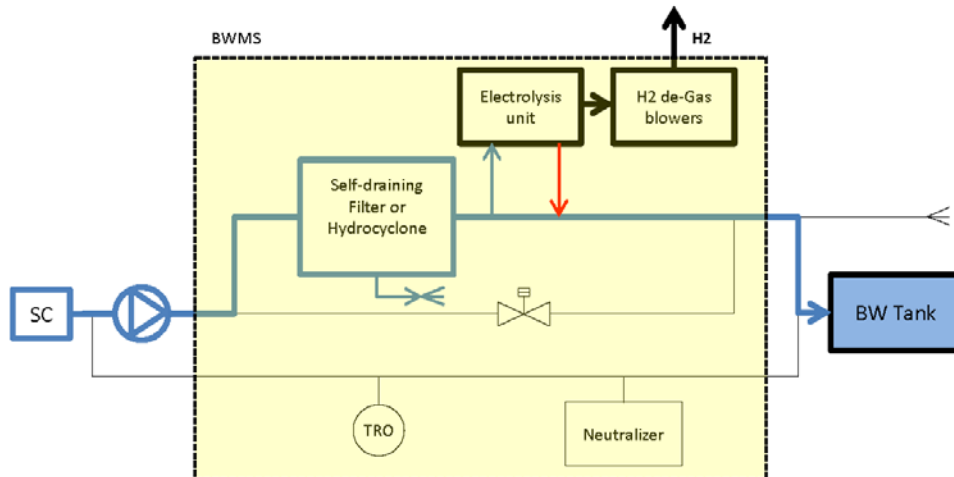
M74

(cont)

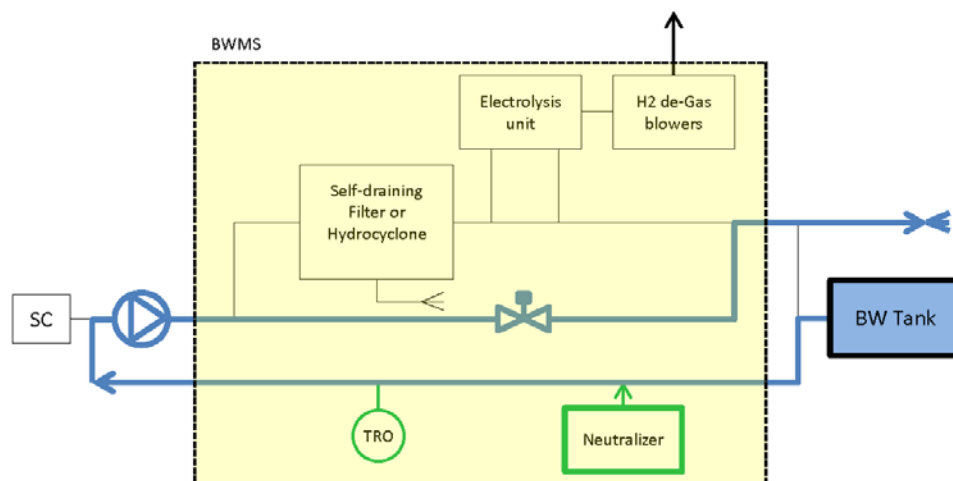
BWMS Technology Group no. 5 In-Line Side-Stream electrolysis (electro-chlorinization)

Note: In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or de-ballasting)

Ballasting operation:



De-ballasting operation:

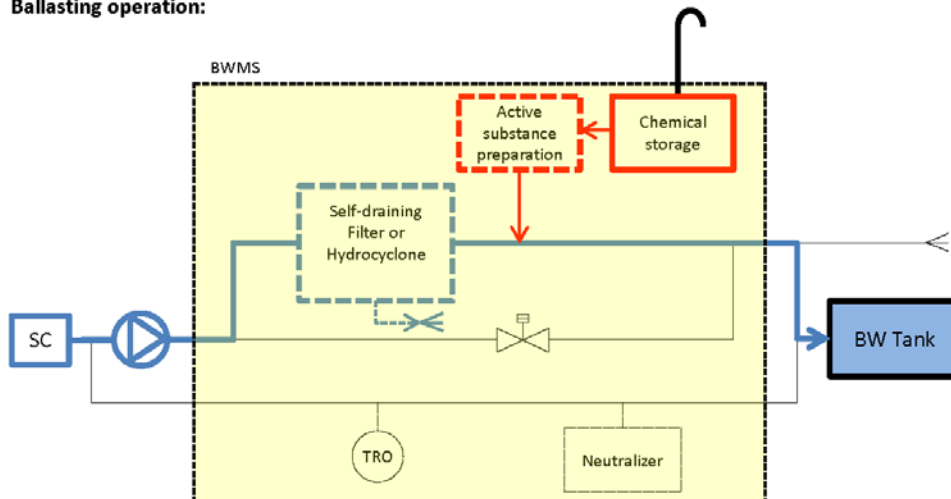


M74

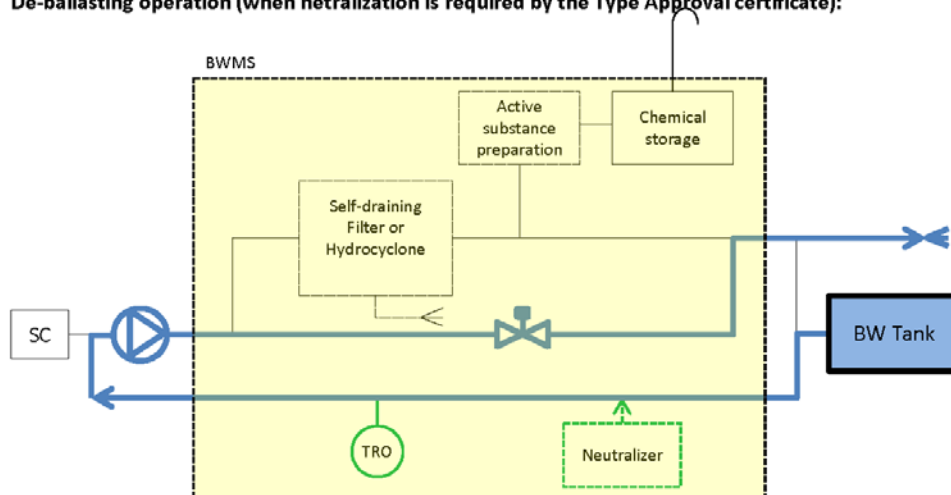
(cont)

BWMS Technology Group no. 6 In-Line Chemical injection

Ballasting operation:



De-ballasting operation (when neutralization is required by the Type Approval certificate):

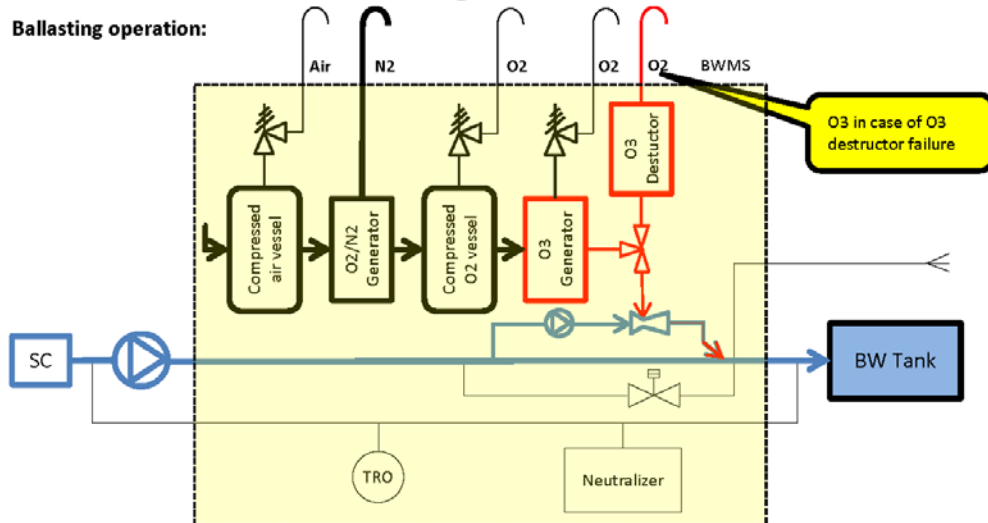


M74

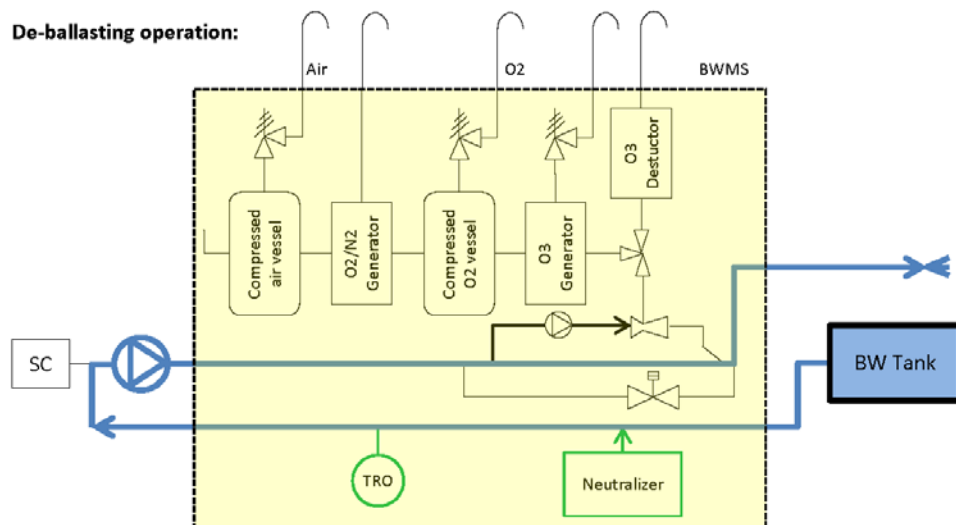
(cont)

BWMS Technology Group no. 7a
In-Line Side-stream Ozone injection without gas/liquid separation tank and
without discharge water treatment tank

Ballasting operation:



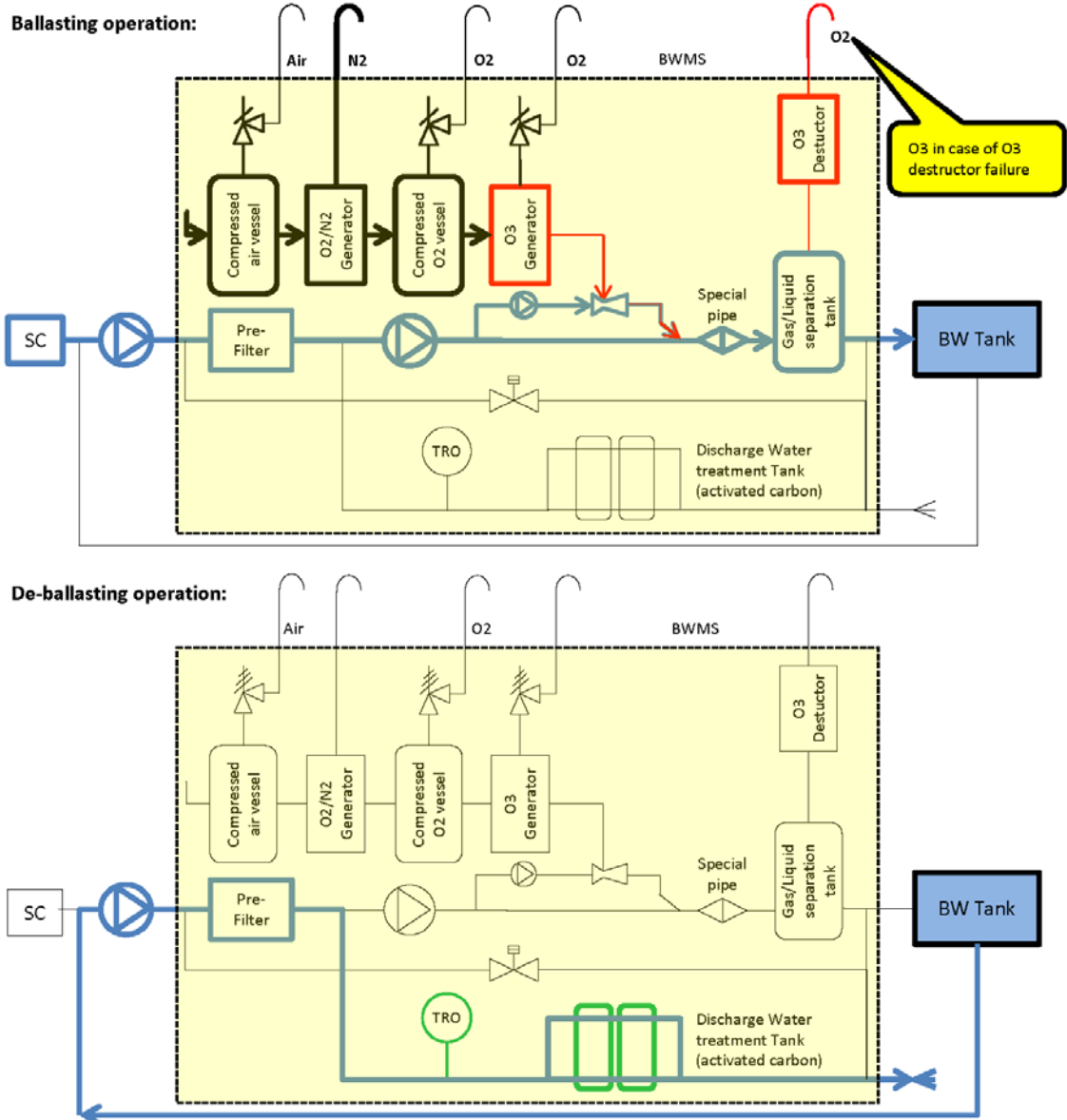
De-ballasting operation:



M74

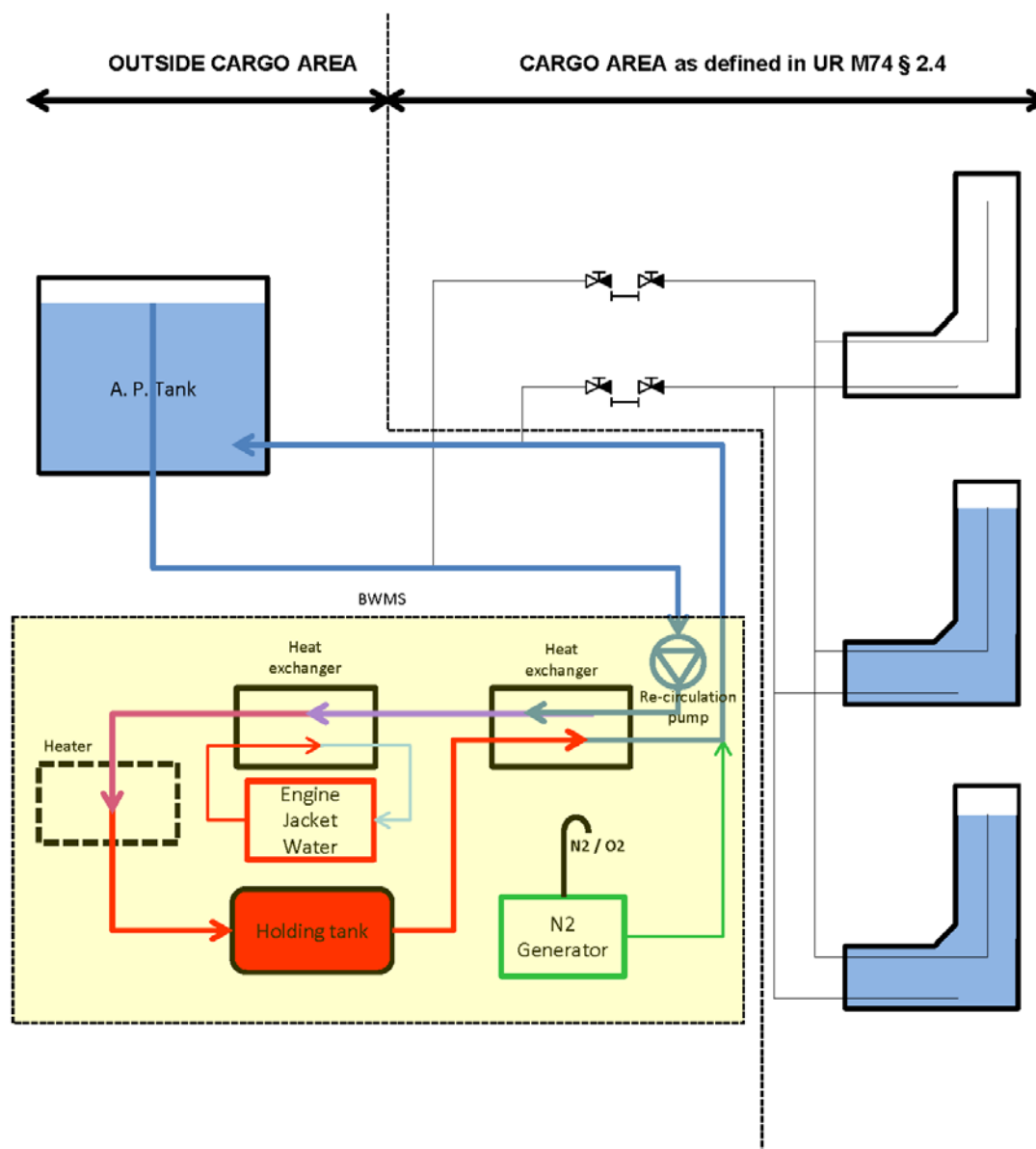
(cont)

BWMS Technology Group no. 7b
In-Line Side-stream Ozone injection with gas/liquid separation tank and with
discharge water treatment tank



M74

(cont)

**BWMS Technology Group no. 8
In-tank Pasteurization + de-oxygenation with N2 Generator**End of
Document

M75 Ventilation of emergency generator rooms

(Feb 2016)

(Rev.1

Jan 2021)

1. Application

The following requirements apply to closable ventilation louvers and ventilator closing appliances serving emergency generator rooms, where fitted.

2. Requirements

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 power-operated 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.
3. Rev.1 of this UR is to be uniformly implemented by IACS Societies for ships contracted for construction on and after 1 January 2022.

End of Document

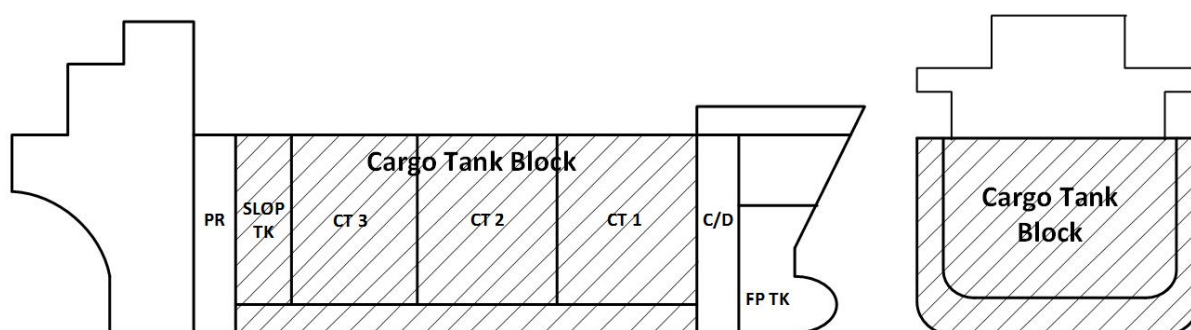
M76

(Apr 2016)
(Rev.1
June 2018)

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

On oil and chemical tankers, carrying liquid cargoes having a flashpoint not exceeding 60°C and/or toxic liquid cargoes*, fuel tanks located with a common boundary to cargo or slop tanks shall not be situated within nor extend partly into the cargo tank block. Such tanks may, however, be situated aft and/or forward of the cargo tank block. They may be accepted when located as independent tanks on open deck in the cargo area subject to spill and fire safety considerations.

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 met.



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.

Footnote:

* For the purpose of this UR, toxic liquid cargoes include those for which toxic vapour detection is specified in column "k" of the table of chapter 17 of the IBC Code.

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.
2. Rev.1 of this UR is to be uniformly implemented by IACS Members when an application for approval for systems is dated on or after 1 July 2019.

End of
Document

M77 Storage and use of SCR reductants

(Sep 2016)
(Rev.1
Aug 2019)
(Rev.2
Dec 2020)
(Rev.3
Sep 2021)
(Rev.4
Feb 2023)

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.

The requirements for SCR reductants tanks with volume below of 500 L are left to the discretion of individual Classification Societies. This discretion is only applicable to Section 2 of the UR.

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.
3. Rev. 1 of 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 2021; or
 - ii) which is installed in ships contracted for construction on or after 1 January 2021.
4. Rev.2 of 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 2022; or
 - ii) which is installed in ships contracted for construction on or after 1 January 2022.
5. Rev.3 of 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 July 2022; or
 - ii) which is installed in ships contracted for construction on or after 1 July 2022.

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(cont)

6. Rev.4 of 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 2024; or
 - ii) which is installed in ships contracted for construction on or after 1 January 2024.

M77 (cont)

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 18611-1:2014) 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 18611-3:2014) 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 ventilation system of extraction type 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. A warning notice requiring the use of such ventilation before entering the compartment shall be provided outside the compartment adjacent to each point of entry.

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 ventilated.

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 included in the ship's stability calculation.

2.7 The requirements specified in M77.2.4 also apply to closed compartments normally entered by persons:

- when they are adjacent to the urea integral tanks and there are possible leak points (e.g. manhole, fittings) from these tanks; or

M77 (cont)

- when the urea piping systems pass through these compartments, unless the piping system is made of steel or other equivalent material with melting point above 925 degrees C and with fully welded joints.

2.8 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.

2.9 Reductant tanks are to be of steel or other equivalent material* with a melting point above 925 degrees C.

Pipes/piping systems are to be of steel or other equivalent material with melting point above 925 degrees C, except downstream of the tank valve, provided this valve is metal seated and arranged as fail-to-closed or with quick closing from a safe position outside the space in the event of fire; in such case, type approved plastic piping may be accepted even if it has not passed a fire endurance test. Reductant tanks and pipes/piping systems are to be made with a material compatible with reductant or coated with appropriate anti-corrosion coating.

2.10 For the protection of crew members, the ship is to have on board suitable personnel protective equipment. Eyewash are to be provided, the location and number of these eyewash stations are to be derived from the detailed installation arrangements.

2.11 Urea storage tanks are to be arranged so that they can be emptied of urea and ventilated by means of portable or permanent systems.

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.

* Footnote to 2.9: Material requirement "to be of steel or other equivalent material" in the first paragraph with a melting point above 925 degrees C is not applicable for integral tanks on FRP vessels such as those listed below, provided that the integral tanks are coated and/or insulated with a self-extinguishing material.

1) FRP vessels complying with Regulation 17 of SOLAS Chapter II-2 based upon its associated IMO guidelines (MSC.1/Circ.1574), and

2) FRP vessels exempted from the application of SOLAS e.g., yachts, fast patrol, navy vessels, etc., generally of less than 500 gross tonnage, subject to yacht codes or flag regulations.

End of Document

M78

(July 2018)
(Rev.1
Feb 2021)

Safety of Internal Combustion Engines Supplied with Low Pressure Gas

1 General

1.1 Scope

1.1.1 Type of engines

This UR addresses the requirements for trunk piston internal combustion engines supplied with low pressure natural gas as fuel. This UR is to be applied in association with other relevant IACS internal combustion engine UR's, as far as found applicable to the specific natural gas burning engine design.

The mandatory international codes for gas carriers (IGC Code) and for other ships burning low flashpoint fuels (IGF Code) must also be considered, as applicable.

Specific requirements of the IGF Code as referenced in this UR shall be applied to engine types covered by this UR installed on any ship, regardless of type, size and trading area, as long as the IGC Code is not referenced or explicitly specified otherwise. Engines can be either dual fuel engines (hereinafter referred to as DF engines) or gas fuel only engines (hereinafter referred to as GF engines).

Note:

1. The requirements of UR M78 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 2019.
2. The "date of an 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, as defined in UR M44, 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 2019 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, as defined in UR M44.
4. Rev.1 of this UR is 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 2022.

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Gas can be introduced as follows:

- into the air inlet manifold, scavenge space, or cylinder air inlet channel port; or
- mixed with air before the turbo-charger ("pre-mixed engines").

The gas / air mixture in the cylinder can be ignited by the combustion of a certain amount of fuel (pilot injection) or by extraneous ignition (sparking plug).

The scope of the UR is limited to natural gas fuelled engines

1.1.2 Applications

This UR covers the following applications, but is not limited to:

- Mechanical propulsion
- Generating sets intended for main propulsion and auxiliary applications.
- Single engine or multi-engine installations

1.2 Definitions

1.2.1 *Certified safe type* means electrical equipment that is certified in accordance with the recommendation published by the International Electrotechnical Commission (IEC), in particular publication IEC 60092-502:1999, or with recognized standards at least equivalent. The certification of electrical equipment is to correspond to the category and group for methane gas.

1.2.2 *Double block and bleed valves* means the set of valves referred to in:

- IGC Code, 16.4.5
- IGF Code, 2.2.9 and 9.4.4 to 9.4.6

1.2.3 *Dual fuel engine ("DF engine")* means an engine that can burn natural gas as fuel simultaneously with liquid fuel, either as pilot oil or bigger amount of liquid fuel (gas mode), and also has the capability of running on liquid diesel fuel oil only (Diesel mode).

1.2.4 *Engine room* is a machinery space or enclosure containing gas fuelled engine(s).

1.2.5 *Gas* means a fluid having a vapour pressure exceeding 2.8 bar absolute at a temperature of 37.8°C.

1.2.6 *Gas admission valve* is a valve or injector on the engine, which controls gas supply to the cylinder(s) according to the cylinder(s) actual gas demand.

1.2.7 *Gas engine* means either a DF engine or a GF engine.

1.2.8 *Gas fuel only engine ("GF engine")* means an engine capable of operating on gas fuel only and not able to switch over to oil fuel operation.

1.2.9 *Gas piping* means piping containing gas or air / gas mixtures, including venting pipes.

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1.2.10 Gas Valve Unit (GVU) is a set of manual shutoff valves, actuated shut-off and venting valves, gas pressure sensors and transmitters, gas temperature sensors and transmitters, gas pressure control valve and gas filter used to control the gas supply to each gas consumer. It also includes a connection for inert gas purging.

1.2.11 IGC Code means the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (as amended by IMO Resolutions MSC.370(93), MSC.411(97) and MSC.441(99)).

1.2.12 IMO means the International Maritime Organisation

1.2.13 IGF Code means the International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels (IMO Resolution MSC.391(95), as amended by Resolution MSC.422(98)).

1.2.14 Low pressure gas means gas with a pressure up to 10 bar.

1.2.15 Lower Heating Value ("LHV") means the amount of heat produced from the complete combustion of a specific amount of fuel, excluding latent heat of vaporization of water.

1.2.16 Methane Number is a measure of resistance of a gas fuel to knock, which is assigned to a test fuel based upon operation in knock testing unit at the same standard knock intensity.

Note: Pure methane is used as the knock resistant reference fuel, that is, methane number of pure methane is 100, and pure hydrogen is used as the knock sensitive reference fuel, methane number of pure hydrogen is 0.

1.2.17 Pilot fuel means the fuel oil that is injected into the cylinder to ignite the main gas-air mixture on DF engines.

1.2.18 Pre-mixed engine means an engine where gas is supplied in a mixture with air before the turbocharger.

1.2.19 Recognized standards means applicable international or national standards acceptable to the Classification Society or standards laid down and maintained by an organisation which complies with the standards adopted by IMO and which are recognized by the Classification Society.

1.2.20 Safety Concept is a document describing the safety philosophy with regard to gas as fuel. It describes how risks associated with this type of fuel are controlled under reasonably foreseeable abnormal conditions as well as possible failure scenarios and their control measures.

Note: A detailed evaluation regarding the hazard potential of injury from a possible explosion is to be carried out and reflected in the safety concept of the engine.

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1.3 Documents and drawings to be submitted**1.3.1 Documents and drawings to be submitted for the approval of DF and GF engines**

The following documents are to be submitted for the approval of DF and GF engines, in addition to those required in UR M44.

No.	Item
1	Schematic layout or other equivalent documents of gas system on the engine
2	Gas piping system (including double-walled arrangement where applicable)
3	Parts for gas admission system ³⁾
4	Arrangement of explosion relief valves (crankcase ¹⁾ , charge air manifold, exhaust gas manifold) as applicable
5	List of certified safe equipment and evidence of relevant certification
6	Safety concept (for information)
7	Report of the risk analysis ²⁾ (for information)
8	Gas specification (for information)

1.3.2 Documents and drawings to be submitted for the approval of DF engine

No.	Item
9	Schematic layout or other equivalent documents of fuel oil system (main and pilot fuel systems) on the engine
10	Shielding of high pressure fuel pipes for pilot fuel system, assembly
11	High pressure parts for pilot fuel oil injection system ³⁾

1.3.3 Documents and drawings to be submitted for the approval of GF engine

No.	Item
12	Ignition system

1.3.4 Where considered necessary, the Society may request further documents to be submitted.

Footnotes:

1) If required by UR M44.

2) See 1.4.

3) The documentation to contain specification of pressures, pipe dimensions and materials.

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1.4 Risk analysis**1.4.1 Scope of the risk analysis**

The risk analysis is to address:

- a failure or malfunction of any system or component involved in the gas operation of the engine
- a gas leakage downstream of the gas valve unit
- the safety of the engine in case of emergency shutdown or blackout, when running on gas
- the inter-actions between the gas fuel system and the engine.

Note: With regard to the scope of the risk analysis it shall be noted that failures in systems external to the engine, such as fuel storage or fuel gas supply systems, may require action from the engine control and monitoring system in the event of an alarm or fault condition. Conversely failures in these external systems may, from the vessel perspective, require additional safety actions from those required by the engine limited risk analysis required by this UR.

1.4.2 Form of the risk analysis

The risk analysis is to be carried out in accordance with international standard ISO 31010:2009: Risk management - Risk assessment techniques, or other recognized standards.

The required analysis is to be based on the single failure concept, which means that only one failure needs to be considered at the same time. Both detectable and non-detectable failures are to be considered. Consequences failures, i.e. failures of any component directly caused by a single failure of another component, are also to be considered.

1.4.3 Procedure for the risk analysis

The risk analysis is to:

- a) Identify all the possible failures in the concerned equipment and systems which could lead:
 - 1) to the presence of gas in components or locations not designed for such purpose, and/or
 - 2) to ignition, fire or explosion.
- b) Evaluate the consequences
- c) Where necessary, identify the failure detection method
- d) Where the risk cannot be eliminated, identify the corrective measures:
 - 1) in the system design, such as:
 - redundancies

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- safety devices, monitoring or alarm provisions which permit restricted operation of the system

2) in the system operation, such as:

- initiation of the redundancy
- activation of an alternative mode of operation.

The results of the risk analysis are to be documented.

1.4.4 Equipment and systems to be analysed

The risk analysis required for engines is to cover at least the following aspects:

a) failure of the gas-related systems or components, in particular:

- gas piping and its enclosure, where provided
- cylinder gas supply valves

Note: Failures of the gas supply components not located directly on the engine, such as block-and-bleed valves and other components of the Gas Valve Unit (GVU), are not to be considered in the analysis.

- b) failure of the ignition system (oil fuel pilot injection or sparking plugs)
- c) failure of the air to fuel ratio control system (charge air by-pass, gas pressure control valve, etc.)
- d) for engines where gas is injected upstream of the turbocharger compressor, failure of a component likely to result in a source of ignition (hot spots)
- e) failure of the gas combustion or abnormal combustion (misfiring, knocking)
- f) failure of the engine monitoring, control and safety systems

Note: Where engines incorporate electronic control systems, a failure mode and effects analysis (FMEA) is to be carried out in accordance with UR M44, Table 1, Footnote 5.

- g) abnormal presence of gas in engine components (e.g. air inlet manifold and exhaust manifold of DF or GF engines) and in the external systems connected to the engines (e.g. exhaust duct).
- h) changes of operating modes for DF engines
- i) hazard potential for crankcase fuel gas accumulation, for engines where the space below the piston is in direct communication with the crankcase, refer to IGF Code 10.3.1.2

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2. Design Requirements**2.1 General Principles**

2.1.1 The manufacturer is to declare the allowable gas composition limits for the engine and the minimum and (if applicable) maximum methane number.

2.1.2 Components containing or likely to contain gas are to be designed to:

- a) minimise the risk of fire and explosion so as to demonstrate an appropriate level of safety commensurate with that of an oil-fuelled engine;
- b) mitigate the consequences of a possible explosion to a level providing a tolerable degree of residual risk, due to the strength of the component(s) or the fitting of suitable pressure relief devices of an approved type.

Also refer to the IGF Code 10.2 and 10.3.

Note:

1. Discharge from pressure relief devices shall prevent the passage of flame to the machinery space and be arranged such that the discharge does not endanger personnel or damage other engine components or systems"
2. Relief devices shall be fitted with a flame arrester.

2.2 Design Requirements**2.2.1 Gas piping****2.2.1.1 General**

The requirements of this section apply to engine-mounted gas piping. The piping shall be designed in accordance with the criteria for gas piping (design pressure, wall thickness, materials, piping fabrication and joining details etc.) as given in the IGF Code chapter 7. For gas carriers, IGC Code chapter 5.1 to 5.9 and 16 applies.

2.2.2 Arrangement of the gas piping system on the engine

Pipes and equipment containing fuel gas are defined as hazardous area Zone 0 (refer to IGF Code 12.5.1).

The space between the gas fuel piping and the wall of the outer pipe or duct is defined as hazardous area Zone 1 (refer to IGF Code 12.5.2.6)

2.2.2.1 Normal "double wall" arrangement

The gas piping system on the engine shall be arranged according to the principles and requirements of the IGF Code 9.6. For gas carriers, IGC Code 16.4.3 applies.

The design criteria for the double pipe or duct are given in the IGF Code 9.8 and 7.4.1.4.

In case of a ventilated double wall, the ventilation inlet is to be located in accordance with the provisions of IGF Code, regulation 13.8.3. For gas carriers, IGC Code 16.4.3.2 applies.

M78 (cont)

The pipe or duct is to be pressure tested in accordance with UR P2.8.1 to ensure gas tight integrity and to show that it can withstand the expected maximum pressure at gas pipe rupture.

2.2.2.2 Alternative arrangement

Single walled gas piping is only acceptable:

- a) for engines installed in ESD protected machinery spaces, as defined in IGF Code 5.4.1.2 and in compliance with other relevant parts of the IGF Code (e.g. 5.6);
- b) in the case as per footnote 18 to paragraph 9.6.2 of IGF Code.

For gas carriers, the IGC Code applies.

In case of gas leakage in an ESD-protected machinery space, which would result in the shut-down of the engine(s) in that space, a sufficient propulsion and manoeuvring capability including essential and safety systems is to be maintained.

Therefore the safety concept of the engine is to clearly indicate application of the “double wall” or “alternative” arrangement.

Note: The minimum power to be maintained is to be assessed on a case-by-case basis from the operational characteristics of the ship.

2.2.3 Charge air system on the engine

The charge air system on the engine is to be designed in accordance with 2.1.2 above. In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained.

Note: Load reduction is to be considered on a case by case basis, depending on engine configuration (single or multiple) and relief mechanism (self-closing valve or bursting disk).

2.2.4 Exhaust system on the engine

The exhaust gas system on the engine is to be designed in accordance with 2.1.2 above.

In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained.

Continuous relief of exhaust gas (through open rupture disc) into the engine room or other enclosed spaces is not acceptable.

2.2.5 Engine crankcase

2.2.5.1 Crankcase explosion relief valves

Crankcase explosion relief valves are to be installed in accordance with UR M9. Refer also to IGF Code 10.3.1.2.

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2.2.5.2 Inerting

For maintenance purposes, a connection, or other means, are to be provided for crankcase inerting and ventilating and gas concentration measuring.

2.2.6 Gas ignition in the cylinder

2.2.6.1 Requirements of IGF Code 10.3 apply. For gas carriers, IGC Code 16.7 applies.

2.2.7 Control, monitoring, alarm and safety systems

The engine control system is to be independent and separate from the safety system.

The gas supply valves are to be controlled by the engine control system or by the engine gas demand.

Combustion is to be monitored on an individual cylinder basis.

In the event that poor combustion is detected on an individual cylinder, gas operation may be allowed in the conditions specified in IGF Code 10.3.1.6.

If monitoring of combustion for each individual cylinder is not practicable due to engine size and design, common combustion monitoring may be accepted.

Unless the risk analysis required by 1.4 of this UR proves otherwise, the monitoring and safety system functions for DF or GF engines are to be provided in accordance with Table 1 of this UR in addition to the general monitoring and safety system functions given by the Classification Societies.

Note: For DF engines, Table 1 applies only to the gas mode.

2.2.8 Gas admission valves

Gas admission valves shall be certified safe as follows:

- 1) The inside of the valve contains gas and shall therefore be certified for Zone 0.
- 2) When the valve is located within a pipe or duct in accordance with 2.2.2.1, the outside of the valve shall be certified for Zone 1.
- 3) When the valve is arranged without enclosure in accordance with the “ESD-protected machinery space” (see 2.2.2.2) concept, no certification is required for the outside of the valve, provided that the valve is de-energized upon gas detection in the space.

However, if they are not rated for the zone they are intended for, it shall be documented that they are suitable for that zone. Documentation and analysis is to be based on IEC 60079-10-1:2015 or IEC 60092-502:1999.

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TABLE 1: Monitoring and Safety System Functions for DF and GF Engines

Parameter	Alarm	Automatic activation of the double block-and-bleed valves	Automatic switching over to oil fuel mode ¹⁾	Engine shutdown
Abnormal pressures in the gas fuel supply line	X	X	X	X ⁵⁾
Gas fuel supply systems - malfunction	X	X	X	X ⁵⁾
Pilot fuel injection or spark ignition systems - malfunction	X	X ²⁾	X	X ²⁾⁵⁾
Exhaust gas temperature after each cylinder - high	X	X ²⁾	X	X ²⁾⁵⁾
Exhaust gas temperature after each cylinder, deviation from average – low ³⁾	X	X ²⁾	X	X ²⁾⁵⁾
Cylinder pressure or ignition - failure, including misfiring, knocking and unstable combustion	X	X ²⁾⁴⁾	X ⁴⁾	X ²⁾⁴⁾⁵⁾
Oil mist concentration in crankcase or bearing temperature ⁶⁾ - high	X	X		X
Pressure in the crankcase – high ⁴⁾	X	X	X	
Engine stops - any cause	X	X		
Failure of the control-actuating medium of the block and bleed valves	X	X	X	
Footnotes: 1) DF engine only, when running in gas mode 2) For GF engines, the double block-and-bleed valves and the engine shutdown may not be activated in case of specific failures affecting only one cylinder, provided that the concerned cylinder can be individually shutoff and the safe operation of the engine in such conditions is demonstrated by the risk analysis. 3) Required only if necessary for the detection of misfiring 4) In the case where the failure can be corrected by an automatic mitigation action, only the alarm may be activated. If the failure persists after a given time, the safety actions are to be activated. 5) GF engine only 6) Where required by UR M10				

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3. Specific Design Requirements**3.1 DF Engines****3.1.1 General**

The maximum continuous power that a DF engine can develop in gas mode may be lower than the approved MCR of the engine (i.e. in oil fuel mode), depending in particular on the gas quality.

This maximum power available in gas mode and the corresponding conditions shall be stated by the engine manufacturer and demonstrated during the type test.

For the application of 4.1.4, 4.2.1 and 4.3 referring to UR M71.5, UR M51.3.3 and UR M51.4.4, the 110% load tests are not required in the gas mode for DF engines.

3.1.2 Starting, changeover and stopping

DF engines are to be arranged to use either oil fuel or gas fuel for the main fuel charge and with pilot oil fuel for ignition. The engines are to be arranged for rapid changeover from gas use to fuel oil use. In the case of changeover to either fuel supply, the engines are to be capable of continuous operation using the alternative fuel supply without interruption to the power supply.

Changeover to gas fuel operation is to be only possible at a power level and under conditions where it can be done with acceptable reliability and safety as demonstrated through testing.

Changeover from gas fuel operation mode to oil fuel operation mode is to be possible at all situations and power levels.

The changeover process itself from and to gas operation is to be automatic but manual interruption is to be possible in all cases.

In case of shut-off of the gas supply, the engines are to be capable of continuous operation by oil fuel only.

3.1.3 Pilot injection

Gas supply to the combustion chamber is not to be possible without operation of the pilot oil injection.

Note: Pilot injection is to be monitored for example by fuel oil pressure and combustion parameters.

3.2 GF Engines**3.2.1 Spark ignition system**

In case of failure of the spark ignition, the engine is to be shut down except if this failure is limited to one cylinder, subject to immediate shut off of the cylinder gas supply and provided that the safe operation of the engine is substantiated by the risk analysis and by tests.

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3.3 Pre-Mixed Engines**3.3.1 Charge air system**

Inlet manifold, turbo-charger, charge air cooler, etc. are to be regarded as parts of the fuel gas supply system. Failures of those components likely to result in a gas leakage are to be considered in the risk analysis (see 1.4).

Flame arresters are to be installed before each cylinder head, unless otherwise justified in the risk analysis, considering design parameters of the engine such as the gas concentration in the charge air system, the path length of the gas-air mixture in the charge air system, etc.

4. Type Testing, Factory Acceptance Tests and Shipboard Trials**4.1 Type Testing****4.1.1 General**

Type approval of DF and GF engines is to be carried out in accordance with UR M71, taking into account the additional requirements below.

4.1.2 Type of engine

In addition to the criteria given in UR M71.3.3 the type of engine is defined by the following:

- gas admission method (direct cylinder injection, charge air space or pre-mixed)
- gas supply valve operation (mechanical or electronically controlled)
- ignition system (pilot injection, spark ignition, glow plug or gas self-ignition)
- ignition system (mechanical or electronically controlled)

4.1.3 Safety precautions

In addition to the safety precautions mentioned in UR M71.4, measures to verify that gas fuel piping on engine is gas tight are to be carried out prior to start-up of the engine.

4.1.4 Test programme

The type testing of the engine is to be carried out in accordance with UR M71.5.

For DF engines, the load tests referred to in UR M71.5 are to be carried out in gas mode at the different percentages of the maximum power available in gas mode (see 3.1.1).

The influence of the methane number and LHV of the fuel gas is not required to be verified during the Stage B type tests. It shall however be justified by the engine designer through internal tests or calculations and documented in the type approval test report.

4.1.5 Measurements and records

In addition to the measurements and records required in UR M71.6, the following engine data are to be measured and recorded:

- Each fuel index for gas and diesel as applicable (or equivalent reading)

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- Gas pressure and temperature at the inlet of the gas manifold
- Gas concentration in the crankcase

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

4.1.6 Stage A – internal tests

In addition to tests required in UR M71.7, the following conditions are to be tested:

- DF engines are to run the load points defined in UR M71.7 in both gas and diesel modes (with and without pilot injection in service) as found applicable for the engine type.
- For DF engines with variable liquid / gas ratio, the load tests are to be carried out at different ratios between the minimum and the maximum allowable values.
- For DF engines, switch over between gas and diesel modes are to be tested at different loads.

4.1.7 Stage B – witnessed tests

4.1.7.1 General

Gas engines are to undergo the different tests required in UR M71.8.

In case of DF engine, all load points must be run in both gas and diesel modes that apply for the engine type as defined by the engine designer (see 4.1.4). This also applies to the overspeed test.

In case of DF engines with variable liquid / gas ratio, the load tests are to be carried out at different ratios between the minimum and the maximum allowable values.

4.1.7.2 Functional tests

In addition to the functional tests required in UR M71.8.3, the following tests are to be carried out:

- For DF engines, the lowest specified speed is to be verified in diesel mode and gas mode.
- For DF engines, switch over between gas and diesel modes are to be tested at different loads.
- The efficiency of the ventilation arrangement of the double walled gas piping system is to be verified.
- Simulation of a gas leakage in way of a cylinder gas supply valve.

Engines intended to produce electrical power are to be tested as follows:

- Capability to take sudden load and loss of load in accordance with the provisions of UR M3.2.3

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- For GF and premixed engines, the influences of LHV, methane number and ambient conditions on the dynamic load response test results are to be theoretically determined and specified in the test report. Referring to the limitations as specified in 2.1.2, the margin for satisfying dynamic load response is to be determined.

Note:

1. For DF engines, switchover to oil fuel during the test is acceptable.
2. Application of electrical load in more than 2 load steps can be permitted in the conditions stated in UR M3.2.3.

4.1.7.3 Integration Tests

GF and DF engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine 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 risk analysis required in 1.4 of this UR, and shall at least include the following incidents:

- Failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure
- Failure of a cylinder gas supply valve
- Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.)
- Abnormal gas pressure
- Abnormal gas temperature¹⁾

4.1.8 Stage C – Component inspection

Component inspection is to be carried out in accordance with the provisions of UR M71.9. The components to be inspected after the test run are to include also:

- gas supply valve including pre-chamber as found applicable
- spark igniter (for GF engines)
- pilot fuel injection valve (for DF engines)

Footnote:

1) This test may be carried out using a simulation signal of the temperature.

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4.2 Factory Acceptance Test**4.2.1 General**

Factory acceptance tests of DF and GF engines are to be carried out in accordance with UR M51, taking into account the additional requirements below.

For DF engines, the load tests referred to in UR M51.3.3 are to be carried out in gas mode at the different percentages of the maximum power available in gas mode (see 3.1.1).

4.2.2 Safety precautions

In addition to the safety precautions mentioned in UR M51.1, measures to verify that gas fuel piping on engine is gas tight are to be carried out prior to start-up of the engine.

4.2.3 Records

In addition to the records required in UR M51.3.2, the following engine data are to be recorded:

- Fuel index, both gas and diesel as applicable (or equivalent reading)
- Gas pressure and temperature

4.2.4 Test loads

Test loads for various engine applications are given in UR M51.3.3. DF engines are to be tested in both diesel and gas mode as found applicable. In addition the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

4.2.5 Integration tests

GF and DF engines are to undergo integration tests 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 risk analysis required in 1.4 of this UR and shall at least include the following incidents:

- Failure of ignition (spark ignition or pilot injection systems), for one cylinder unit
- Failure of a cylinder gas supply valve
- Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.)
- Abnormal gas pressure
- Abnormal gas temperature

The above tests may be carried out using simulation or other alternative methods, subject to special consideration by the Society.

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4.3 Shipboard Trials

Shipboard trials are to be carried out in accordance with the provisions of UR M51.4.

For DF engines, the test loads required in UR M51.4.4 are to be carried out in all operating modes (gas mode, diesel mode, etc.).

For DF engines, the load tests referred to in UR M51.4.4 are to be carried out in gas mode at the different percentages of the maximum power available in gas mode (see 3.1.1).

End of Document

M79 Towing winch emergency release systems

(Oct 2018)

(Rev.1

Feb 2020)

1 Scope

1.1 This UR defines minimum safety standards for winch emergency release systems provided on towing winches that are used on towing ships within close quarters, ports or terminals, including those ships normally not intended for towing operation in transverse direction.

1.2 This UR is not intended to cover towing winches on board ships used solely for long distance ocean towage, anchor handling or similar offshore activities.

2 Purpose

2.1 The purpose of this UR is to provide requirements to prevent the capsize of a tug when in the act of towage as a result of the towline force acting transversely to the tug (in beam direction) as a consequence of an unexpected event (could be loss of propulsion/steering or otherwise), whereby the resulting couple generated by offset and opposing transverse forces (towline force is opposed by thrust or hull resistance force) causes the tug to heel and, ultimately, to capsize. This capsize may be referred to as “girting”, “girling”, “girding” or “tripping”. See Figure 1 which shows the forces acting during towage operations.

Note:

1. This UR is to be uniformly implemented by IACS Societies for vessels contracted for construction on or after 1 January 2020.

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. Rev.1 of this UR is to be uniformly implemented by IACS Societies for vessels contracted for construction on or after 1 July 2021.

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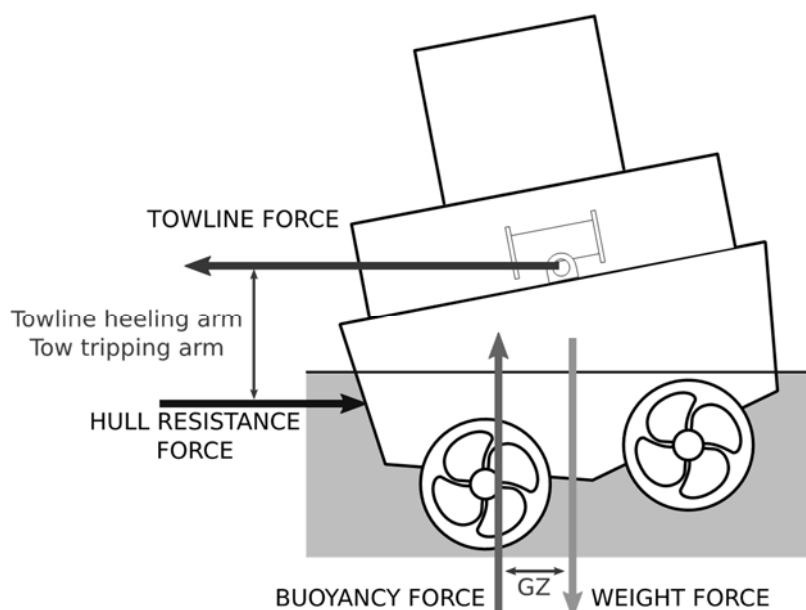


Figure 1: Forces during towing

3. Definitions

3.1 **'Emergency release system'** refers to the mechanism and associated control arrangements that are used to release the load on the towline in a controlled manner under both normal and black out conditions.

3.2 **'Maximum design load'** is the maximum load that can be held by the winch as defined by the manufacturer (the manufacturer's rating).

3.3 **'Fleet angle'** is the angle between the applied load (towline force) and the towline as it is wound onto the winch drum, see Figure 2.

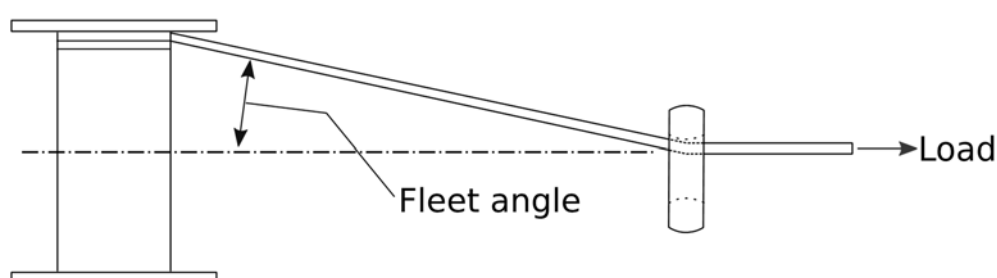


Figure 2: Towline 'fleet angle'

4 General requirements

4.1 The in-board end of the towline is to be attached to the winch drum with a weak link or similar arrangement that is designed to release the towline at low load.

4.2 All towing winches are to be fitted with an emergency release system.

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5.1 Performance requirements

5.1.1 The emergency release system is to operate across the full range of towline load, fleet angle and ship heel angle under all normal and reasonably foreseeable abnormal conditions (these may include, but are not limited to, the following: vessel electrical failure, variable towline load (for example due to heavy weather), etc.).

5.1.2 The emergency release system shall be capable of operating with towline loads up to at least 100 per cent of the maximum design load.

5.1.3 The emergency release system is to function as quickly as is reasonably practicable and within a maximum of three seconds after activation.

5.1.4 The emergency release system is to allow the winch drum to rotate and the towline to pay out in a controlled manner such that, when the emergency release system is activated, there is sufficient resistance to rotation to avoid uncontrolled unwinding of the towline from the drum. Spinning (free, uncontrolled rotation) of the winch drum is to be avoided, as this could cause the towline to get stuck and disable the release function of the winch.

5.1.5 Once the emergency release is activated, the towline load required to rotate the winch drum is to be no greater than:

- (a) the lesser of five tonnes or five per cent of the maximum design load when two layers of towline are on the drum, or
- (b) 15 per cent of the maximum design load where it is demonstrated that this resistance to rotation does not exceed 25 per cent of the force that will result in listing sufficient for the immersion of the lowest unprotected opening.

5.1.6 Emergency release of the towline is to be possible in the event of a blackout. For this purpose, where additional sources of energy are required, such sources are to comply with 5.1.7.

5.1.7 The sources of energy required by 5.1.6 are to be sufficient to achieve the most onerous of the following conditions (as applicable):

- (a) sufficient for at least three attempts to release the towline (i.e. three activations of the emergency release system). Where the system provides energy for more than one winch it is to be sufficient for three activations of the most demanding winch connected to it.
- (b) Where the winch design is such that the drum release mechanism requires continuous application of power (e.g. where the brake is applied by spring tension and released using hydraulic or pneumatic power), sufficient power is to be provided to operate the emergency release system (e.g. hold the brake open and allow release of the towline) in the event of a blackout for a minimum of five minutes. This may be reduced to the time required for the full length of the towline to feed off the winch drum at the load specified in 5.1.5 if this is less than five minutes.

5.2 Operational requirements

5.2.1 Emergency release operation must be possible from the bridge and from the winch control station on deck. The winch control station on deck is to be in a safe location. A

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position in close proximity to the winch is not regarded as “safe location”, unless it is documented that the position is at least protected against towline break or winch failure.

5.2.2 The emergency release control is to be located close to an emergency stop button for winch operation, if provided, and shall be clearly identifiable, clearly visible, easily accessible and positioned to allow safe operability.

5.2.3 The emergency release function is to take priority over any emergency stop function. Activation of the winch emergency stop from any location is not to inhibit operation of the emergency release system from any location.

5.2.4 Emergency release system control buttons are to require positive action to cancel, the positive action may be made at a different control position from the one where the emergency release was activated. It must always be possible to cancel the emergency release from the bridge regardless of the activation location and without manual intervention on the working deck.

5.2.5 Controls for emergency use are to be protected against accidental use.

5.2.6 Indications are to be provided on the bridge for all power supply and/or pressure levels related to the normal operation of the emergency release system. Alarms are to activate automatically if any level falls outside of the limits within which the emergency release system is fully operational.

5.2.7 Wherever practicable, control of the emergency release system is to be provided by a hard-wired system, fully independent of programmable electronic systems.

5.2.8 Computer based systems that operate or may affect the control of emergency release systems are to meet the requirements for Category III systems of UR E22.

5.2.9 Components critical for the safe operation of the emergency release system are to be identified by the manufacturer.

6 Test requirements

6.1 General

6.1.1 All testing defined within Section 5 is to be witnessed by a Classification Society surveyor.

6.1.2 For each emergency release system or type thereof, the performance requirements of Section 5.1 are to be verified either at the manufacturer's works or as part of the commissioning of the towing winch when it is installed on board. Where verification solely through testing is impracticable (e.g. due to health and safety), testing may be combined with inspection, analysis or demonstration in agreement with the Society.

6.1.3 The performance capabilities, as well as instructions for operation, of the emergency release system are to be documented by the manufacturer and made available on board the ship on which the winch has been installed.

6.1.4 Instructions for surveys of the emergency release system are to be documented by the manufacturer, agreed by the Society and made available on board the ship on which the winch has been installed.

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6.1.5 Where necessary for conducting the annual and special surveys of the winch, adequately sized strong points are to be provided on deck.

6.2 Installation trials

6.2.1 The full functionality of the emergency release system is to be tested as part of the shipboard commissioning trials to the satisfaction of the surveyor. Testing may be conducted either during a bollard pull test or by applying the towline load against a strong point on the deck of the tug that is certified to the appropriate load.

6.2.2 Where the performance of the winch in accordance with Section 5.1 has previously been verified, the load applied for the installation trials is to be at least the lesser of 30% of the maximum design load or 80% of vessel bollard pull.

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M80 Requirements for AC Generating sets

(May 2019)

M80.1 General

1. This UR provides requirements for AC Generating sets (i.e. Reciprocating Internal Combustion engines^{a)}, ^{b)}, alternators^{c)} and couplings) in addition to those stated in UR E13, UR M3, UR M51, and UR M53.
 - a) Reciprocating Internal Combustion engines are to comply with the requirements in UR M51 and M53.
 - b) The Reciprocating Internal Combustion engine speed governor and overspeed protective device are to comply with the requirements of UR M3.
 - c) Alternators are to comply with the requirements in UR E13
2. The requirements are applicable to AC generating sets driven by reciprocating internal combustion engines irrespective of their types (i.e. diesel engine, dual fuel engine, gas-fuel engine), except for those sets consisting of a propulsion engine which also drives power take off (PTO) generator(s).

M80.2 Generating sets - requirements

1. The generating set shall show torsional vibration levels which are compatible with the allowable limits for the alternator, shafts, coupling and damper.
2. The coupling selection for the generating set shall take into account the stresses and torques imposed on it by the torsional vibration of the system. The torsional vibration calculations are to be submitted to the Classification Society for approval when the engine power is 110 kW or above.
3. The rated power shall be appropriate for the actual use of the generator set.

Note:

1. This UR is to be uniformly implemented by IACS Societies for AC generating sets:
 - i) when an application for certification of the generating set is dated on or after 1 July 2020; or
 - ii) which are installed in new ships contracted for construction on or after 1 July 2020.
2. 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.
3. The “date of application for certification of the generating set” is the date of whatever document the Classification Society requires/accepts as an application or request for certification of an individual generating set.

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4. The entity responsible of assembling the generating set shall install a rating plate marked with at least the following information:
- (i) the generating set manufacturer's name or mark;
 - (ii) the set serial number;
 - (iii) the set date of manufacture (month/year);
 - (iv) the rated power (both in kW and KVA) with one of the prefixes COP, PRP (or, only for emergency Generating sets, LTP) as defined in ISO 8528-1:2018;
 - (v) the rated power factor;
 - (vi) the set rated frequency (Hz);
 - (vii) the set rated voltage (V);
 - (viii) the set rated current (A);
 - (ix) the mass (kg).

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M81 Safety measures against chemical treatment fluids used for exhaust gas cleaning systems and the residues which have hazardous properties

(Jan 2021)
(Rev.1
July 2023)

1. General

1.1 With regard to regulation 14 of MARPOL Annex VI requiring ships to use fuel oil with a sulphur content not exceeding that stipulated in regulations 14.1 or 14.4, regulation 4 allows, with the approval of the Administration, the use of an alternative compliance method at least as effective in terms of emission reductions as that required by the MARPOL Annex VI, including the standards set forth in regulation 14.

1.2 As some types of exhaust gas cleaning systems to be approved by the Administration as “alternative compliance method” consume chemicals which are typically carried on board in bulk quantities, the prescriptive requirements contained in this UR related safety measures against chemical treatment fluids apply to exhaust gas cleaning systems using such fluids. In this context, the term “chemical treatment fluid” means the aqueous solution of sodium hydroxide (NaOH) or calcium hydroxide (Ca(OH)₂) that has corrosive properties or are considered to represent a hazard to personnel (See section 2 of this UR).

1.3 For exhaust gas cleaning systems using chemicals other than the above, safety measures are to be taken according to the result of a risk assessment to be conducted to analyze the risks, in order to eliminate or mitigate the hazards to personnel brought by the use of such exhaust gas cleaning systems, to an extent equivalent to systems complying with M81 2.1 to M81 2.16.

Note:

1. This UR is to be uniformly implemented by IACS Societies for EGCS:
 - i) when an application for installation, i.e. submission date of plans, is made on or after 1 July 2022; or
 - ii) which is installed in ships contracted for construction on or after 1 July 2022.
2. Rev.1 of this UR is to be uniformly implemented by IACS Societies for EGCS:
 - i) when an application for installation, i.e. submission date of plans, is made on or after 01 July 2024; or
 - ii) which is installed in ships contracted for construction on or after 01 July 2024.
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.

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(cont)**2. Requirements for exhaust gas cleaning systems using aqueous solution of NaOH or Ca(OH)₂ for chemical treatment fluid**

2.1 The storage tank for chemical treatment fluids 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. In cases where such valves are provided below top of tank, they are to be arranged with quick acting shutoff valves which are to be capable of being remotely operated from a position accessible even in the event of chemical treatment fluid leakages. Tank and piping arrangements are to be approved.

2.2 The storage tank is to be protected from excessively high or low temperatures applicable to the particular concentration chemical treatment fluids. Depending on the operational area of the ship, this may necessitate the fitting of heating and/or cooling systems.

2.3 If a storage tank for chemical treatment fluids is installed in a closed compartment, the area is to be served by an effective mechanical ventilation system of extraction type providing not less than 6 air changes per hour which is independent from the ventilation system of other spaces. The ventilation system is to be capable of being controlled from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment shall be provided outside the compartment adjacent to each point of entry.

2.4 The storage tank may be located within the engine room. In this case, the requirements of 2.3 shall be complied with, except that 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 maintained in operation continuously except when the storage tank is empty and has been thoroughly ventilated.

2.5 Each storage tank for chemical treatment fluids is to be provided with level monitoring arrangements and high/low level alarms. In cases where heating and/or cooling systems are provided, high and/or low temperature alarms or temperature monitoring are also to be provided accordingly.

2.6 The storage tanks are to have sufficient strength to withstand a pressure corresponding to the maximum height of a fluid column in the overflow pipe, with a minimum of 2.4 m above the top plate taking into consideration the specific density of the treatment fluid.

2.7 Where chemical treatment fluid is stored in integral tanks, the following are to be considered during the design and construction:

- .1 These tanks may be designed and constructed as integral part of the hull, (e.g. double bottom, wing tanks).
- .2 These tanks are to be coated with appropriate anti-corrosion coating and are to be segregated by cofferdams, void spaces, pump rooms, empty tanks or other similar spaces so as to not be located adjacent to accommodation, cargo spaces containing cargoes which react with chemical treatment fluids in a hazardous manner as well as any food stores, oil tanks and fresh water tanks.
- .3 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.
- .4 These tanks are to be included in the ship's stability calculation.

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- 2.8 The requirements specified in M81 2.3 also apply to closed compartments normally entered by persons:
- .1 when they are adjacent to the integral storage tank for chemical treatment fluids and there are possible leak points (e.g. manhole, fittings) from these tanks; or
 - .2 when the treatment fluid piping systems pass through these compartments, unless the piping system is made of steel or other equivalent material with melting point above 925 degrees C and with fully welded joints.

2.9 The chemical treatment fluid piping and venting systems are to be independent of other ship service piping and/or systems. The chemical treatment fluid 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 tank for chemical treatment fluids.

2.10 Storage tanks and pipes/piping systems and drip trays for chemical treatment fluids which transfer undiluted chemical treatment fluids are to be of steel or other equivalent material with a melting point above 925 degrees C.

2.11 Storage tanks and pipes/piping systems for chemical treatment fluids are to be made with a material compatible with chemical treatment fluids, or coated with appropriate anti-corrosion coating.

Footnote:

Several metals are incompatible with the chemical treatment fluids, e.g. NaOH is incompatible with zinc, aluminum, etc.

2.12 Regardless of design pressure and temperature, piping systems containing chemical treatment fluids only are to comply with the requirements applicable to Class I piping systems. As far as practicable, e.g. except for the flange connections that connect to tank valves, the piping systems are to be joined by welding.

2.13 The following connections are to be screened and fitted with drip trays to prevent the spread of any spillage where they are installed:

- .1 Detachable connections between pipes (flanged connections and mechanical joints, etc.);
- .2 Detachable connections between pipes and equipment such as pumps, strainers, heaters, valves; and
- .3 Detachable connections between equipment mentioned in the above subparagraph.

The drip trays are to be fitted with drain pipes which lead to appropriate tanks, such as residue tanks, which are fitted with high level alarm. Otherwise, the drip trays are to be fitted with alarms for leak detection. In cases where such tank is an integral tank, M81 2.7.1 and M81 2.7.2 are to be applied to the tank.

2.14 For the protection of crew members, the ship is to have on board suitable personnel protective equipment. The number of personnel protective equipment carried onboard is to be appropriate for the number of personnel engaged in regular handling operations or that may be exposed in the event of a failure; but in no case is there to be less than two sets available onboard.

M81
(cont)

2.15 Personnel protective equipment is to consist of protective clothing, boots, gloves and tight-fitting goggles.

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. As a minimum, the following stations are to be provided:

- .1 In the vicinity of transfer or treatment pump locations. If there are multiple transfer or treatment pump locations on the same deck then one eyewash and safety shower station may be considered for acceptance provided that the station is easily accessible from all such pump locations on the same deck.
- .2 An eyewash station and safety shower are to be provided in the vicinity of a chemical bunkering station on-deck. If the bunkering connections are located on both port and starboard sides, then consideration is to be given to providing two eyewash stations and safety showers, one for each side.
- .3 An eyewash station and safety shower are to be provided in the vicinity of any part of the system where a spillage/drainage may occur and in the vicinity of system connections/components that require periodic maintenance.

2.16 Storage tanks for chemical treatment fluids are to be arranged so that they can be safely emptied of the fluids and ventilated by means of portable or permanent systems.

3. Requirement for Exhaust Gas Cleaning Systems discharge water pipeline

3.1 Overboard discharges from exhaust gas cleaning system (EGCS) are not to be interconnected to other systems.

3.2 Due consideration is to be given to the location of overboard discharges with respect to vessel propulsion features, such as thrusters, propellers or to prevent any discharge water onto survival craft during abandonment.

3.3 The piping material for the EGCS discharge water pipeline system is to be selected based on the corrosive nature of the liquid media.

3.4 Special attention is to be paid to the corrosion resistivity of EGCS overboard discharge piping. Where applicable, adequate arrangements are to be provided to prevent galvanic corrosion due to the use of dissimilar metals.

3.5 In case distance piece is fitted between the outboard discharge valve and the shell plating, it shall be made of corrosion resistant material steel or be coated with an anti-corrosive material suitable for the operating environment. The thickness of the distance piece shall be at least the minimum values specified in .1 and .2 as below; otherwise Sch.160 thickness specified in piping standards shall, as far as practicable, be used.

- .1 12 mm in cases where complete pipe is made of corrosion resistant material steel.
- .2 15 mm of mild steel in cases where the inside the pipe is treated with an anticorrosive coating or fitted with a sleeve of corrosion resistant material.

M81
(cont)**4. Miscellaneous**

4.1 Tanks for residues generated from the exhaust gas cleaning process are to satisfy the following requirements:

- .1 The tanks are to be independent from other tanks, except in cases where these tanks are also used as the overflow tanks for chemical treatment fluids storage tank.
- .2 Tank capacities are to be decided in consideration of the number and kinds of installed exhaust gas cleaning systems as well as the maximum number of days between ports where residue can be discharged ashore. In the absence of precise data, a figure of 30 days is to be used.
- .3 Where residue tanks used in closed loop chemical treatment systems are also used as the overflow tanks for chemical treatment fluids storage tank, the requirements for storage tanks apply.

End of Document

M82

(Mar 2023)

Type Testing Procedure of Explosion Relief Devices for Combustion Air Inlet and Exhaust Gas Manifolds of I.C. Engines Using Gas as Fuel

1 Scope

To specify testing procedure for explosion relief devices for combustion air inlet manifold and exhaust gas manifold of internal combustion engines using gas as fuel.

2 Definitions

Definitions addressing gas as fuel as given in the UR M78, Safety of Internal Combustion Engines Supplied with Low Pressure Gas, apply.

Explosion relief device (ERD) means a device to protect a component against a determined overpressure in the event of a gas explosion. The device is fitted with a flame arrester and may be a valve, a rupture disc or other, as applicable.

Note:

1. I.C. Engines using gas as fuel are to be fitted with components and arrangements complying with this UR when:
 - i) an application for certification of an engine is dated on or after 1 July 2024; or
 - ii) installed in new ships for which the date of contract for construction is on or after 1 July 2024.
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.

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(cont)**3 Documents**

Prior to testing, the following documentation for the ERD shall be submitted for approval:

- drawings (sectional drawings, details, assembly etc.)
- specification data sheet including operating conditions and design limits such as:
 - maximum permissible operating pressure, resulting from maximum charging air or exhaust gas back pressure
 - maximum permissible operating temperature, resulting from maximum charging air or exhaust gas temperature
 - static opening pressure, resulting from maximum charging air or exhaust gas back pressure
 - maximum explosion pressure, i.e. maximum pressure that the device can withstand
 - geometric relief area
- product marking
- installation and operation manual
- test program
- specification of test vessel

4 Tests**4.1 Test specimens**

The ERD used for the explosion test is to be selected from the manufacturer's production line by a representative of the Society:

- as a finished certified component itself, or
- on samples taken from earlier stages in the production of the component, when applicable.

If necessary, an additional ERD may need to be selected for the demonstration of the opening pressure. The selected ERD has to be clearly marked.

If applicable, the selected ERD shall be representative for the type range and operating conditions, for example:

- kind of ERD (valve, rupture disc, etc.),
- mounting orientation (vertical, horizontal)
- design of ERD (e.g., spring design, sealing)
- design of flame arrester
- ERD intended to be fitted to the air inlet or exhaust gas manifold of an engine having a turbocharger with characteristics as per the testing conditions in 4.3.2.

The selection of the representative ERD is subject to approval by the Society.

M82 (cont)

4.2 Demonstration of opening pressure

The ERD which has been selected is to be subjected to a pressure test at the manufacturer's works to demonstrate that the static opening pressure is kept within the manufacturer's specification and that the ERD is air tight at the maximum permissible operating pressure for at least 30 seconds.

4.3 Explosion test

4.3.1 Test facility

The test facilities are to be accredited to a national or international standard, e.g. ISO/IEC 17025:2017, and are to be acceptable to the Society.

The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.

The test facilities are to have equipment for controlling and measuring a methane gas concentration within a test vessel to an accuracy of $\pm 0.1\%$.

The test facilities are to be capable of effective point-located ignition of a methane/air mixture.

The test facility arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognizing the speed of the events during an explosion (10 kHz or above).

The explosion test (Para 4.3.5) is to be documented by high speed (250 frames/s or above) video recording. The video recording shall be provided with a time stamp.

4.3.2 Test vessel

The test vessel is a simplified model of the air inlet or exhaust gas manifold. The free area of the connected turbo charger (compressor or turbine wheel) is to be considered.

The test vessel shall comply with the following requirements:

- The shape of the test vessel is to correspond to a pipe with $L/D \geq 10$.
- The test vessel is to be equipped with a rupture disc at one front end to simulate the turbo charger. The relief area of the rupture disc shall be in relationship to the test vessel diameter based on turbocharger manufacturer data for an equivalent free area of compressor or turbine wheel. The opening pressure shall be $\pm 10\%$ of the static opening pressure of the ERD.
- The volume of the test vessel is to comply with the specific relief area of the ERD of $700 \text{ cm}^2/\text{m}^3 \pm 15\%$.
- The test vessel is to be provided with all necessary flanges and connection to mount the ERD in the intended position, to mount a rupture disc as turbo charger simulation, to connect the Methane-air mixture supply and the measurement equipment.
- The ignition is to be made at the middle of the test vessel.
- The test vessel is to be designed to verify a homogeneous air / methane mixture inside the vessel.

M82 (cont)

- The test vessel is to have connections for measuring the pressure in the test vessel in at least two positions, one at the ERD and the other at the test vessel center.
- The test vessel is to have a design pressure of not less than the maximum explosion pressure of a stoichiometric air / methane mixture at test conditions in Para 4.3.6.
- The test vessel configuration is subject to approval by the Society.

Typical test vessel configurations:

All test vessel configurations to be equipped with a rupture disc (1) (turbo charger simulation) at one front end. The ignition is in the centre of the test vessel ($\frac{1}{2}$). The pressure sensors are mounted at the valve flanges (p1) and at the test vessel centre (p2). The measuring of the methane concentration to verify a homogeneous air / methane mixture can be performed at both ends of the test vessel, e.g. (c1) and (c2).



Figure 1 Configuration without ERD (flanges for ERDs closed (2))

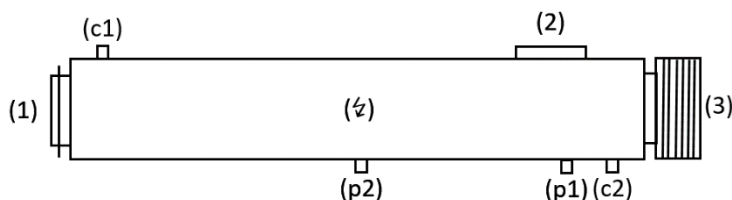


Figure 2 Configuration with ERD (3) mounted at the front end of the test vessel

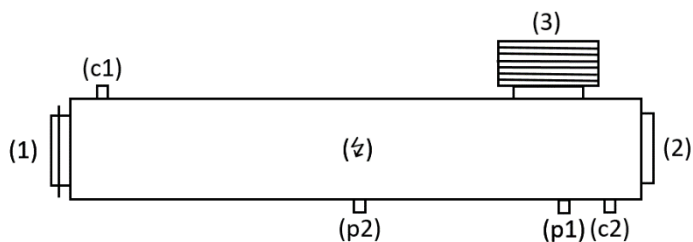


Figure 3 Configuration with ERD (3) mounted on top of the test vessel

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4.3.3 Explosion test process

The explosion testing is to be performed in two stages according to 4.3.4 and 4.3.5 for each ERD that is required to be approved as type tested.

The explosion testing is to be witnessed by a Society surveyor.

Calibration records for the instrumentation used to collect data are to be presented to, and reviewed by, the attending surveyor.

4.3.4 Reference test – Explosion test without ERD

Two explosion tests are to be carried out in the test vessel without ERD. The test vessel configuration is shown in Figure 1.

The aim of this test is to establish a reference pressure level in the test vessel which can be used for determination of the capability of a relief valve in terms of pressure relief.

4.3.5 ERD test – Explosion test with ERD

Two explosion tests are to be carried out in the test vessel with the same ERD at the required position. If the ERD is a rupture disc with flame arrester, the rupture disc shall be replaced.

If shielding arrangements to deflect the emission of explosion combustion products at the ERD are intended, the ERD are to be tested with the shielding arrangements fitted. The test vessel configuration is shown in Figure 2 or 3.

4.3.6 Explosion test method

The test conditions shall comply with the intended use of the ERD, such as:

- pipe diameter
- operating pressure
- operating temperature
- installation orientation.

All explosion tests are to be carried out using an air and methane mixture with a volumetric methane concentration of $9.5\% \pm 0.5\%$. A homogeneous air / methane mixture inside the test vessel is to be verified. The concentration of methane shall not differ by more than 0.5%.

The initial pressure in the test vessel is to be the specified maximum operating pressure of the ERD.

The initial temperature in the test vessel is to be the specified maximum operating temperature of the ERD.

If the initial pressure and/or initial temperature deviate from the design limits, the ERD manufacturer shall prove the acceptability of this deviation either using standards or generally applicable calculation methods.

The ignition is to be made using an explosive charge of 50 - 100 Joule.

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Successive explosion testing to establish an ERD functionality is to be carried out as quickly as possible during stable weather conditions.

The pressure rise and decay during all explosion testing is to be recorded.

The effect of an ERD in terms of pressure relief following an explosion is ascertained from maximum pressure recorded at the centre of the test vessel during the two stages. The pressure relief within the test vessel due to the installation of an ERD is the difference between average pressure of the two explosions of the reference test (4.3.4) and the average of the two explosions of the ERD test (4.3.5).

For acceptance of correct functioning of the flame arrester, there is to be no indication of flame or combustion outside of the ERD during its testing (4.3.5). This is to be monitored by a high-speed video camera (4.3.1), for which ambient light conditions are to be considered to maximise the potential for flame/combustion detection. The use of a dark, ideally matt finish, background and an avoidance of direct light onto the video camera monitored area are recommended.

After each ERD test (4.3.5), the external condition of the flame arrester to be examined for signs of damage and/or deformation that may affect the operation of the ERD.

4.4 Check of ERD components

After completing the explosion tests, the ERDs are to be dismantled and the condition of all components are to be ascertained and documented.

5 Test report

A complete test report has to be submitted to the Society for

- the demonstration of opening pressure (4.2) and
- the explosion test (4.3).

The reports shall include respective information according to the requirements in 4, as applicable:

- test specimens
- test facility, including measuring equipment and test vessel
- measuring results (pressures, temperatures, flame velocities, volumetric methane concentration, ambient conditions etc.)
- video documentation of explosion tests
- photo documentation of ERD components

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(cont)**6 Assessment**

To verify compliance with this requirement the assessment has to address the following:

- Function and mechanical integrity of the ERD.
 - After dismantling of the ERD, the flame arrester shall not show signs of damage or any deformation that may affect the operation of the ERD.
 - If a valve is used any indication of valve sticking or uneven opening during the explosion that may affect subsequent operation of the valve has to be considered.
 - The mechanical integrity of the ERD is proven up to a maximum explosion pressure (as average of the two explosions) of the ERD tests in 4.3.5.
- The functioning of the flame arresters is considered satisfactory if there is no indication of flame or combustion outside the ERD during the explosion tests.

7 Approval

The approval of an ERD is at the discretion of individual classification societies based on the appraisal of plans and particulars and the test report of type testing.

The type approval is valid only for an ERD fitted to the air inlet or exhaust gas manifold of an engine having a turbocharger with compressor or turbine wheel characteristics corresponding to those required in 4.3.2 for the test vessel rupture disc in terms of free area.

End of Document
