This Project Guide is intended to provide the information necessary for the layout of a marine propulsion plant.

The information is to be considered as preliminary. It is intended for the project stage only and subject to modification in the interest of technical progress. The Project Guide provides the general technical data available at the date of issue.

It should be noted that all figures, values, measurements or information about performance stated in this project guide are for guidance only and should not be used for detailed design purposes or as a substitute for specific drawings and instructions prepared for such purposes.

Data updates
Data not finally calculated at the time of issue is marked ‘Available on request’. Such data may be made available at a later date, however, for a specific project the data can be requested. Pages and table entries marked ‘Not applicable’ represent an option, function or selection which is not valid.

The latest, most current version of the individual Project Guide sections are available on the Internet at: www.marine.man.eu → ‘Two-Stroke’.

Extent of Delivery
The final and binding design and outlines are to be supplied by our licensee, the engine maker, see Chapter 20 of this Project Guide.

In order to facilitate negotiations between the yard, the engine maker and the customer, a set of ‘Extent of Delivery’ forms is available in which the basic and the optional executions are specified.

Electronic versions

Edition 0.5
April 2014
All data provided in this document is non-binding. This data serves informational purposes only and is especially not guaranteed in any way.

Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.

If this document is delivered in another language than English and doubts arise concerning the translation, the English text shall prevail.
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<td>20 Project Support and Documentation</td>
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Engine Design
The ME-GI Dual Fuel Engine

The development in gas and fuel oil prices in combination with the emission control regulations, has created a need for dual fuel engines.

The ME-GI engine is designed as an add-on to the MAN B&W two-stroke ME engine technology. It allows the engine to run on either heavy fuel oil (HFO) or liquid natural gas (LNG).

ME-GI vs ME engine design

Although few technical differences separate fuel oil and gas burning engines, the ME-GI engine provides optimal fuel flexibility. Fig. 1.00.01 shows the components that are modified and added to the engine, allowing it to operate on gas.

The new units are:

• A chain pipe gas supply system for high-pressure gas distribution to a gas control block on each cylinder
• Leakage detection and ventilation system for venting the space between the inner and outer pipe of the double-wall piping and detecting leakages. Inlet air is taken from a non-hazardous area and exhausted to outside the engine room
• Sealing oil system, delivering sealing oil to the gas valves separating control oil and gas. Fully integrated on the engine, the shipyard does not need to consider this installation
• Inert gas system that enables purging of the gas system on the engine with inert gas

Fig. 1.00.01: Gas module with chain pipes, gas control block and fuel gas double-wall high-pressure pipes
• Control and safety system, comprising a hydrocarbon analyser for checking the hydrocarbon content of the air in the double-wall gas pipes.

Engine operating modes

One main advantage of the ME-GI engine is its fuel flexibility. The control concept comprises three different fuel modes, see Fig. 1.00.02:

• gas operation with minimum pilot oil amount
• specified dual fuel operation (SDF) with injection of a fixed gas amount
• fuel-oil-only mode.

Gas operation mode is used for gas operation. It can only be started manually by an operator on the Main Operating Panel (MOP) in the control room. The minimum preset amount of pilot fuel oil is as little as 3% at SMCR.

Specified dual fuel operation (SDF) mode gives the operator full fuel flexibility and the option to inject a fixed amount of gas fuel. The ME control system adds fuel oil until the required engine load is reached.

Fuel-oil-only mode is known from the ME engine. Operating the engine in this mode can only be done on fuel oil. In this mode, the engine is considered ‘gas safe’. If a failure in the gas system occurs, it results in a gas shutdown and a return to the fuel-oil only mode.

Safety

The ME-GI control and safety system is designed to fail to safe condition. All failures detected during gas fuel running result in a gas fuel stop and a change-over to fuel oil operation. This condition applies also to failures of the control system itself.

Following the change-over, the high-pressure gas pipes and the complete gas supply system are blow-out and freed from gas by purging.

The change-over to fuel oil mode is always done without any power loss of the engine.

Fuel gas supply systems

Different applications call for different gas supply systems, and operators and shipowners demand alternative solutions.

Therefore, MAN Diesel & Turbo aims to have a number of different gas supply systems prepared, tested and available. Examples of fuel gas supply systems are presented in Section 7.08.

Fig. 1.00.02: Fuel type modes for the ME-GI engines for LNG carriers
The ever valid requirement of ship operators is to obtain the lowest total operational costs, and especially the lowest possible specific fuel oil consumption at any load, and under the prevailing operating conditions.

However, low-speed two-stroke main engines of the MC-C type, with a chain driven camshaft, have limited flexibility with regard to fuel injection and exhaust valve activation, which are the two most important factors in adjusting the engine to match the prevailing operating conditions.

A system with electronically controlled hydraulic activation provides the required flexibility, and such systems form the core of the ME Engine Control System, described later in detail in Chapter 16.

Concept of the ME engine

The ME engine concept consists of a hydraulic-mechanical system for activation of the fuel injection and the exhaust valves. The actuators are electronically controlled by a number of control units forming the complete Engine Control System.

MAN Diesel & Turbo has specifically developed both the hardware and the software in-house, in order to obtain an integrated solution for the Engine Control System.

The fuel pressure booster consists of a simple plunger powered by a hydraulic piston activated by oil pressure. The oil pressure is controlled by an electronically controlled proportional valve.

The exhaust valve is opened hydraulically by means of a two-stage exhaust valve actuator activated by the control oil from an electronically controlled proportional valve. The exhaust valves are closed by the ‘air spring’.

In the hydraulic system, the normal lube oil is used as the medium. It is filtered and pressurised by a Hydraulic Power Supply unit mounted on the engine or placed in the engine room.

The starting valves are opened pneumatically by electronically controlled ‘On/Off’ valves, which make it possible to dispense with the mechanically activated starting air distributor.

By electronic control of the above valves according to the measured instantaneous crankshaft position, the Engine Control System fully controls the combustion process.

System flexibility is obtained by means of different ‘Engine running modes’, which are selected either automatically, depending on the operating conditions, or manually by the operator to meet specific goals. The basic running mode is ‘Fuel economy mode’ to comply with IMO NOx emission limitation.

Engine design and IMO regulation compliance

The ME-C engine is the shorter, more compact version of the ME engine. It is well suited wherever a small engine room is requested, for instance in container vessels.

For MAN B&W ME/ME-C-TII designated engines, the design and performance parameters comply with the International Maritime Organisation (IMO) Tier II emission regulations.

For engines built to comply with IMO Tier I emission regulations, please refer to the Marine Engine IMO Tier I Project Guide.
Tier II fuel optimisation

NO\textsubscript{x} regulations place a limit on the SFOC on two-stroke engines. In general, NO\textsubscript{x} emissions will increase if SFOC is decreased and vice versa. In the standard configuration, MAN B&W engines are optimised close to the IMO NO\textsubscript{x} limit and, therefore, NO\textsubscript{x} emissions may not be further increased.

The IMO NO\textsubscript{x} limit is given as a weighted average of the NO\textsubscript{x} emission at 25, 50, 75 and 100\% load. This relationship can be utilised to tilt the SFOC profile over the load range. This means that SFOC can be reduced at part load or low load at the expense of a higher SFOC in the high-load range without exceeding the IMO NO\textsubscript{x} limit.

Improved fuel consumption on gas fuel

In the ME-GI concept, NO\textsubscript{x} is reduced substantially on gas fuel compared to diesel/HFO operation. As much as possible of this NO\textsubscript{x} margin is exchanged for improved SFOC, while not exceeding the E3 NO\textsubscript{x} cycle value for the diesel reference case.

The SFOC optimisation is carried out in the part-load range from 75\% load and below. Further to this SFOC improvement on gas, no other part- or low-load optimisation methods are applicable for the ME-GI engine.

In this project guide, data is based on high-load optimisation unless explicitly noted. For derated engines, calculations can be made in the CEAS application described in Section 20.02.
Engine Type Designation

6 S 90 M E -C 9 .2 -GI -TII

- Emission regulation
- Fuel injection concept
- Version number
- Mark number
- Design
- Concept
- Engine programme
- Diameter of piston in cm
- Stroke/bore ratio
- Number of cylinders

- TII IMO Tier level
- (blank) Fuel oil only
- GI Gas injection

- B Exhaust valve controlled by camshaft
- C Compact engine
- E Electronically controlled
- C Camshaft controlled

- G ‘Green’ Ultra long stroke
- S Super long stroke
- L Long stroke
- K Short stroke
Power, Speed and Fuel Oil

MAN B&W L70ME-C8.5-GI-TII

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<td>6</td>
<td>19,620</td>
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<tr>
<td>7</td>
<td>22,890</td>
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<td>8</td>
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**Fig 1.03.01: Power, speed and fuel kW/cyl.**

**SFOC gas engines [g/kWh]**

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<th>50%</th>
<th>75%</th>
<th>100%</th>
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<tr>
<td><strong>Gas and pilot fuel (42,700 kJ/kg)</strong></td>
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<td></td>
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<tr>
<td>L1</td>
<td>162.5</td>
<td>162.0</td>
<td>169.0</td>
</tr>
<tr>
<td>L2</td>
<td>158.5</td>
<td>156.0</td>
<td>163.0</td>
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<tr>
<td>L3</td>
<td>165.0</td>
<td>163.5</td>
<td>169.0</td>
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<tr>
<td>L4</td>
<td>161.0</td>
<td>157.5</td>
<td>163.0</td>
</tr>
<tr>
<td><strong>Liquid fuel only (42,700 kJ/kg)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1/L3</td>
<td>168.5</td>
<td>166.0</td>
<td>170.0</td>
</tr>
<tr>
<td>L2/L4</td>
<td>164.5</td>
<td>160.0</td>
<td>164.0</td>
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</tbody>
</table>

Specific gas consumption consists of 3% pilot liquid fuel and gas fuel. Gas fuel LCV (50,000 kJ/kg) is converted to diesel fuel LCV (42,700 kJ/kg) for comparison with diesel engine.

**Distributed fuel data [g/kWh]**

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<th>50%</th>
<th>75%</th>
<th>100%</th>
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<td><strong>Gas fuel (50,000 kJ/kg)</strong></td>
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<tr>
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<td><strong>Pilot fuel (42,700 kJ/kg)</strong></td>
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<tr>
<td>L2/L4</td>
<td>10.0</td>
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Engine Power Range and Fuel Oil Consumption

**Engine Power**

The following tables contain data regarding the power, speed and specific fuel oil consumption of the engine.

Engine power is specified in kW for each cylinder number and layout points L₁, L₂, L₃ and L₄:

For conversions between kW and metric horsepower, please note that 1 BHP = 75 kpm/s = 0.7355 kW.

L₁ designates nominal maximum continuous rating (nominal MCR), at 100% engine power and 100% engine speed.

L₂, L₃ and L₄ designate layout points at the other three corners of the layout area, chosen for easy reference.

**Specific Fuel Oil Consumption (SFOC)**

The figures given in this folder represent the values obtained when the engine and turbocharger are matched with a view to obtaining the lowest possible SFOC values while also fulfilling the IMO NOX Tier II emission limitations.

Stricter emission limits can be met on request, using proven technologies.

The SFOC figures are given in g/kWh with a tolerance of 5% and are based on the use of fuel with a lower calorific value of 42,700 kJ/kg (~10,200 kcal/kg) at ISO conditions:

- Ambient air pressure: 1,000 mbar
- Ambient air temperature: 25 °C
- Cooling water temperature: 25 °C
- Specific fuel oil consumption varies with ambient conditions and fuel oil lower calorific value. For calculation of these changes, see Chapter 2.

**Gas consumption**

The energy consumption (heat rate) for the -GI engine is lower when running on gas in dual fuel mode (heat rate in kJ/kWh) compared to fuel only mode.

When a given amount of oil is known in g/kWh, and after deducting the pilot fuel oil the additional gas consumption can be found by converting the energy supplied as gas into cubic metre per hour according to the LCV of the gas.

In the following sections, the energy consumption is calculated as related equivalent fuel consumption, i.e. with all our usual figures.

**Example:**

Rel. SFOC og gas........ 169 g/kWh
Ref. LCV ................. 42,700 kJ
Heat rate.............. 0.169 x 42,700 = 7,216 kJ/kWh

The heat rate is also referred to as the ‘Guiding Equivalent Energy Consumption’.

Fig. 1.04.01: Layout diagram for engine power and speed

Overload corresponds to 110% of the power at MCR, and may be permitted for a limited period of one hour every 12 hours.

The engine power figures given in the tables remain valid up to tropical conditions at sea level as stated in IACS M28 (1978), i.e.:

Blower inlet temperature ............... 45 °C
Blower inlet pressure .................... 1,000 mbar
Seawater temperature ..................... 32 °C
Relative humidity ....................... 60%
Lubricating oil data

The cylinder oil consumption figures stated in the tables are valid under normal conditions.

During running-in periods and under special conditions, feed rates can be increased. This is explained in Section 9.02.
Performance Curves

Updated engine and capacities data is available from the CEAS program on www.marine.man.eu → ‘Two-Stroke’ → ‘CEAS Engine Calculations’.
ME-GI Engine Description

Please note that engines built by our licensees are in accordance with MAN Diesel & Turbo drawings and standards but, in certain cases, some local standards may be applied; however, all spare parts are interchangeable with MAN Diesel & Turbo designed parts.

Some components may differ from MAN Diesel & Turbo’s design because of local production facilities or the application of local standard components.

In the following, reference is made to the item numbers specified in the ‘Extent of Delivery’ (EoD) forms, both for the ‘Basic’ delivery extent and for some ‘Options’.

Bedplate and Main Bearing

The bedplate is made with the thrust bearing in the aft end of the engine. The bedplate consists of high, welded, longitudinal girders and welded cross girders with cast steel bearing supports.

For fitting to the engine seating in the ship, long, elastic holding-down bolts, and hydraulic tightening tools are used.

The bedplate is made without taper for engines mounted on epoxy chocks.

The oil pan, which is made of steel plate and is welded to the bedplate, collects the return oil from the forced lubricating and cooling oil system. The oil outlets from the oil pan are vertical as standard and provided with gratings.

The main bearings consist of thin walled steel shells lined with bearing metal. The main bearing bottom shell can be rotated out and in by means of special tools in combination with hydraulic tools for lifting the crankshaft. The shells are kept in position by a bearing cap.

Frame Box

The frame box is of welded design. On the exhaust side, it is provided with relief valves for each cylinder while, on the manoeuvring side, it is provided with a large hinged door for each cylinder. The crosshead guides are welded on to the frame box.

The frame box is bolted to the bedplate. The bedplate, frame box and cylinder frame are tightened together by stay bolts.

Cylinder Frame and Stuffing Box

The cylinder frame is cast and provided with access covers for cleaning the scavenge air space, if required, and for inspection of scavenge ports and piston rings from the manoeuvring side. Together with the cylinder liner it forms the scavenge air space.

The cylinder frame is fitted with pipes for the piston cooling oil inlet. The scavenge air receiver, turbocharger, air cooler box and gallery brackets are located on the cylinder frame. At the bottom of the cylinder frame there is a piston rod stuffing box, provided with sealing rings for scavenge air, and with oil scraper rings which prevent crankcase oil from coming up into the scavenge air space.

Drains from the scavenge air space and the piston rod stuffing box are located at the bottom of the cylinder frame.

Cylinder Liner

The cylinder liner is made of alloyed cast iron and is suspended in the cylinder frame. The top of the cylinder liner is fitted with a cooling jacket. The cylinder liner has scavenge ports and drilled holes for cylinder lubrication.

Cylinder liners prepared for installation of temperature sensors is basic execution on engines type 90 while an option on all other engines.
Cylinder Cover

The cylinder cover is of forged steel, made in one piece, and has bores for cooling water. It has a central bore for the exhaust valve, and bores for the fuel valves, gas valves, a starting valve and an indicator valve.

The side of the cylinder cover facing the hydraulic cylinder unit (HCU) block has a face for the mounting of a special valve block, the Gas Control Block, see later description.

In addition, the cylinder cover is provided with one set of bores for supplying gas from the gas control block to each gas injection valve.

Crankshaft

The crankshaft is of the semi-built type, made from forged or cast steel throws. For engines with 9 cylinders or more, the crankshaft is supplied in two parts.

At the aft end, the crankshaft is provided with the collar for the thrust bearing, a flange for fitting the gear wheel for the step-up gear to the hydraulic power supply unit if fitted on the engine, and the flange for the turning wheel and for the coupling bolts to an intermediate shaft.

At the front end, the crankshaft is fitted with the collar for the axial vibration damper and a flange for the fitting of a tuning wheel. The flange can also be used for a Power Take Off, if so desired.

Coupling bolts and nuts for joining the crankshaft together with the intermediate shaft are not normally supplied.

Thrust Bearing

The propeller thrust is transferred through the thrust collar, the segments, and the bedplate, to the end chocks and engine seating, and thus to the ship's hull.

The thrust bearing is located in the aft end of the engine. The thrust bearing is of the B&W-Michell type, and consists primarily of a thrust collar on the crankshaft, a bearing support, and segments of steel lined with white metal.

Engines type 60 and larger with 9 cylinders or more will be specified with the 360° degree type thrust bearing, while the 240° degree type is used in all other engines. MAN Diesel & Turbo's flexible thrust cam design is used for the thrust collar on a range of engine types.

The thrust shaft is an integrated part of the crankshaft and it is lubricated by the engine's lubricating oil system.

Step-up Gear

In case of mechanically, engine driven Hydraulic Power Supply, the main hydraulic oil pumps are driven from the crankshaft via a step-up gear. The step-up gear is lubricated from the main engine system.

Turning Gear and Turning Wheel

The turning wheel is fitted to the thrust shaft, and it is driven by a pinion on the terminal shaft of the turning gear, which is mounted on the bedplate. The turning gear is driven by an electric motor with built-in brake.

A blocking device prevents the main engine from starting when the turning gear is engaged. Engagement and disengagement of the turning gear is effected manually by an axial movement of the pinion.

The control device for the turning gear, consisting of starter and manual control box, can be ordered as an option.
**Axial Vibration Damper**

The engine is fitted with an axial vibration damper, mounted on the fore end of the crankshaft. The damper consists of a piston and a split-type housing located forward of the foremost main bearing.

The piston is made as an integrated collar on the main crank journal, and the housing is fixed to the main bearing support.

For functional check of the vibration damper a mechanical guide is fitted, while an electronic vibration monitor can be supplied as an option.

**Tuning Wheel / Torsional Vibration Damper**

A tuning wheel or torsional vibration damper may have to be ordered separately, depending on the final torsional vibration calculations.

**Connecting Rod**

The connecting rod is made of forged or cast steel and provided with bearing caps for the crosshead and crankpin bearings.

The crosshead and crankpin bearing caps are secured to the connecting rod with studs and nuts tightened by means of hydraulic jacks.

The crosshead bearing consists of a set of thin-walled steel shells, lined with bearing metal. The crosshead bearing cap is in one piece, with an angular cut-out for the piston rod.

The crankpin bearing is provided with thin-walled steel shells, lined with bearing metal. Lube oil is supplied through ducts in the crosshead and connecting rod.

**Piston**

The piston consists of a piston crown and piston skirt. The piston crown is made of heat-resistant steel. A piston cleaning ring located in the very top of the cylinder liner scrapes off excessive ash and carbon formations on the piston topland.

The piston has four ring grooves which are hard-chrome plated on both the upper and lower surfaces of the grooves. The uppermost piston ring is of the CPR type (Controlled Pressure Relief), whereas the other three piston rings all have an oblique cut. The uppermost piston ring is higher than the others. All four rings are alu-coated on the outer surface for running-in.

The piston skirt is made of cast iron with a bronze band or Mo coating.

**Piston Rod**

The piston rod is of forged steel and is surface-hardened on the running surface for the stuffing box. The piston rod is connected to the crosshead with four bolts. The piston rod has a central bore which, in conjunction with a cooling oil pipe, forms the inlet and outlet for cooling oil.

**Crosshead**

The crosshead is of forged steel and is provided with cast steel guide shoes with white metal on the running surface. The guide shoe is of the low friction type and crosshead bearings of the wide pad design.

The telescopic pipe for oil inlet and the pipe for oil outlet are mounted on the guide shoes.

**Scavenge Air System**

The air intake to the turbocharger takes place directly from the engine room through the turbocharger intake silencer. From the turbocharger, the air is led via the charging air pipe, air cooler and scavenge air receiver to the scavenge ports of the cylinder liners, see Chapter 14. The scavenge air receiver on engines type 65 is of the D-shape design.
Scavenge Air Cooler

For each turbocharger is fitted a scavenge air cooler of the mono-block type designed for seawater cooling, alternatively, a central cooling system with freshwater can be chosen. The working pressure is up to 4.5 bar.

The scavenge air cooler is so designed that the difference between the scavenge air temperature and the water inlet temperature at specified MCR can be kept at about 12 °C.

Auxiliary Blower

The engine is provided with electrically-driven scavenge air blowers integrated in the scavenge air cooler. The suction side of the blowers is connected to the scavenge air space after the air cooler.

Between the air cooler and the scavenge air receiver, non-return valves are fitted which automatically close when the auxiliary blowers supply the air.

The auxiliary blowers will start operating consecutively before the engine is started in order to ensure sufficient scavenge air pressure to obtain a safe start.

Further information is given in Chapter 14.

Exhaust Gas System

From the exhaust valves, exhaust gas is led to the exhaust gas receiver where the fluctuating pressure from the individual cylinders is equalised, and the total volume of gas is led to the turbocharger(s). After the turbocharger(s), the gas is led to the external exhaust pipe system.

Compensators are fitted between the exhaust valves and the receiver, and between the receiver and the turbocharger(s).

The exhaust gas receiver and exhaust pipes are provided with insulation, covered by galvanised steel plating.

A protective grating is installed between the exhaust gas receiver and the turbocharger.

Exhaust Turbocharger

The engines can be fitted with either MAN, ABB or MHI turbochargers. As an option, MAN TCA turbochargers can be delivered with variable nozzle technology that reduces the fuel consumption at part load by controlling the scavenge air pressure.

The turbocharger selection is described in Chapter 3, and the exhaust gas system in Chapter 15.

Reversing

Reversing of the engine is performed electronically and controlled by the Engine Control System, by changing the timing of the fuel injection, the exhaust valve activation and the starting valves.

The Hydraulic Power Supply

The Hydraulic Power Supply (HPS) filters and pressurises the lube oil for use in the hydraulic system. The HPS consists of either mechanically driven (by the engine) main pumps with electrically driven start-up pumps or electrically driven combined main and start-up pumps. The hydraulic pressure varies up to max 300 bar.

The mechanically driven HPS is engine driven and mounted aft for engines with chain drive aft (8 cylinders or less), and at the middle for engines with chain drive located in the middle (9 cylinders or more). An electrically driven HPS is usually mounted aft on the engine.

A combined HPS, mechanically driven with electrically driven start-up/back-up pumps with back-up capacity, is available as an option for engines type 90-60 while basic execution for type 50.
Hydraulic Cylinder Unit

The hydraulic cylinder unit (HCU), one per cylinder, consists of a base plate on which a distributor block is mounted. The distributor block is fitted with a number of accumulators to ensure that the necessary hydraulic oil peak flow is available for the electronically controlled fuel injection.

The distributor block serves as a mechanical support for the hydraulically activated fuel oil pressure booster and the hydraulically activated exhaust valve actuator.

Fuel Oil Pressure Booster and Fuel Oil High Pressure Pipes

The engine is provided with one hydraulically activated fuel oil pressure booster for each cylinder.

Injection of fuel oil (pilot oil) is activated by a multi-way valve (FIVA) while injection of fuel gas is activated by the ELGI valve. Both valves are electronically controlled by the Cylinder Control Unit (CCU) of the Engine Control System.

The fuel oil high-pressure pipes are of the double-wall type with built-in conical support. The pipes are insulated but not heated.

Further information is given in Section 7.00.

Gas Pipes

A chain pipe system is fitted for high-pressure gas distribution to each adapter block. The chain pipes are connected to the gas control block via the adapter block.

Gas pipes are designed with double walls, with the outer shielding pipe designed so as to prevent gas outflow to the machinery spaces in the event of leaking or rupture of the inner gas pipe.

The intervening gas pipe space, including also the space around valves, flanges, etc., is vented by separate mechanical ventilation with a capacity of 30 air changes per hour. Any leakage gas will be led to the ventilated part of the double-wall piping system and will be detected by HC sensors.

The pressure in the intervening space is kept below that of the engine room. The extractor fan motor is placed outside the duct and the machinery space. The ventilation inlet air must be taken from a gas safe area and exhausted to a safe place.

The gas pipes on the engine are designed for and pressure tested at 50% higher pressure than the normal working pressure, and are supported so as to avoid mechanical vibrations. The gas pipes should furthermore be protected against drops of heavy items.

The chain piping to the individual cylinders are flexible enough to cope with the mechanical stress from the thermal expansion of the engine from cold to hot condition. The chain pipes are connected to the gas control blocks by means of adapter blocks.

The gas pipe system is designed so as to avoid excessive gas pressure fluctuations during operation.

The gas pipes are to be connected to an inert gas purging system.

Gas Control Block

The gas control block consists of a square steel block, bolted to the HCU side of the cylinder cover.

The gas control block incorporates a large volume accumulator and is provided with a window/shutdown valve, a purge valve and a blow-off valve. All high-pressure gas sealings lead into spaces that are connected to the double-wall pipe system, for leakage detection.

Minute volumes around the gas injection valves in the cylinder cover are kept under vacuum from the venting air in the double-wall gas pipes.

Internal bores connect the hydraulic oil, sealing oil and the gas to the various valves. A non-return valve is positioned at the gas inlet to the gas accumulator, in order to ensure that gas cannot flow backwards in the system.
An ELGI and ELWI valve and control oil supply are also incorporated in the gas control block.

The gas pressure in the channel between the gas injection valve and the window valve is measured. The pressure measuring is used to monitor the function of and to detect a leaking window valve, gas-injection valve or blow-off valve.

Any larger pressure increase would indicate a severe leakage in the window/shut down valve and a pressure decrease would indicate a severe leakage in the gas injection valve seats or in the blow-off valve. The safety system will detect this and shut down the gas injection.

From the accumulator, the gas passes through a bore in the gas control block to the window valve, which in the gas mode is opening and closing in each cycle by hydraulic oil. From the window/shutdown valve, the gas is led to the gas injection valve via bores in the gas control block and in the cylinder cover. A blow-off valve placed on the gas control block is designed to empty the gas bores during gas standby or gas stop.

A purge valve, also placed on the gas control block, is designed to empty the accumulator when the engine is no longer to operate in the gas mode.

Both hydraulically actuated blow-off and purge valves are also utilised during inert gas purging, all controlled by the gas injection engine control system (ME-GI-ECS).

Fuel Valves, Gas Valves and Starting Air Valve

The cylinder cover is equipped with two or three fuel valves, two or three gas valves, a starting air valve and an indicator cock.

The opening of the fuel valves is controlled by the high pressure fuel oil created by the fuel oil pressure booster, and the valves are closed by a spring.

The opening of the gas valves is controlled by the ELGI valve, which operates on control oil taken from the system oil.

An automatic vent slide allows circulation of fuel oil through the valve and the high pressure pipes when the engine is stopped. The vent slide also prevents the compression chamber from being filled up with fuel oil in the event that the valve spindle sticks. Oil from the vent slide and other drains is led away in a closed system.

Supply of starting air is provided by one solenoid valve per cylinder, controlled by the CCUs of the Engine Control System.

The starting valve is opened by control air, timed by the Engine Control System, and is closed by a spring.

Slow turning before starting is a program incorporated in the basic Engine Control System.

The starting air system is described in detail in Section 13.01.

Exhaust Valve

The exhaust valve consists of the valve housing and the valve spindle. The valve housing is made of cast iron and is arranged for water cooling. The housing is provided with a water cooled bottom piece of steel with a flame hardened seat. The exhaust valve spindle is a DuraSpindle (Nimonic on S80 and engines type 65-50, however) and the housing provided with a spindle guide.

The exhaust valve is tightened to the cylinder cover with studs and nuts. The exhaust valve is opened hydraulically by the electronic valve activation system and is closed by means of air pressure.

The operation of the exhaust valve is controlled by the FIVA valve, which also activates the fuel injection.

In operation, the valve spindle slowly rotates, driven by the exhaust gas acting on small vanes fixed to the spindle.
Sealing of the exhaust valve spindle guide is provided by means of Controlled Oil Level (COL), an oil bath in the bottom of the air cylinder, above the sealing ring. This oil bath lubricates the exhaust valve spindle guide and sealing ring as well.

**Indicator Cock**

The engine is fitted with an indicator cock to which the PMI pressure transducer is connected.

**MAN B&W Alpha Cylinder Lubrication**

The electronically controlled MAN B&W Alpha cylinder lubrication system is applied to the ME engines, and controlled by the ME Engine Control System.

The main advantages of the MAN B&W Alpha cylinder lubrication system, compared with the conventional mechanical lubricator, are:

- Improved injection timing
- Increased dosage flexibility
- Constant injection pressure
- Improved oil distribution in the cylinder liner
- Possibility for prelubrication before starting.

More details about the cylinder lubrication system can be found in Chapter 9.

**Piping Arrangements**

The engine is delivered with piping arrangements for:

- Fuel oil
- High pressure gas supply
- Heating of fuel oil
- Lubricating oil, piston cooling oil, hydraulic oil and sealing oil for gas valves
- Cylinder lubricating oil
- Cooling water to scavenge air cooler
- Jacket and turbocharger cooling water
- Cleaning of turbocharger
- Fire extinguishing in scavenge air space
- Starting air
- Control air
- Oil mist detector (required only for make Schaller Automation)
- Various drain pipes.

All piping arrangements are made of steel piping, except the control air and steam heating of fuel pipes, which are made of copper.

The pipes are provided with sockets for local instruments, alarm and safety equipment and, furthermore, with a number of sockets for supplementary signal equipment. Chapter 18 deals with the instrumentation.

**Gallery Arrangement**

The engine is provided with gallery brackets, stanchions, railings and platforms (exclusive of ladders). The brackets are placed at such a height as to provide the best possible overhauling and inspection conditions.

Some main pipes of the engine are suspended from the gallery brackets, and the topmost gallery platform on the manoeuvring side is provided with overhauling holes for the pistons.

The engine is prepared for top bracings on the exhaust side, or on the manoeuvring side.
Engine Cross Section of L70ME-C8
Engine Layout and Load Diagrams

Introduction

The effective power ‘P’ of a diesel engine is proportional to the mean effective pressure $p_e$ and engine speed ‘n’, i.e. when using ‘c’ as a constant:

$$ P = c \times p_e \times n $$

so, for constant mep, the power is proportional to the speed:

$$ P = c \times n^i $$

(for constant mep)

When running with a Fixed Pitch Propeller (FPP), the power may be expressed according to the propeller law as:

$$ P = c \times n^3 $$ (propeller law)

Thus, for the above examples, the power P may be expressed as a power function of the speed ‘n’ to the power of ‘i’, i.e.:

$$ P = c \times n^i $$

Fig. 2.01.01 shows the relationship for the linear functions, $y = ax + b$, using linear scales.

The power functions $P = c \times n^i$ will be linear functions when using logarithmic scales:

$$ \log (P) = i \times \log (n) + \log (c) $$

Thus, propeller curves will be parallel to lines having the inclination $i = 3$, and lines with constant mep will be parallel to lines with the inclination $i = 1$.

Therefore, in the Layout Diagrams and Load Diagrams for diesel engines, logarithmic scales are used, giving simple diagrams with straight lines.

Propulsion and Engine Running Points

Propeller curve

The relation between power and propeller speed for a fixed pitch propeller is as mentioned above described by means of the propeller law, i.e. the third power curve:

$$ P = c \times n^3 $$, in which:

$P = $ engine power for propulsion

$n = $ propeller speed

$c = $ constant

Propeller design point

Normally, estimates of the necessary propeller power and speed are based on theoretical calculations for loaded ship, and often experimental tank tests, both assuming optimum operating conditions, i.e. a clean hull and good weather. The combination of speed and power obtained may be called the ship’s propeller design point (PD),

---

*Fig. 2.01.02: Power function curves in logarithmic scales*

---
placed on the light running propeller curve 6. See below figure. On the other hand, some shipyards, and/or propeller manufacturers sometimes use a propeller design point (PD) that incorporates all or part of the so-called sea margin described below.

The so-called sea margin, which is traditionally about 15% of the propeller design (PD) power.

**Engine layout (heavy propeller)**

When determining the necessary engine layout speed that considers the influence of a heavy running propeller for operating at high extra ship resistance, it is (compared to line 6) recommended to choose a heavier propeller line 2. The propeller curve for clean hull and calm weather line 6 may then be said to represent a ‘light running’ (LR) propeller.

Compared to the heavy engine layout line 2, we recommend using a light running of 3.0-7.0% for design of the propeller.

**Engine margin**

Besides the sea margin, a so-called ‘engine margin’ of some 10% or 15% is frequently added. The corresponding point is called the ‘specified MCR for propulsion’ (MP), and refers to the fact that the power for point SP is 10% or 15% lower than for point MP.

Point MP is identical to the engine’s specified MCR point (M) unless a main engine driven shaft generator is installed. In such a case, the extra power demand of the shaft generator must also be considered.

**Constant ship speed lines**

The constant ship speed lines $\propto$, are shown at the very top of the figure. They indicate the power required at various propeller speeds in order to keep the same ship speed. It is assumed that, for each ship speed, the optimum propeller diameter is used, taking into consideration the total propulsion efficiency. See definition of $\propto$ in Section 2.02.

**Note:**

Light/heavy running, fouling and sea margin are overlapping terms. Light/heavy running of the propeller refers to hull and propeller deterioration and heavy weather, whereas sea margin i.e. extra power to the propeller, refers to the influence of the wind and the sea. However, the degree of light running must be decided upon experience from the actual trade and hull design of the vessel.
Propeller diameter and pitch, influence on the optimum propeller speed

In general, the larger the propeller diameter \( D \), the lower is the optimum propeller speed and the \( kW \) required for a certain design draught and ship speed, see curve D in the figure below.

The maximum possible propeller diameter depends on the given design draught of the ship, and the clearance needed between the propeller and the aft body hull and the keel.

The example shown in the figure is an 80,000 dwt crude oil tanker with a design draught of 12.2 m and a design speed of 14.5 knots.

When the optimum propeller diameter \( D \) is increased from 6.6 m to 7.2 m, the power demand is reduced from about 9,290 kW to 8,820 kW, and the optimum propeller speed is reduced from 120 r/min to 100 r/min, corresponding to the constant ship speed coefficient \( \propto = 0.28 \) (see definition of \( \propto \) in Section 2.02, page 2).

Once an optimum propeller diameter of maximum 7.2 m has been chosen, the corresponding optimum pitch in this point is given for the design speed of 14.5 knots, i.e. \( P/D = 0.70 \).

However, if the optimum propeller speed of 100 r/min does not suit the preferred / selected main engine speed, a change of pitch away from optimum will only cause a relatively small extra power demand, keeping the same maximum propeller diameter:

- going from 100 to 110 r/min (\( P/D = 0.62 \)) requires 8,900 kW i.e. an extra power demand of 80 kW.
- going from 100 to 91 r/min (\( P/D = 0.81 \)) requires 8,900 kW i.e. an extra power demand of 80 kW.

In both cases the extra power demand is only of 0.9%, and the corresponding ‘equal speed curves’ are \( \propto = +0.1 \) and \( \propto = -0.1 \), respectively, so there is a certain interval of propeller speeds in which the ‘power penalty’ is very limited.

Fig. 2.02.01: Influence of diameter and pitch on propeller design
**Constant ship speed lines**

The constant ship speed lines \( \propto \), are shown at the very top of Fig. 2.02.02. These lines indicate the power required at various propeller speeds to keep the same ship speed provided that the optimum propeller diameter with an optimum pitch diameter ratio is used at any given speed, taking into consideration the total propulsion efficiency.

Normally, the following relation between necessary power and propeller speed can be assumed:

\[
P_2 = P_1 \times \left( \frac{n_2}{n_1} \right)^\propto
\]

where:

- \( P \) = Propulsion power
- \( n \) = Propeller speed, and
- \( \propto \) = the constant ship speed coefficient.

For any combination of power and speed, each point on lines parallel to the ship speed lines gives the same ship speed.

When such a constant ship speed line is drawn into the layout diagram through a specified propulsion MCR point 'MP1', selected in the layout area and parallel to one of the \( \propto \)-lines, another specified propulsion MCR point 'MP2' upon this line can be chosen to give the ship the same speed for the new combination of engine power and speed.

Fig. 2.02.02 shows an example of the required power speed point MP1, through which a constant ship speed curve \( \propto = 0.25 \) is drawn, obtaining point MP2 with a lower engine power and a lower engine speed but achieving the same ship speed.

Provided the optimum pitch/diameter ratio is used for a given propeller diameter the following data applies when changing the propeller diameter:

- for general cargo, bulk carriers and tankers \( \propto = 0.25 - 0.30 \)
- and for reefers and container vessels \( \propto = 0.15 - 0.25 \)

When changing the propeller speed by changing the pitch diameter ratio, the \( \propto \) constant will be different, see above.

*Fig. 2.02.02: Layout diagram and constant ship speed lines*
Fig. 2.03.01 Layout diagram sizes

See also Section 2.05 for actual project.
**Engine Layout and Load Diagram**

**Engine Layout Diagram**

An engine’s layout diagram is limited by two constant mean effective pressure (mep) lines \( L_1 - L_3 \) and \( L_1 - L_4 \), and by two constant engine speed lines \( L_2 - L_3 \) and \( L_2 - L_4 \). The \( L_1 \) point refers to the engine’s nominal maximum continuous rating, see Fig. 2.04.01.

Within the layout area there is full freedom to select the engine’s specified SMCR point \( M \) which suits the demand for propeller power and speed for the ship.

On the horizontal axis the engine speed and on the vertical axis the engine power are shown on percentage scales. The scales are logarithmic which means that, in this diagram, power function curves like propeller curves (3rd power), constant mean effective pressure curves (1st power) and constant ship speed curves (0.15 to 0.30 power) are straight lines.

**Specified maximum continuous rating (M)**

Based on the propulsion and engine running points, as previously found, the layout diagram of a relevant main engine may be drawn-in. The SMCR point \( M \) must be inside the limitation lines of the layout diagram; if it is not, the propeller speed will have to be changed or another main engine type must be chosen. The selected SMCR has an influence on the turbocharger and its matching and the compression ratio.

For ME and ME-C/-GI engines, the timing of the fuel injection and the exhaust valve activation are electronically optimised over a wide operating range of the engine.

For ME-B engines, only the fuel injection (and not the exhaust valve activation) is electronically controlled over a wide operating range of the engine.

For a standard high-load optimised engine, the lowest specific fuel oil consumption for the ME and ME-C engines is obtained at 70% and for MC/MC-C/ME-B engines at 80% of the SMCR point \( M \).

For ME-C-GI engines operating on LNG, a further SFOC reduction can be obtained.

**Continuous service rating (S)**

The continuous service rating is the power needed in service – including the specified sea margin and heavy/light running factor of the propeller – at which the engine is to operate, and point \( S \) is identical to the service propulsion point (SP) unless a main engine driven shaft generator is installed.

![Fig. 2.04.01: Engine layout diagram](image-url)
Definitions

The engine's load diagram, see Fig. 2.04.02, defines the power and speed limits for continuous as well as overload operation of an installed engine having a specified MCR point M that confirms the ship's specification.

The service points of the installed engine incorporate the engine power required for ship propulsion and shaft generator, if installed.

Operating curves and limits for continuous operation

The continuous service range is limited by four lines: 4, 5, 7 and 3 (9), see Fig. 2.04.02. The propeller curves, line 1, 2 and 6 in the load diagram are also described below.

Line 1:
Propeller curve through specified MCR (M), engine layout curve.

Line 2:
Propeller curve, fouled hull and heavy weather – heavy running.

Line 3 and line 9:
Line 3 represents the maximum acceptable speed for continuous operation, i.e. 105% of M.

During trial conditions the maximum speed may be extended to 107% of M, see line 9.

The above limits may in general be extended to 105% and during trial conditions to 107% of the nominal L1 speed of the engine, provided the torsional vibration conditions permit.

The overspeed set-point is 109% of the speed in M, however, it may be moved to 109% of the nominal speed in L1, provided that torsional vibration conditions permit.

Running at low load above 100% of the nominal L1 speed of the engine is, however, to be avoided for extended periods. Only plants with controllable pitch propellers can reach this light running area.

Line 4:
Represents the limit at which an ample air supply is available for combustion and imposes a limitation on the maximum combination of torque and speed.

Fig. 2.04.02: Standard engine load diagram
**Recommendation**

Continuous operation without limitations is allowed only within the area limited by lines 4, 5, 7 and 3 of the load diagram, except on low load operation for CP propeller plants mentioned in the previous section.

The area between lines 4 and 1 is available for operation in shallow waters, heavy weather and during acceleration, i.e. for non-steady operation without any strict time limitation.

After some time in operation, the ship's hull and propeller will be fouled, resulting in heavier running of the propeller, i.e. the propeller curve will move to the left from line 6 towards line 2, and extra power is required for propulsion in order to keep the ship's speed.

In calm weather conditions, the extent of heavy running of the propeller will indicate the need for cleaning the hull and possibly polishing the propeller.

Once the specified MCR has been chosen, the capacities of the auxiliary equipment will be adapted to the specified MCR, and the turbocharger specification and the compression ratio will be selected.

If the specified MCR is to be increased later on, this may involve a change of the pump and cooler capacities, change of the fuel valve nozzles, adjusting of the cylinder liner cooling, as well as rematching of the turbocharger or even a change to a larger size of turbocharger. In some cases it can also require larger dimensions of the piping systems.

It is therefore of utmost importance to consider, already at the project stage, if the specification should be prepared for a later power increase. This is to be indicated in the Extent of Delivery.

---

**Line 5:**
Represents the maximum mean effective pressure level (mep), which can be accepted for continuous operation.

**Line 6:**
Propeller curve, clean hull and calm weather – light running, used for propeller layout/design.

**Line 7:**
Represents the maximum power for continuous operation.

**Limits for overload operation**

The overload service range is limited as follows:

**Line 8:**
Represents the overload operation limitations.

The area between lines 4, 5, 7 and the heavy dashed line 8 is available for overload running for limited periods only (1 hour per 12 hours).

**Line 9:**
Speed limit at sea trial.

**Limits for low load running**

As the fuel injection for ME engines is automatically controlled over the entire power range, the engine is able to operate down to around 15-20% of the nominal Lₙ speed, whereas for MC/MC-C engines it is around 20-25% (electronic governor).
Extended load diagram for ships operating in extreme heavy running conditions

When a ship with fixed pitch propeller is operating in normal sea service, it will in general be operating in the hatched area around the design propeller curve 6, as shown on the standard load diagram in Fig. 2.04.02.

Sometimes, when operating in heavy weather, the fixed pitch propeller performance will be more heavy running, i.e. for equal power absorption of the propeller, the propeller speed will be lower and the propeller curve will move to the left.

As the low speed main engines are directly coupled to the propeller, the engine has to follow the propeller performance, i.e. also in heavy running propeller situations. For this type of operation, there is normally enough margin in the load area between line 6 and the normal torque/speed limitation line 4, see Fig. 2.04.02. To the left of line 4 in torque-rich operation, the engine will lack air from the turbocharger to the combustion process, i.e. the heat load limits may be exceeded and bearing loads might also become too high.

For some special ships and operating conditions, it would be an advantage - when occasionally needed - to be able to operate the propeller/main engine as much as possible to the left of line 6, but inside the torque/speed limit, line 4.

Such cases could be for:

- ships sailing in areas with very heavy weather
- ships operating in ice
- ships with two fixed pitch propellers/two main engines, where one propeller/one engine is declutched for one or the other reason.

The increase of the operating speed range between line 6 and line 4 of the standard load diagram, see Fig. 2.04.02, may be carried out as shown for the following engine Example with an extended load diagram for speed derated engine with increased light running.

Extended load diagram for speed derated engines with increased light running

The maximum speed limit (line 3) of the engines is 105% of the SMCR (Specified Maximum Continuous Rating) speed, as shown in Fig. 2.04.02.

However, for speed and, thereby, power derated engines it is possible to extend the maximum speed limit to 105% of the engine's nominal MCR speed, line 3', but only provided that the torsional vibration conditions permit this. Thus, the shafting, with regard to torsional vibrations, has to be approved by the classification society in question, based on the extended maximum speed limit.

When choosing an increased light running to be used for the design of the propeller, the load diagram area may be extended from line 3 to line 3', as shown in Fig. 2.04.03, and the propeller/main engine operating curve 6 may have a correspondingly increased heavy running margin before exceeding the torque/speed limit, line 4.

A corresponding slight reduction of the propeller efficiency may be the result, due to the higher propeller design speed used.
Examples of the use of the Load Diagram

In the following are some examples illustrating the flexibility of the layout and load diagrams.

- Example 1 shows how to place the load diagram for an engine without shaft generator coupled to a fixed pitch propeller.

- Example 2 shows the same layout for an engine with fixed pitch propeller (example 1), but with a shaft generator.

- Example 3 is a special case of example 2, where the specified MCR is placed near the top of the layout diagram. In this case the shaft generator is cut off, and the GenSets used when the engine runs at specified MCR. This makes it possible to choose a smaller engine with a lower power output, and with changed specified MCR.

- Example 4 shows diagrams for an engine coupled to a controllable pitch propeller, with or without a shaft generator, constant speed or combinator curve operation.

For a specific project, the layout diagram for actual project shown later in this chapter may be used for construction of the actual load diagram.
Example 1: Normal running conditions.
Engine coupled to fixed pitch propeller (FPP) and without shaft generator

### Layout diagram

**Power, % of L₁**

- 100%
- 75%
- 50%
- 25%
- 10%

**Engine speed, % of L₁**

- 100%

Propulsion and engine service curve for fouled hull and heavy weather

**M** Specified MCR of engine

**S** Continuous service rating of engine

**MP** Specified MCR for propulsion

**SP** Continuous service rating of propulsion

The specified MCR (M) and its propeller curve 1 will normally be selected on the engine service curve 2.

Once point M has been selected in the layout diagram, the load diagram can be drawn, as shown in the figure, and hence the actual load limitation lines of the diesel engine may be found by using the inclinations from the construction lines and the %-figures stated.

*Fig. 2.04.04: Normal running conditions. Engine coupled to a fixed pitch propeller (FPP) and without a shaft generator*
Example 2: Normal running conditions.
Engine coupled to fixed pitch propeller (FPP) and with shaft generator

In example 2 a shaft generator (SG) is installed, and therefore the service power of the engine also has to incorporate the extra shaft power required for the shaft generator’s electrical power production.

In the figure, the engine service curve shown for heavy running incorporates this extra power.

The specified MCR M will then be chosen and the load diagram can be drawn as shown in the figure.

Fig. 2.04.06: Normal running conditions. Engine coupled to a fixed pitch propeller (FPP) and with a shaft generator
Example 3: Special running conditions.
Engine coupled to fixed pitch propeller (FPP) and with shaft generator

**Layout diagram**

- M: Specified MCR of engine
- S: Continuous service rating of engine
- MP: Specified MCR for propulsion
- SP: Continuous service rating of propulsion
- SG: Shaft generator

Also for this special case in example 3, a shaft generator is installed but, compared to example 2, this case has a specified MCR for propulsion, MP, placed at the top of the layout diagram.

This involves that the intended specified MCR of the engine M' will be placed outside the top of the layout diagram.

One solution could be to choose a larger diesel engine with an extra cylinder, but another and cheaper solution is to reduce the electrical power production of the shaft generator when running in the upper propulsion power range.

In choosing the latter solution, the required specified MCR power can be reduced from point M' to point M as shown. Therefore, when running in the upper propulsion power range, a diesel generator has to take over all or part of the electrical power production.

However, such a situation will seldom occur, as ships are rather infrequently running in the upper propulsion power range.

Point M, having the highest possible power, is then found at the intersection of line L₁ − L₄ with line 1 and the corresponding load diagram is drawn.

**Load diagram**

- Line 1: Propeller curve through point S
- Point M: Intersection between line 1 and line L₁ – L₃

**Fig. 2.04.07: Special running conditions. Engine coupled to a fixed pitch propeller (FPP) and with a shaft generator**
Example 4: Engine coupled to controllable pitch propeller (CPP) with or without shaft generator

**Layout diagram - with shaft generator**

The hatched area shows the recommended speed range between 100% and 96.7% of the specified MCR speed for an engine with shaft generator running at constant speed.

The service point S can be located at any point within the hatched area.

The procedure shown in examples 2 and 3 for engines with FPP can also be applied here for engines with CPP running with a combinator curve.

**Load diagram**

Therefore, when the engine’s specified MCR point (M) has been chosen including engine margin, sea margin and the power for a shaft generator, if installed, point M may be used in the load diagram, which can then be drawn.

The position of the combinator curve ensures the maximum load range within the permitted speed range for engine operation, and it still leaves a reasonable margin to the limit indicated by curves 4 and 5.

**Layout diagram - without shaft generator**

If a controllable pitch propeller (CPP) is applied, the combinator curve (of the propeller) will normally be selected for loaded ship including sea margin.

The combinator curve may for a given propeller speed have a given propeller pitch, and this may be heavy running in heavy weather like for a fixed pitch propeller.

Therefore it is recommended to use a light running combinator curve (the dotted curve which includes the sea power margin) as shown in the figure to obtain an increased operation margin of the diesel engine in heavy weather to the limit indicated by curves 4 and 5.

---

**Fig. 2.04.08: Engine with Controllable Pitch Propeller (CPP), with or without a shaft generator**

M  Specified MCR of engine
S  Continuous service rating of engine

The hatched area shows the recommended speed range between 100% and 96.7% of the specified MCR speed for an engine with shaft generator running at constant speed.

The service point S can be located at any point within the hatched area.

The procedure shown in examples 2 and 3 for engines with FPP can also be applied here for engines with CPP running with a combinator curve.

The position of the combinator curve ensures the maximum load range within the permitted speed range for engine operation, and it still leaves a reasonable margin to the limit indicated by curves 4 and 5.

---

**Combinator curve for loaded ship and incl. sea margin**

**Recommended range for shaft generator operation with constant speed**
Diagram for actual project

This figure contains a layout diagram that can be used for constructing the load diagram for an actual project, using the %-figures stated and the inclinations of the lines.

Fig. 2.05.01: Construction of layout diagram
Specific Fuel Oil Consumption, ME versus MC engines

This section is not applicable to -GI engines
SFOC for High Efficiency Turbochargers

All -GI engines are as standard fitted with high efficiency turbochargers, option: 4 59 104, and can as standard only be high load optimised.

The high efficiency turbocharger is applied to the engine in the basic design with the view to obtaining the lowest possible related Specific Fuel Oil Consumption (SFOC) values, see example in Fig. 2.07.01.

For standard high load optimised ME/ME-C engines operating on fuel oil the lowest SFOC at part-load running may be obtained at 70% of the specified MCR. However, for -GI engines operating on gas fuel the SFOC may be further reduced on part load operation.

For more information visit: www.marine.man.eu → 'Two-Stroke' → 'Turbocharger Selection'.

![SFOC graph](image-url)
SFOC reference conditions and guarantee

SFOC at reference conditions

The SFOC is given in g/kWh based on the reference ambient conditions stated in ISO 3046-1:2002(E) and ISO 15550:2002(E):

- 1,000 mbar ambient air pressure
- 25 °C ambient air temperature
- 25 °C scavenge air coolant temperature

and is related to a fuel oil with a lower calorific value of 42,700 kJ/kg (-10,200 kcal/kg).

Any discrepancies between g/kWh and g/BHP/h are due to the rounding of numbers for the latter.

For lower calorific values and for ambient conditions that are different from the ISO reference conditions, the SFOC will be adjusted according to the conversion factors in the table below.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition change</th>
<th>With ( p_{\text{max}} ) adjusted</th>
<th>Without ( p_{\text{max}} ) adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scav. air coolant temperature</td>
<td>per 10 °C rise</td>
<td>+ 0.60%</td>
<td>+ 0.41%</td>
</tr>
<tr>
<td>Blower inlet temperature</td>
<td>per 10 °C rise</td>
<td>+ 0.20%</td>
<td>+ 0.71%</td>
</tr>
<tr>
<td>Blower inlet pressure</td>
<td>per 10 mbar rise</td>
<td>- 0.02%</td>
<td>- 0.05%</td>
</tr>
<tr>
<td>Fuel oil lower calorific value</td>
<td>rise 1%</td>
<td>- 1.00%</td>
<td>- 1.00%</td>
</tr>
<tr>
<td></td>
<td>(42,700 kJ/kg)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

With for instance 1 °C increase of the scavenge air coolant temperature, a corresponding 1 °C increase of the scavenge air temperature will occur and involves an SFOC increase of 0.06% if \( p_{\text{max}} \) is adjusted to the same value.

SFOC guarantee

The Energy Efficiency Design Index (EEDI) has increased the focus on part-load SFOC. We therefore offer the option of selecting the SFOC guarantee at a load point in the range between 50% and 100%, EoD: 4 02 002.

All engine design criteria, e.g. heat load, bearing load and mechanical stresses on the construction are defined at 100% load independent of the guarantee point selected. This means that turbocharger matching, engine adjustment and engine load calibration must also be performed at 100% independent of guarantee point. At 100% load, the SFOC tolerance is 5%.

When choosing an SFOC guarantee below 100%, the tolerances, which were previously compensated for by the matching, adjustment and calibration at 100%, will affect engine running at the lower SFOC guarantee load point. This includes tolerances on measurement equipment, engine process control and turbocharger performance.

Consequently, SFOC guarantee tolerances are:

- 100% – 85%: 5% tolerance
- 84% – 65%: 6% tolerance
- 64% – 50%: 7% tolerance

Please note that the SFOC guarantee can only be given in one (1) load point.

Recommended cooling water temperature during normal operation

In general, it is recommended to operate the main engine with the lowest possible cooling water temperature to the air coolers, as this will reduce the fuel consumption of the engine, i.e. the engine performance will be improved.

However, shipyards often specify a constant (maximum) central cooling water temperature of 36 °C, not only for tropical ambient temperature conditions, but also for lower ambient temperature conditions. The purpose is probably to reduce the electric power consumption of the cooling water pumps and/or to reduce water condensation in the air coolers.

Thus, when operating with 36 °C cooling water instead of for example 10 °C (to the air coolers), the specific fuel oil consumption will increase by approx. 2 g/kWh.
Examples of Graphic Calculation of related SFOC for -GI engines

The following diagrams a (a1, a2 and a3), b (b1 and b2) and c (c1 and c2), valid for fixed pitch propeller (b) and constant speed (c), respectively, show the reduction of related SFOC in g/kWh, relative to the SFOC of fuel oil operated engine for the nominal MCR L1 rating.

**Mep influence**

The solid mep lines in b1 and c1 show the SFOC reduction, and are valid at 100%, 70% and 50% of SMCR point (M), and refer to derated engines operation on fuel oil.

Point M is drawn into the above-mentioned Diagrams b1 or c1. A straight line along the constant mep curves (parallel to L1-L3) is drawn through point M. The intersections of this line and the curves indicate the reduction in specific fuel oil consumption at 100, 70 and 50% of the SMCR point, related to the SFOC stated for the nominal MCR L1 rating, when operating on fuel oil.

**Rpm influence**

The straight vertical lines in b2 and c2 along the engine speed (rpm) lines show the extra SFOC reductions, and are valid at 100%/90%/80%, 75%, 65% and 50%/35% of SMCR point (M), and refer to -GI engines operating on LNG.

Point M is already drawn into the above-mentioned diagram b2 or c2. A straight vertical line along the constant rpm curves (parallel to L1-L2) is drawn through point M. The intersections of this line and the curves indicate the extra SFOC reduction at 100%/90%/80%, 75%, 65% and 50%/35% of SMCR, for -GI engines operating on LNG, compared to the SFOC valid for engine operating on fuel oil.

An example of the calculated SFOC curves are shown in Diagram a (a1, a2 and a3), and is valid for an engine with fixed pitch propeller, see Fig. 2.10.01.
### Related equivalent SFOC Calculations for 6L70ME-C8.5-GI-TII

Valid for standard high-load optimised engine

<table>
<thead>
<tr>
<th>Engine</th>
<th>kW</th>
<th>r/min</th>
<th>g/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>5L70ME-C8.5-GI-TII</td>
<td>16,350</td>
<td></td>
<td>108</td>
</tr>
<tr>
<td>6L70ME-C8.5-GI-TII</td>
<td>19,620</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7L70ME-C8.5-GI-TII</td>
<td>22,890</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8L70ME-C8.5-GI-TII</td>
<td>26,160</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Data SMCR point (M):**

- Power: 100% of (M) kW
- Speed: 100% of (M) r/min
- SFOC found, fuel oil operation g/kWh
- SFOC found, gas fuel operation g/kWh

**Diagram a2**

Part Load SFOC corrections for gas fuel operation

<table>
<thead>
<tr>
<th>∆SFOC g/kWh</th>
<th>SFOC g/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>170</td>
</tr>
<tr>
<td>-1</td>
<td>165</td>
</tr>
<tr>
<td>-2</td>
<td>160</td>
</tr>
<tr>
<td>-3</td>
<td>155</td>
</tr>
<tr>
<td>-4</td>
<td>150</td>
</tr>
<tr>
<td>-5</td>
<td>145</td>
</tr>
<tr>
<td>-6</td>
<td>140</td>
</tr>
<tr>
<td>-7</td>
<td>135</td>
</tr>
<tr>
<td>-8</td>
<td>130</td>
</tr>
<tr>
<td>-9</td>
<td>125</td>
</tr>
<tr>
<td>-10</td>
<td>120</td>
</tr>
<tr>
<td>-11</td>
<td>115</td>
</tr>
<tr>
<td>-12</td>
<td>110</td>
</tr>
<tr>
<td>-13</td>
<td>105</td>
</tr>
<tr>
<td>-14</td>
<td>100</td>
</tr>
<tr>
<td>-15</td>
<td>95</td>
</tr>
<tr>
<td>-16</td>
<td>90</td>
</tr>
</tbody>
</table>

**Diagram a1 and a3**

Nominal SFOC for fuel oil operation

Part Load SFOC curve for fuel oil and gas fuel operation, respectively

**Nominal SFOC for fuel oil operation**

<table>
<thead>
<tr>
<th>∆SFOC g/kWh</th>
<th>SFOC g/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>170</td>
</tr>
<tr>
<td>+1</td>
<td>165</td>
</tr>
<tr>
<td>+2</td>
<td>160</td>
</tr>
<tr>
<td>+3</td>
<td>155</td>
</tr>
<tr>
<td>+4</td>
<td>150</td>
</tr>
<tr>
<td>+5</td>
<td>145</td>
</tr>
<tr>
<td>+6</td>
<td>140</td>
</tr>
<tr>
<td>+7</td>
<td>135</td>
</tr>
<tr>
<td>+8</td>
<td>130</td>
</tr>
<tr>
<td>+9</td>
<td>125</td>
</tr>
<tr>
<td>+10</td>
<td>120</td>
</tr>
<tr>
<td>+11</td>
<td>115</td>
</tr>
<tr>
<td>+12</td>
<td>110</td>
</tr>
<tr>
<td>+13</td>
<td>105</td>
</tr>
<tr>
<td>+14</td>
<td>100</td>
</tr>
<tr>
<td>+15</td>
<td>95</td>
</tr>
<tr>
<td>+16</td>
<td>90</td>
</tr>
</tbody>
</table>

% of SMCR

**Diagram a2**

178 64 17-8.0

**Diagram a1 and a3**

178 64 10-8.0

---

**Fig. 2.09.01**
Related equivalent SFOC for 6L70ME-C8.5-GI-TII with fixed pitch propeller

Diagram b

Extra SFOC corrections for gas fuel operation

Fig. 2.09.02
Related equivalent SFOC for 6L70ME-C8.5-GI-TII with constant speed

Diagram c1

Basic SFOC (reduction) for fuel oil operation in g/kWh relative to the nominal in L1

Diagram c2

Extra SFOC corrections for gas fuel operation

Fig. 2.09.03
Related equivalent SFOC calculations, example

Valid for standard high-load optimised engine

<table>
<thead>
<tr>
<th>Data at nominal MCR (L₁): 6L70ME-C8.5-GI-TII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power 100%</td>
</tr>
<tr>
<td>Speed 100%</td>
</tr>
</tbody>
</table>

Nominal SFOC, fuel oil operation:
• High efficiency turbocharger 170.0 g/kWh

Example of specified MCR = M

<table>
<thead>
<tr>
<th>Power</th>
<th>17,658 kW (90.0% L₁)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>102.6 r/min (95.0% L₁)</td>
</tr>
<tr>
<td>Turbocharger type</td>
<td>high efficiency</td>
</tr>
<tr>
<td>SFOC found in M:</td>
<td></td>
</tr>
<tr>
<td>• Fuel oil operation</td>
<td>168.4 g/kWh</td>
</tr>
<tr>
<td>• Gas fuel operation</td>
<td>167.5 g/kWh</td>
</tr>
</tbody>
</table>

The SMCR point M used in the above example for the SFOC calculations:

M = 90.0% L₁, power and 95.0% L₁, speed
Fig. 2.10.01a: Example of SFOC for derated 6L70ME-C8.5-GI-TII with fixed pitch propeller and high efficiency turbocharger
Basic SFOC reduction found for fuel oil operation.

The reductions, see diagram b1, in g/kWh compared to SFOC in L1:

<table>
<thead>
<tr>
<th>Part load points</th>
<th>ΔSFOC g/kWh (a1)</th>
<th>SFOC g/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 100% M</td>
<td>-1.6</td>
<td>168.4</td>
</tr>
<tr>
<td>2  70% M</td>
<td>-5.6</td>
<td>164.4</td>
</tr>
<tr>
<td>3  50% M</td>
<td>-2.5</td>
<td>167.5</td>
</tr>
</tbody>
</table>

Extra Related equivalent SFOC corrections found for gas fuel operation, see diagram b2.

<table>
<thead>
<tr>
<th>Part load points</th>
<th>ΔSFOC g/kWh (a2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 100% M</td>
<td>-1.0</td>
</tr>
<tr>
<td>A2  90% M</td>
<td>-1.0</td>
</tr>
<tr>
<td>A3  80% M</td>
<td>-1.0</td>
</tr>
<tr>
<td>B   75% M</td>
<td>-3.5</td>
</tr>
<tr>
<td>C   65% M</td>
<td>-4.2</td>
</tr>
<tr>
<td>D1  50% M</td>
<td>-5.2</td>
</tr>
<tr>
<td>D2  35% M</td>
<td>-5.2</td>
</tr>
</tbody>
</table>

Fig. 2.10.01b: Example of SFOC for derated 6L70ME-C8.5-GI-TII with fixed pitch propeller and high efficiency turbocharger
The total SFOC reductions found, see diagram a1 and a2, in g/kWh compared to SFOC in L1:

<table>
<thead>
<tr>
<th>Part load points</th>
<th>ΔSFOC  g/kWh (a1)</th>
<th>SFOC (fuel oil) g/kWh</th>
<th>ΔSFOC  g/kWh (a2)</th>
<th>SFOC (gas fuel) g/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  100% M</td>
<td>-1.6</td>
<td>168.4</td>
<td>-1.0</td>
<td>167.4</td>
</tr>
<tr>
<td>2  70% M</td>
<td>-5.6</td>
<td>164.4</td>
<td>-3.9</td>
<td>160.5</td>
</tr>
<tr>
<td>3  50% M</td>
<td>-2.5</td>
<td>167.5</td>
<td>-5.2</td>
<td>162.3</td>
</tr>
</tbody>
</table>

**Diagram a3**

- Fuel oil: a1
- Gas fuel: a1+a2
- Nominal SFOC for fuel oil operation

---

*Fig. 2.10.01c: Example of Related equivalent SFOC for derated 6L70ME-C8.5-GI-TII with fixed pitch propeller and high efficiency turbocharger*
Fuel Consumption at an Arbitrary Load

Once the specified MCR (M) of the engine has been chosen, the specific fuel oil consumption at an arbitrary point S₁, S₂ or S₃ can be estimated based on the SFOC at point ‘1’ and ‘2’.

These SFOC values can be calculated by using the graphs for the relevant engine type for the propeller curve I and for the constant speed curve II, giving the SFOC at points 1 and 2, respectively.

Next the SFOC for point S₁ can be calculated as an interpolation between the SFOC in points ‘1’ and ‘2’, and for point S₃ as an extrapolation.

The SFOC curve through points S₂, on the left of point 1, is symmetrical about point 1, i.e. at speeds lower than that of point 1, the SFOC will also increase.

The above-mentioned method provides only an approximate value. A more precise indication of the expected SFOC at any load can be calculated by using our computer program. This is a service which is available to our customers on request.

Fig. 2.11.01: SFOC at an arbitrary load
Turbocharger Selection & Exhaust Gas By-pass
Turbocharger Selection

Updated turbocharger data based on the latest information from the turbocharger makers are available from the Turbocharger Selection program on www.marine.man.eu → 'Two-Stroke' → 'Turbocharger Selection'.

The data specified in the printed edition are valid at the time of publishing.

The MC/ME engines are designed for the application of either MAN, ABB or Mitsubishi (MHI) turbochargers.

The turbocharger choice is made with a view to obtaining the lowest possible Specific Fuel Oil Consumption (SFOC) values at the nominal MCR by applying high efficiency turbochargers.

The engines are, as standard, equipped with as few turbochargers as possible, see Table 3.01.01.

One more turbocharger can be applied, than the number stated in the tables, if this is desirable due to space requirements, or for other reasons. Additional costs are to be expected.

However, we recommend the 'Turbocharger Selection' program on the Internet, which can be used to identify a list of applicable turbochargers for a specific engine layout.

For information about turbocharger arrangement and cleaning systems, see Section 15.01.

<table>
<thead>
<tr>
<th>Cyl.</th>
<th>MAN (TCA)</th>
<th>ABB (A100)</th>
<th>MHI (MET)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1 x TCA77</td>
<td>1 x A275-L</td>
<td>1 x MET71MA</td>
</tr>
<tr>
<td>6</td>
<td>1 x TCA88</td>
<td>1 x A280-L</td>
<td>1 x MET83MA</td>
</tr>
<tr>
<td>7</td>
<td>1 x TCA88</td>
<td>1 x A285-L</td>
<td>1 x MET83MA</td>
</tr>
<tr>
<td>8</td>
<td>2 x TCA77</td>
<td>1 x A285-L</td>
<td>2 x MET66MA</td>
</tr>
</tbody>
</table>

Table 3.01.01: High efficiency turbochargers
MAN Diesel

Climate Conditions and Exhaust Gas Bypass

**Extreme ambient conditions**

As mentioned in Chapter 1, the engine power figures are valid for tropical conditions at sea level: 45 °C air at 1,000 mbar and 32 °C seawater, whereas the reference fuel consumption is given at ISO conditions: 25 °C air at 1,000 mbar and 25 °C charge air coolant temperature.

Marine diesel engines are, however, exposed to greatly varying climatic temperatures winter and summer in arctic as well as tropical areas. These variations cause changes of the scavange air pressure, the maximum combustion pressure, the exhaust gas amount and temperatures as well as the specific fuel oil consumption.

For further information about the possible countermeasures, please refer to our publication titled: "Influence of Ambient Temperature Conditions"

The publication is available at www.marine.man.eu → 'Two-Stroke' → 'Technical Papers'

**Arctic running condition**

For air inlet temperatures below -10 °C the precautions to be taken depend very much on the operating profile of the vessel. The following alternative is one of the possible countermeasures. The selection of countermeasures, however, must be evaluated in each individual case.

**Exhaust gas receiver with variable bypass**

Option: 4 60 118

Compensation for low ambient temperature can be obtained by using exhaust gas bypass system.

This arrangement ensures that only part of the exhaust gas goes via the turbine of the turbocharger, thus supplying less energy to the compressor which, in turn, reduces the air supply to the engine.

Please note that if an exhaust gas bypass is applied, the turbocharger size and specification has to be determined by other means than stated in this Chapter.

**Emergency Running Condition**

**Exhaust gas receiver with total bypass flange and blank counterflange**

Option: 4 60 119

Bypass of the total amount of exhaust gas round the turbocharger is only used for emergency running in the event of turbocharger failure on engines, see Fig. 3.02.01.

This enables the engine to run at a higher load with only one turbocharger under emergency conditions. The engine's exhaust gas receiver will in this case be fitted with a bypass flange of approximately the same diameter as the inlet pipe to the turbocharger. The emergency pipe is yard's supply.

*Fig. 3.02.01: Total bypass of exhaust for emergency running*
Emission Control

IMO Tier II NOx emission limits

All ME, ME-B and ME-C/-GI engines are, as standard, fulfilling the IMO Tier II NOx emission requirements, a speed dependent NOx limit measured according to ISO 8178 Test Cycles E2/E3 for Heavy Duty Diesel Engines.

The E2/E3 test cycles are referred to in the Extent of Delivery as EoD: 4 06 200 Economy mode with the options: 4 06 201 Engine test cycle E3 or 4 06 202 Engine test cycle E2.

NOx reduction methods for IMO Tier III

As adopted by IMO for future enforcement, the engine must fulfil the more restrictive IMO Tier III NOx requirements when sailing in a NOx Emission Control Area (NOx ECA).

The Tier III NOx requirements can be met by Exhaust Gas Recirculation (EGR), a method which directly affects the combustion process by lowering the generation of NOx.

Alternatively, the required NOx level could be met by installing Selective Catalytic Reaction (SCR), an after treatment system that reduces the emission of NOx already generated in the combustion process.

Details of MAN Diesel & Turbo’s NOx reduction methods for IMO Tier III can be found in our publication:

Emission Project Guide

The publication is available at www.marine.man.eu → 'Two-Stroke' → 'Project Guides' → 'Other Guides'.
Electricity Production
Electricity Production

Introduction

Next to power for propulsion, electricity production is the largest fuel consumer on board. The electricity is produced by using one or more of the following types of machinery, either running alone or in parallel:

- Auxiliary diesel generating sets
- Main engine driven generators
- Exhaust gas- or steam driven turbo generator utilising exhaust gas waste heat (Thermo Efficiency System)
- Emergency diesel generating sets.

The machinery installed should be selected on the basis of an economic evaluation of first cost, operating costs, and the demand for man-hours for maintenance.

In the following, technical information is given regarding main engine driven generators (PTO), different configurations with exhaust gas and steam driven turbo generators, and the auxiliary diesel generating sets produced by MAN Diesel & Turbo.

Power Take Off

With a generator coupled to a Power Take Off (PTO) from the main engine, electrical power can be produced based on the main engine’s low SFOC/SGC. Several standardised PTO systems are available, see Fig. 4.01.01 and the designations in Fig. 4.01.02:

- PTO/RCF (Power Take Off/Renk Constant Frequency): Generator giving constant frequency, based on mechanical-hydraulic speed control.
- PTO/CFE (Power Take Off/Constant Frequency Electrical): Generator giving constant frequency, based on electrical frequency control.
- PTO/GCR (Power Take Off/Gear Constant Ratio): Generator coupled to a constant ratio step-up gear, used only for engines running at constant speed.

The DMG/CFE (Direct Mounted Generator/Constant Frequency Electrical) and the SMG/CFE (Shaft Mounted Generator/Constant Frequency Electrical) are special designs within the PTO/CFE group in which the generator is coupled directly to the main engine crankshaft or the intermediate propeller shaft, respectively, without a gear. The electrical output of the generator is controlled by electrical frequency control.

Within each PTO system, several designs are available, depending on the positioning of the gear:

- BW I: Gear with a vertical generator mounted onto the fore end of the diesel engine, without any connections to the ship structure.
- BW II: A free-standing gear mounted on the tank top and connected to the fore end of the diesel engine, with a vertical or horizontal generator.
- BW III: A crankshaft gear mounted onto the fore end of the diesel engine, with a side-mounted generator without any connections to the ship structure.
- BW IV: A free-standing step-up gear connected to the intermediate propeller shaft, with a horizontal generator.

The most popular of the gear based alternatives are the BW III/RCF type for plants with a fixed pitch propeller (FPP). The BW III/RCF requires no separate seating in the ship and only little attention from the shipyard with respect to alignment.
### Alternative types and layouts of shaft generators

<table>
<thead>
<tr>
<th>Design</th>
<th>Seating</th>
<th>Total efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW I/RCF</td>
<td>On engine (vertical generator)</td>
<td>88-91</td>
</tr>
<tr>
<td>BW II/RCF</td>
<td>On tank top</td>
<td>88-91</td>
</tr>
<tr>
<td>BW III/RCF</td>
<td>On engine</td>
<td>88-91</td>
</tr>
<tr>
<td>BW IV/RCF</td>
<td>On tank top</td>
<td>88-91</td>
</tr>
<tr>
<td>DMG/CFE</td>
<td>On engine</td>
<td>84-88</td>
</tr>
<tr>
<td>SMG/CFE</td>
<td>On tank top</td>
<td>89-91</td>
</tr>
<tr>
<td>BW I/GCR</td>
<td>On engine (vertical generator)</td>
<td>92</td>
</tr>
<tr>
<td>BW II/GCR</td>
<td>On tank top</td>
<td>92</td>
</tr>
<tr>
<td>BW III/GCR</td>
<td>On engine</td>
<td>92</td>
</tr>
<tr>
<td>BW IV/GCR</td>
<td>On tank top</td>
<td>92</td>
</tr>
</tbody>
</table>

**Fig. 4.01.01: Types of PTO**
Designation of PTO

For further information, please refer to our publication titled:

*Shaft Generators for MC and ME engines*

The publication is available at www.marine.man.eu → 'Two-Stroke' → 'Technical Papers'.

**Power take off:**

BW III S70ME-C8-GI/RCF 700-60

50: 50 Hz
60: 60 Hz

kW on generator terminals

RCF: Renk constant frequency unit
CFE: Electrically frequency controlled unit
GCR: Step-up gear with constant ratio

Mark version

Engine type on which it is applied

Layout of PTO: See Fig. 4.01.01

Make: MAN Diesel & Turbo

*Fig. 4.01.02: Example of designation of PTO*
PTO/RCF

Side mounted generator, BW III/RCF
(Fig. 4.01.01, Alternative 3)

The PTO/RCF generator systems have been developed in close cooperation with the German gear manufacturer RENK. A complete package solution is offered, comprising a flexible coupling, a step-up gear, an epicyclic, variable-ratio gear with built-in clutch, hydraulic pump and motor, and a standard generator, see Fig. 4.01.04.

For marine engines with controllable pitch propellers running at constant engine speed, the hydraulic system can normally be omitted. For constant speed engines a PTO/GCR design is normally used.

Fig. 4.01.04 shows the principles of the PTO/RCF arrangement. As can be seen, a step-up gear box (called crankshaft gear) with three gear wheels is bolted directly to front- and part side engine crankcase structure. The bearings of the three gear wheels are mounted in the gear box so that the weight of the wheels is not carried by the crankshaft. Between the crankcase and the gear drive, space is available for tuning wheel, counterweights, axial vibration damper, etc.

The first gear wheel is connected to the crankshaft via a special flexible coupling, made in one piece with a tooth coupling driving the crankshaft gear, thus isolating the gear drive against torsional and axial vibrations.

By means of a simple arrangement, the shaft in the crankshaft gear carrying the first gear wheel and the female part of the toothed coupling can be moved forward, thus disconnecting the two parts of the toothed coupling.

The power from the crankshaft gear is transferred, via a multi-disc clutch, to an epicyclic variable-ratio gear and the generator. These are mounted on a common PTO bedplate, bolted to brackets integrated with the engine crankcase structure.

The BW III/RCF unit is an epicyclic gear with a hydrostatic superposition drive. The hydrostatic input drives the annulus of the epicyclic gear in either direction of rotation, hence continuously varying the gearing ratio to keep the generator speed constant throughout an engine speed variation of 30%. In the standard layout, this is between 100% and 70% of the engine speed at specified MCR, but it can be placed in a lower range if required.

The input power to the gear is divided into two paths – one mechanical and the other hydrostatic – and the epicyclic differential combines the power of the two paths and transmits the combined power to the output shaft, connected to the generator. The gear is equipped with a hydrostatic motor driven by a pump, and controlled by an electronic control unit. This keeps the generator speed constant during single running as well as when running in parallel with other generators.
The multi-disc clutch, integrated into the gear input shaft, permits the engaging and disengaging of the epicyclic gear, and thus the generator, from the main engine during operation.

An electronic control system with a RENK controller ensures that the control signals to the main electrical switchboard are identical to those for the normal auxiliary generator sets. This applies to ships with automatic synchronising and load sharing, as well as to ships with manual switchboard operation.

Internal control circuits and interlocking functions between the epicyclic gear and the electronic control box provide automatic control of the functions necessary for the reliable operation and protection of the BW III/RCF unit. If any monitored value exceeds the normal operation limits, a warning or an alarm is given depending upon the origin, severity and the extent of deviation from the permissible values. The cause of a warning or an alarm is shown on a digital display.

Fig. 4.01.04: Power take off with RENK constant frequency gear: BW III/RCF, option: 485253
Extent of delivery for BW III/RCF units

The delivery comprises a complete unit ready to be built-on to the main engine. Fig. 4.02.01 shows the required space and the standard electrical output range on the generator terminals.

Standard sizes of the crankshaft gears and the RCF units are designed for: 700, 1200, 1800 and 2600 kW, while the generator sizes of make A. van Kaick are:

<table>
<thead>
<tr>
<th>Type DSG</th>
<th>440 V 1800 kVA</th>
<th>60 Hz r/min</th>
<th>380 V 1500 kVA</th>
<th>50 Hz r/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>62 M2-4</td>
<td>707</td>
<td>566</td>
<td>627</td>
<td>501</td>
</tr>
<tr>
<td>62 L1-4</td>
<td>855</td>
<td>684</td>
<td>761</td>
<td>609</td>
</tr>
<tr>
<td>62 L2-4</td>
<td>1,056</td>
<td>845</td>
<td>940</td>
<td>752</td>
</tr>
<tr>
<td>74 M1-4</td>
<td>1,271</td>
<td>1,017</td>
<td>1,137</td>
<td>909</td>
</tr>
<tr>
<td>74 M2-4</td>
<td>1,432</td>
<td>1,146</td>
<td>1,280</td>
<td>1,024</td>
</tr>
<tr>
<td>74 L1-4</td>
<td>1,651</td>
<td>1,321</td>
<td>1,468</td>
<td>1,174</td>
</tr>
<tr>
<td>74 L2-4</td>
<td>1,924</td>
<td>1,539</td>
<td>1,709</td>
<td>1,368</td>
</tr>
<tr>
<td>86 K1-4</td>
<td>1,942</td>
<td>1,554</td>
<td>1,844</td>
<td>1,475</td>
</tr>
<tr>
<td>86 M1-4</td>
<td>2,345</td>
<td>1,876</td>
<td>2,148</td>
<td>1,718</td>
</tr>
<tr>
<td>86 L2-4</td>
<td>2,792</td>
<td>2,234</td>
<td>2,542</td>
<td>2,033</td>
</tr>
<tr>
<td>99 K1-4</td>
<td>3,222</td>
<td>2,578</td>
<td>2,989</td>
<td>2,391</td>
</tr>
</tbody>
</table>

In the event that a larger generator is required, please contact MAN Diesel & Turbo.

If a main engine speed other than the nominal is required as a basis for the PTO operation, it must be taken into consideration when determining the ratio of the crankshaft gear. However, it has no influence on the space required for the gears and the generator.

The PTO can be operated as a motor (PTI) as well as a generator by making some minor modifications.

Yard deliveries are:

1. Cooling water pipes to the built-on lubricating oil cooling system, including the valves.
2. Electrical power supply to the lubricating oil stand-by pump built on to the RCF unit.
3. Wiring between the generator and the operator control panel in the switchboard.
4. An external permanent lubricating oil filling-up connection can be established in connection with the RCF unit. The system is shown in Fig. 4.03.03 ‘Lubricating oil system for RCF gear’. The dosage tank and the pertaining piping are to be delivered by the yard. The size of the dosage tank is stated in the table for RCF gear in ‘Necessary capacities for PTO/RCF’ (Fig. 4.03.02).

The necessary preparations to be made on the engine are specified in Figs. 4.03.01a and 4.03.01b.

Additional capacities required for BW III/RCF

The capacities stated in the ‘List of capacities’ for the main engine in question are to be increased by the additional capacities for the crankshaft gear and the RCF gear stated in Fig. 4.03.02.
The stated kW at the generator terminals is available between 70% and 100% of the engine speed at specified MCR.

Space requirements have to be investigated case by case on plants with 2,600 kW generator.

Dimension H: This is only valid for A. van Kaick generator type DSG, enclosure IP23, frequency = 60 Hz, speed = 1,800 r/min.

---

**Fig. 4.02.01: Space requirement for side mounted generator PTO/RCF type BWlll L70-C/RCF**
Engine preparations for PTO

Fig. 4.03.01a: Engine preparations for PTO, BWIII/RCF system
Pos.
1 Special face on bedplate and frame box
2 Ribs and brackets for supporting the face and machined blocks for alignment of gear or stator housing
3 Machined washers placed on frame box part of face to ensure that it is flush with the face on the bedplate
4 Rubber gasket placed on frame box part of face
5 Shim placed on frame box part of face to ensure that it is flush with the face of the bedplate
6 Distance tubes and long bolts
7 Threaded hole size, number and size of spring pins and bolts to be made in agreement with PTO maker
8 Flange of crankshaft, normally the standard execution can be used
9 Studs and nuts for crankshaft flange
10 Free flange end at lubricating oil inlet pipe (incl. blank flange)
11 Oil outlet flange welded to bedplate (incl. blank flange)
12 Face for brackets
13 Brackets
14 Studs for mounting the brackets
15 Studs, nuts and shims for mounting of RCF-/generator unit on the brackets
16 Shims, studs and nuts for connection between crankshaft gear and RCF-/generator unit
17 Engine cover with connecting bolts to bedplate/frame box to be used for shop test without PTO
18 Intermediate shaft between crankshaft and PTO
19 Oil sealing for intermediate shaft
20 Engine cover with hole for intermediate shaft and connecting bolts to bedplate/frame box
21 Plug box for electronic measuring instrument for checking condition of axial vibration damper
22 Tacho encoder for ME control system or MAN B&W Alpha lubrication system on MC engine
23 Tacho trigger ring for ME control system or MAN B&W Alpha lubrication system on MC engine

| Pos. no: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|
| BWIII/RCF | A | A | A | A | B | A | B | A | A | A | A | A | B | B | A | A | A | A | A | A |
| BWIII/CFE | A | A | A | A | B | A | B | A | A | A | A | A | A | A | A | A | A | A | A | A | A |
| BWII/RCF | A | A | A | A | B | A | B | A | A | A | A | A | A | A | A | A | A | A | A | A | A |
| BWII/CFE | A | A | A | A | B | A | B | A | A | A | A | A | A | A | A | A | A | A | A | A | A |
| BWI/RCF | A | A | A | A | B | A | B | A | A | A | A | A | A | A | A | A | A | A | A | A | A |
| BWI/CFE | A | A | A | A | B | A | B | A | A | A | A | A | A | A | A | A | A | A | A | A | A |
| DMG/CHE | A | A | A | A | B | A | B | A | A | A | A | A | A | A | A | A | A | A | A | A | A |

A: Preparations to be carried out by engine builder
B: Parts supplied by PTO maker
C: See text of pos. no.

Table 4.03.01b: Engine preparations for PTO
Crankshaft gear lubricated from the main engine lubricating oil system

The figures are to be added to the main engine capacity list:

<table>
<thead>
<tr>
<th>Nominal output of generator</th>
<th>kW</th>
<th>700</th>
<th>1,200</th>
<th>1,800</th>
<th>2,600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lubricating oil flow</td>
<td>m³/h</td>
<td>4.1</td>
<td>4.1</td>
<td>4.9</td>
<td>6.2</td>
</tr>
<tr>
<td>Heat dissipation</td>
<td>kW</td>
<td>12.1</td>
<td>20.8</td>
<td>31.1</td>
<td>45.0</td>
</tr>
</tbody>
</table>

RCF gear with separate lubricating oil system:

<table>
<thead>
<tr>
<th>Nominal output of generator</th>
<th>kW</th>
<th>700</th>
<th>1,200</th>
<th>1,800</th>
<th>2,600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling water quantity</td>
<td>m³/h</td>
<td>14.1</td>
<td>22.1</td>
<td>30.0</td>
<td>39.0</td>
</tr>
<tr>
<td>Heat dissipation</td>
<td>kW</td>
<td>55</td>
<td>92</td>
<td>134</td>
<td>180</td>
</tr>
<tr>
<td>El. power for oil pump</td>
<td>kW</td>
<td>11.0</td>
<td>15.0</td>
<td>18.0</td>
<td>21.0</td>
</tr>
<tr>
<td>Dosage tank capacity</td>
<td>m³</td>
<td>0.40</td>
<td>0.51</td>
<td>0.69</td>
<td>0.95</td>
</tr>
<tr>
<td>El. power for Renk controller</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24V DC ± 10%, 8 amp</td>
</tr>
</tbody>
</table>

From main engine:
- Design lube oil pressure: 2.25 bar
- Lube oil pressure at crankshaft gear: min. 1 bar
- Lube oil working temperature: 50 °C
- Lube oil type: SAE 30

Cooling water inlet temperature: 36 °C
Pressure drop across cooler: approximately 0.5 bar
Fill pipe for lube oil system store tank (~ø32)
Drain pipe to lube oil system drain tank (~ø40)
Electric cable between Renk terminal at gearbox and operator control panel in switchboard: Cable type FMGCG 19 x 2 x 0.5

Table 4.03.02: Necessary capacities for PTO/RCF, BW III/RCF system

The letters refer to the list of ‘Counterflanges’, which will be extended by the engine builder, when PTO systems are installed on the main engine.

Fig. 4.03.03: Lubricating oil system for RCF gear
DMG/CFE Generators
Option: 4 85 259

Fig. 4.01.01 alternative 5, shows the DMG/CFE (Direct Mounted Generator/Constant Frequency Electrical) which is a low speed generator with its rotor mounted directly on the crankshaft and its stator bolted on to the frame box as shown in Figs. 4.03.04 and 4.03.05.

The DMG/CFE is separated from the crankcase by a plate and a labyrinth stuffing box.

The DMG/CFE system has been developed in cooperation with the German generator manufacturers Siemens and AEG, but similar types of generator can be supplied by others, e.g. Fuji, Taiyo and Nishishiba in Japan.

For generators in the normal output range, the mass of the rotor can normally be carried by the foremost main bearing without exceeding the permissible bearing load (see Fig. 4.03.05), but this must be checked by the engine manufacturer in each case.

If the permissible load on the foremost main bearing is exceeded, e.g. because a tuning wheel is needed, this does not preclude the use of a DMG/CFE.

Fig. 4.03.04: Standard engine, with direct mounted generator (DMG/CFE)
Fig. 4.03.05: Standard engine, with direct mounted generator and tuning wheel

Fig. 4.03.06: Diagram of DMG/CFE with static converter
In such a case, the problem is solved by installing a small, elastically supported bearing in front of the stator housing, as shown in Fig. 4.03.05.

As the DMG type is directly connected to the crankshaft, it has a very low rotational speed and, consequently, the electric output current has a low frequency – normally of the order of 15 Hz.

Therefore, it is necessary to use a static frequency converter between the DMG and the main switchboard. The DMG/CFE is, as standard, laid out for operation with full output between 100% and 75% and with reduced output between 75% and 40% of the engine speed at specified MCR.

**Static converter**

The static frequency converter system (see Fig. 4.03.06) consists of a static part, i.e. thyristors and control equipment, and a rotary electric machine.

The DMG produces a three-phase alternating current with a low frequency, which varies in accordance with the main engine speed. This alternating current is rectified and led to a thyristor inverter producing a three-phase alternating current with constant frequency.

Since the frequency converter system uses a DC intermediate link, no reactive power can be supplied to the electric mains. To supply this reactive power, a synchronous condenser is used. The synchronous condenser consists of an ordinary synchronous generator coupled to the electric mains.

**Extent of delivery for DMG/CFE units**

The delivery extent is a generator fully built-on to the main engine including the synchronous condenser unit and the static converter cubicles which are to be installed in the engine room.

The DMG/CFE can, with a small modification, be operated both as a generator and as a motor (PTI).

Yard deliveries are:

1. Installation, i.e. seating in the ship for the synchronous condenser unit and for the static converter cubicles
2. Cooling water pipes to the generator if water cooling is applied
3. Cabling.

The necessary preparations to be made on the engine are specified in Fig. 4.03.01a and Table 4.03.01b.

**SMG/CFE Generators**

The PTO SMG/CFE (see Fig. 4.01.01 alternative 6) has the same working principle as the PTO DMG/CFE, but instead of being located on the front end of the engine, the alternator is installed aft of the engine, with the rotor integrated on the intermediate shaft.

In addition to the yard deliveries mentioned for the PTO DMG/CFE, the shipyard must also provide the foundation for the stator housing in the case of the PTO SMG/CFE.

The engine needs no preparation for the installation of this PTO system.
PTO type: BW II/GCR

Power Take Off/Gear Constant Ratio

The PTO system type BW II/GCR illustrated in Fig. 4.01.01 alternative 5 can generate electrical power on board ships equipped with a controllable pitch propeller, running at constant speed.

The PTO unit is mounted on the tank top at the fore end of the engine see Fig. 4.04.01. The PTO generator is activated at sea, taking over the electrical power production on board when the main engine speed has stabilised at a level corresponding to the generator frequency required on board.

The installation length in front of the engine, and thus the engine room length requirement, naturally exceeds the length of the engine aft end mounted shaft generator arrangements. However, there is some scope for limiting the space requirement, depending on the configuration chosen.

PTO type: BW IV/GCR

Power Take Off/Gear Constant Ratio

The shaft generator system, type PTO BW IV/GCR, installed in the shaft line (Fig. 4.01.01 alternative 6) can generate power on board ships equipped with a controllable pitch propeller running at constant speed.

The PTO system can be delivered as a tunnel gear with hollow flexible coupling or, alternatively, as a generator step-up gear with thrust bearing and flexible coupling integrated in the shaft line.

The main engine needs no special preparation for mounting these types of PTO systems as they are connected to the intermediate shaft.

The PTO system installed in the shaft line can also be installed on ships equipped with a fixed pitch propeller or controllable pitch propeller running in

Fig. 4.04.01: Generic outline of Power Take Off (PTO) BW II/GCR
combinator mode. This will, however, require an additional RENK Constant Frequency gear (Fig. 4.01.01 alternative 2) or additional electrical equipment for maintaining the constant frequency of the generated electric power.

**Tunnel gear with hollow flexible coupling**

This PTO system is normally installed on ships with a minor electrical power take off load compared to the propulsion power, up to approximately 25% of the engine power.

The hollow flexible coupling is only to be dimensioned for the maximum electrical load of the power take off system and this gives an economic advantage for minor power take off loads compared to the system with an ordinary flexible coupling integrated in the shaft line.

The hollow flexible coupling consists of flexible segments and connecting pieces, which allow replacement of the coupling segments without dismounting the shaft line, see Fig. 4.04.02.

**Generator step-up gear and flexible coupling integrated in the shaft line**

For higher power take off loads, a generator step-up gear and flexible coupling integrated in the shaft line may be chosen due to first costs of gear and coupling.

The flexible coupling integrated in the shaft line will transfer the total engine load for both propulsion and electrical power and must be dimensioned accordingly.

The flexible coupling cannot transfer the thrust from the propeller and it is, therefore, necessary to make the gear-box with an integrated thrust bearing.

This type of PTO system is typically installed on ships with large electrical power consumption, e.g. shuttle tankers.

![Fig. 4.04.02: Generic outline of BW IV/GCR, tunnel gear](https://example.com/image.jpg)
**Auxiliary Propulsion System/Take Home System**

From time to time an Auxiliary Propulsion System/Take Home System capable of driving the CP propeller by using the shaft generator as an electric motor is requested.

MAN Diesel & Turbo can offer a solution where the CP propeller is driven by the alternator via a two-speed tunnel gear box. The electric power is produced by a number of GenSets. The main engine is disengaged by a clutch (RENK PSC) made as an integral part of the shafting. The clutch is installed between the tunnel gear box and the main engine, and conical bolts are used to connect and disconnect the main engine and the shafting. See Figure 4.04.03.

A thrust bearing, which transfers the auxiliary propulsion propeller thrust to the engine thrust bearing when the clutch is disengaged, is built into the RENK PSC clutch. When the clutch is engaged, the thrust is transferred statically to the engine thrust bearing through the thrust bearing built into the clutch.

To obtain high propeller efficiency in the auxiliary propulsion mode, and thus also to minimise the auxiliary power required, a two-speed tunnel gear, which provides lower propeller speed in the auxiliary propulsion mode, is used.

The two-speed tunnel gear box is made with a friction clutch which allows the propeller to be clutched in at full alternator/motor speed where the full torque is available. The alternator/motor is started in the de-clutched condition with a start transformer.

The system can quickly establish auxiliary propulsion from the engine control room and/or bridge, even with unmanned engine room.

Re-establishment of normal operation requires attendance in the engine room and can be done within a few minutes.
Waste Heat Recovery Systems (WHRS)

Due to the increasing fuel prices seen from 2004 and onwards many shipowners have shown interest in efficiency improvements of the power systems on board their ships. A modern two-stroke diesel engine has one of the highest thermal efficiencies of today’s power systems, but even this high efficiency can be improved by combining the diesel engine with other power systems.

One of the possibilities for improving the efficiency is to install one or more systems utilising some of the energy in the exhaust gas after the two-stroke engine, which in MAN Diesel & Turbo terms is designated as WHRS (Waste Heat Recovery Systems).

WHRS can be divided into different types of subsystems, depending on how the system utilises the exhaust gas energy. Choosing the right system for a specific project depends on the electricity demand on board the ship and the acceptable first cost for the complete installation. MAN Diesel & Turbo uses the following designations for the current systems on the market:

- **PTG (Power Turbine Generator):** An exhaust gas driven turbine connected to a generator via a gearbox.

- **STG (Steam Turbine Generator):** A steam driven turbine connected to a generator via a gearbox. The steam is produced in a large exhaust gas driven boiler installed on the main engine exhaust gas piping system.

- **Combined Turbines:** A combination of the two first systems. The arrangement is often that the power turbine is connected to the steam turbine via a gearbox and the steam turbine is further connected to a large generator, which absorbs the power from both turbines.

The PTG system will produce power equivalent to approx. 3.5% of the main engine SMCR, when the engine is running at SMCR. For the STG system this value is between 5 and 7% depending on the system installed. When combining the two systems, a power output equivalent to 10% of the main engine’s SMCR is possible, when the engine is running at SMCR.

The WHRS output depends on the main engine rating and whether service steam consumption must be deducted or not.

As the electrical power produced by the system needs to be used on board the ship, specifying the correct size system for a specific project must be considered carefully. In cases where the electrical power consumption on board the ship is low, a smaller system than possible for the engine type may be considered. Another possibility is to install a shaft generator/motor to absorb excess power produced by the WHRS. The main engine will then be unloaded, or it will be possible to increase the speed of the ship, without penalising the fuel bill.

Because the energy from WHRS is taken from the exhaust gas of the main engine, this power produced can be considered as "free". In reality, the main engine SFOC will increase slightly, but the gain in electricity production on board the ship will far surpass this increase in SFOC. As an example, the SFOC of the combined output of both the engine and the system with power and steam turbine can be calculated to be as low as 152 g/kWh (ref. LCV 42,700 kJ/kg).
Power Turbine Generator (PTG)

The power turbines of today are based on the different turbocharger suppliers’ newest designs of high efficiency turbochargers, i.e. MAN TCA, ABB A-L and Mitsubishi MET turbochargers.

MAN Diesel & Turbo offers PTG solutions called TCS-PTG in the range from approx. 1,000 kW to 5,000 kW, see Fig. 4.05.02.

The power turbine basically is the turbine side of a normal high-efficient turbocharger with some modifications to the bearings and the turbine shaft. This is in order to be able to connect it to a gearbox instead of the normal connection to the compressor side. The power turbine will be installed on a separate exhaust gas pipe from the exhaust gas receiver, which bypasses the turbochargers.

The performance of the PTG and the main engine will depend on a careful matching of the engine turbochargers and the power turbine, for which reason the turbocharger/s and the power turbine need to be from the same manufacturer. In Fig. 4.05.01, a diagram of the PTG arrangement is shown.

The newest generation of high efficiency turbochargers allows bypassing of some of the main engine exhaust gas, thereby creating a new balance of the air flow through the engine. In this way, it is possible to extract power from the power turbine equivalent to 3.5% of the main engine's SMCR, when the engine is running at SMCR.

Fig. 4.05.01: PTG diagram
Fig. 4.05.02: MAN Diesel & Turbo 1,500 kW TCS-PTG solution
Steam Turbine Generator (STG)

In most cases the exhaust gas pipe system of the main engine is equipped with a boiler system. With this boiler, some of the energy in the exhaust gas is utilised to produce steam for use on board the ship.

If the engine is WHR matched, the exhaust gas temperature will be between 50°C and 65°C higher than on a conventional engine, which makes it possible to install a larger boiler system and, thereby, produce more steam. In short, MAN Diesel & Turbo designates this system STG. Fig. 4.05.03 shows an example of the STG diagram.

For WHR matching the engine, a bypass is installed to increase the temperature of the exhaust gas and improve the boiler output. The bypass valve is controlled by the engine control system.

The extra steam produced in the boiler can be utilised in a steam turbine, which can be used to drive a generator for power production on board the ship. A STG system could be arranged as shown in Fig. 4.05.04, where a typical system size is shown with the outline dimensions.

The steam turbine can either be a single or dual pressure turbine, depending on the size of the system. Steam pressure for a single pressure system is 7 to 10 bara, and for the dual pressure system the high-pressure cycle will be 9 to 10 bara and the low-pressure cycle will be 4 to 5 bara.

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*Fig. 4.05.03: STG system diagram*
Fig. 4.05.04: STG steam turbine generator arrangement with condenser - typical arrangement
Full WHRS Steam and Power Turbines Combined

Because the installation of the power turbine also will result in an increase of the exhaust gas temperature after the turbochargers, it is possible to install both the power turbine, the larger boiler and steam turbine on the same engine. This way, the energy from the exhaust gas is utilised in the best way possible by today’s components.

When looking at the system with both power and steam turbine, quite often the power turbine and the steam turbine are connected to the same generator. In some cases, it is also possible to have each turbine on a separate generator. This is, however, mostly seen on stationary engines, where the frequency control is simpler because of the large grid to which the generator is coupled.

For marine installations the power turbine is, in most cases, connected to the steam turbine via a gearbox, and the steam turbine is then connected to the generator. It is also possible to have a generator with connections in both ends, and then connect the power turbine in one end and the steam turbine in the other. In both cases control of one generator only is needed.

For dimensions of a typical full WHRS see Fig. 4.05.06.

As mentioned, the systems with steam turbines require a larger boiler to be installed. The size of the boiler system will be considerably bigger than the size of an ordinary boiler system, and the actual boiler size has to be calculated from case to case. Casing space for the exhaust boiler must be reserved in the initial planning of the ship’s machinery spaces.
Fig. 4.05.06: Full ST & PT full waste heat recovery unit arrangement with condenser - typical arrangement
WHRS generator output

Because all the components come from different manufacturers, the final output and the system efficiency have to be calculated from case to case.

However, Table 4.05.07 shows a guidance of possible outputs in L1 based on theoretically calculated outputs from the system.

WHRS output at a rating lower than L1

As engines are seldom rated in L1, it is recommended to contact MAN Diesel & Turbo Copenhagen, department Marine Installation, e-mail: lee4@mandieselturbo.com for specific WHRS generator output.

In order to receive as correctly as possible an engine tuned for WHRS data, please specify requested engine rating (power × rpm) and ship service steam consumption (kg/hour).

Detailed information about the different WHRS systems is found in our publication:

Waste Heat Recovery System (WHRS)

The publication is available at www.marine.man.eu → ‘Two-Stroke’ → ‘Technical Papers’.

Guidance output of WHR for L70MC-C8.2-TII and L70ME-C8.2/-GI-TII engine rated in L1 at ISO conditions

<table>
<thead>
<tr>
<th>Cyl.</th>
<th>Engine power % SMCR kW</th>
<th>PTG kWe</th>
<th>STG kWe</th>
<th>Full WHRS with combined turbines kWe</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>100 16,350</td>
<td>472</td>
<td>970</td>
<td>1,290</td>
</tr>
<tr>
<td></td>
<td>75 12,263</td>
<td>392</td>
<td>579</td>
<td>861</td>
</tr>
<tr>
<td>6</td>
<td>100 19,620</td>
<td>567</td>
<td>1,202</td>
<td>1,572</td>
</tr>
<tr>
<td></td>
<td>75 14,715</td>
<td>468</td>
<td>745</td>
<td>1,069</td>
</tr>
<tr>
<td>7</td>
<td>100 22,890</td>
<td>662</td>
<td>1,510</td>
<td>1,939</td>
</tr>
<tr>
<td></td>
<td>75 17,168</td>
<td>546</td>
<td>982</td>
<td>1,338</td>
</tr>
<tr>
<td>8</td>
<td>100 26,160</td>
<td>761</td>
<td>1,817</td>
<td>2,379</td>
</tr>
<tr>
<td></td>
<td>75 19,620</td>
<td>629</td>
<td>1,193</td>
<td>1,657</td>
</tr>
</tbody>
</table>

Note 1: The above given preliminary WHRS generator outputs is based on HP service steam consumption of 0.3 ton/h and LP service steam consumption of 0.7 ton/h for the ship at ISO condition.

Note 2: 75% SMCR is selected due to the EEDI focus on the engine load.

Table 4.05.07: Theoretically calculated outputs
Waste Heat Recovery Element and Safety Valve

The boiler water or steam for power generator is preheated in the Waste Heat Recovery (WHR) element, also called the first-stage air cooler.

The WHR element is typically built as a high-pressure water/steam heat exchanger which is placed on top of the scavenge air cooler, see Fig. 4.05.08.

Full water flow must be passed through the WHR element continuously when the engine is running. This must be considered in the layout of the steam feed water system (the WHR element supply heating). Refer to our ‘WHR element specification’ which is available from MAN Diesel & Turbo, Copenhagen.

Safety valve and blow-off

In normal operation, the temperature and pressure of the WHR element is in the range of 140-150 °C and 8-21 bar respectively.

In order to prevent leaking components from causing personal injuries or damage to vital parts of the main engine, a safety relief valve will blow off excess pressure. The safety relief valve is connected to an external connection, ‘W’, see Fig. 4.05.09.

Connection ‘W’ must be passed to the funnel or another free space according to the class rules for steam discharge from safety valve.

As the system is pressurised according to class rules, the safety valve must be type approved.

Fig. 4.05.08: WHR element on Scavenge air cooler
Fig. 4.05.09: WHR safety valve blow-off through connection ‘W’ to the funnel
L16/24-TII GenSet Data

**Power layout**

<table>
<thead>
<tr>
<th>Model</th>
<th>Eng. kW</th>
<th>Gen. kW</th>
<th>Eng. kW</th>
<th>Gen. kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>5L16/24</td>
<td>500</td>
<td>475</td>
<td>450</td>
<td>430</td>
</tr>
<tr>
<td>6L16/24</td>
<td>660</td>
<td>625</td>
<td>570</td>
<td>542</td>
</tr>
<tr>
<td>7L16/24</td>
<td>770</td>
<td>730</td>
<td>665</td>
<td>632</td>
</tr>
<tr>
<td>8L16/24</td>
<td>880</td>
<td>835</td>
<td>760</td>
<td>722</td>
</tr>
<tr>
<td>9L16/24</td>
<td>990</td>
<td>940</td>
<td>855</td>
<td>812</td>
</tr>
</tbody>
</table>

**Dimensions and weights**

<table>
<thead>
<tr>
<th>No. of Cyls.</th>
<th>A (mm)</th>
<th>* B (mm)</th>
<th>* C (mm)</th>
<th>H (mm)</th>
<th>** Dry weight GenSet (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 (1,000 r/min)</td>
<td>2,751</td>
<td>1,400</td>
<td>4,151</td>
<td>2,457</td>
<td>9.5</td>
</tr>
<tr>
<td>5 (1,200 r/min)</td>
<td>2,751</td>
<td>1,400</td>
<td>4,151</td>
<td>2,457</td>
<td>9.5</td>
</tr>
<tr>
<td>6 (1,000 r/min)</td>
<td>3,026</td>
<td>1,490</td>
<td>4,516</td>
<td>2,457</td>
<td>10.5</td>
</tr>
<tr>
<td>6 (1,200 r/min)</td>
<td>3,026</td>
<td>1,490</td>
<td>4,516</td>
<td>2,457</td>
<td>10.5</td>
</tr>
<tr>
<td>7 (1,000 r/min)</td>
<td>3,501</td>
<td>1,585</td>
<td>5,086</td>
<td>2,457</td>
<td>11.4</td>
</tr>
<tr>
<td>7 (1,200 r/min)</td>
<td>3,501</td>
<td>1,585</td>
<td>5,086</td>
<td>2,495</td>
<td>11.4</td>
</tr>
<tr>
<td>8 (1,000 r/min)</td>
<td>3,776</td>
<td>1,680</td>
<td>5,456</td>
<td>2,495</td>
<td>12.4</td>
</tr>
<tr>
<td>8 (1,200 r/min)</td>
<td>3,776</td>
<td>1,680</td>
<td>5,456</td>
<td>2,495</td>
<td>12.4</td>
</tr>
<tr>
<td>9 (1,000 r/min)</td>
<td>4,051</td>
<td>1,680</td>
<td>5,731</td>
<td>2,495</td>
<td>13.1</td>
</tr>
<tr>
<td>9 (1,200 r/min)</td>
<td>4,051</td>
<td>1,680</td>
<td>5,731</td>
<td>2,495</td>
<td>13.1</td>
</tr>
</tbody>
</table>

*P Free passage between the engines, width 600 mm and height 2,000 mm

Q Min. distance between engines: 1,800 mm

* Depending on alternator

** Weight incl. standard alternator (based on a Leroy Somer alternator)

All dimensions and masses are approximate and subject to change without prior notice.

Fig. 4.06.01: Power and outline of L16/24, IMO Tier II
## MAN Diesel 4.06

**Page 2 of 3**

### L16/24-TII GenSet Data

5L: 90 kW/cyl., 6L-9L: 95 kW/Cyl. at 1,000 rpm

#### Reference Condition: Tropic

<table>
<thead>
<tr>
<th>Reference Temperature</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature</td>
<td>45</td>
</tr>
<tr>
<td>LT-water temperature</td>
<td>38</td>
</tr>
<tr>
<td>Air pressure</td>
<td>1</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>50</td>
</tr>
</tbody>
</table>

#### Temperature basis

<table>
<thead>
<tr>
<th>Setpoint HT cooling water engine outlet</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Setpoint LT cooling water engine outlet</td>
<td>79 nominal (Range of mechanical thermostatic element 77 to 85)</td>
</tr>
<tr>
<td>2) Setpoint Lube oil inlet engine</td>
<td>35 nominal (Range of mechanical thermostatic element 29 to 41)</td>
</tr>
<tr>
<td>3) Setpoint Lube oil outlet engine</td>
<td>66 nominal (Range of mechanical thermostatic element 63 to 72)</td>
</tr>
</tbody>
</table>

#### Number of Cylinders

<table>
<thead>
<tr>
<th>Number of Cylinders</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine output</td>
<td>kW</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>rpm</td>
<td>1,000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Heat to be dissipated

<table>
<thead>
<tr>
<th></th>
<th>kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling water (C.W.) Cylinder</td>
<td>107</td>
</tr>
<tr>
<td>Charge air cooler; cooling water HT</td>
<td>138</td>
</tr>
<tr>
<td>Charge air cooler; cooling water LT</td>
<td>56</td>
</tr>
<tr>
<td>Lube oil (L.O.) cooler</td>
<td>98</td>
</tr>
<tr>
<td>Heat radiation engine</td>
<td>15</td>
</tr>
</tbody>
</table>

#### Flow rates

<table>
<thead>
<tr>
<th></th>
<th>m³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal (inside engine)</td>
<td></td>
</tr>
<tr>
<td>HT circuit (cylinder + charge air cooler HT stage)</td>
<td>10.9</td>
</tr>
<tr>
<td>LT circuit (lube oil + charge air cooler LT stage)</td>
<td>15.7</td>
</tr>
<tr>
<td>Lube oil</td>
<td>18</td>
</tr>
<tr>
<td>External (from engine to system)</td>
<td></td>
</tr>
<tr>
<td>LT water flow (at 38°C inlet)</td>
<td>5.2</td>
</tr>
<tr>
<td>LT water flow (at 38°C inlet)</td>
<td>15.7</td>
</tr>
</tbody>
</table>

#### Air data

<table>
<thead>
<tr>
<th></th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature of charge air at charge air cooler outlet</td>
<td>49</td>
</tr>
<tr>
<td>Air flow rate</td>
<td>m³/h²</td>
</tr>
<tr>
<td></td>
<td>2,721</td>
</tr>
<tr>
<td></td>
<td>3,446</td>
</tr>
<tr>
<td></td>
<td>4,021</td>
</tr>
<tr>
<td></td>
<td>4,595</td>
</tr>
<tr>
<td></td>
<td>4,959</td>
</tr>
<tr>
<td></td>
<td>5,169</td>
</tr>
<tr>
<td>Heat content (190°C)</td>
<td>t/h</td>
</tr>
<tr>
<td></td>
<td>375</td>
</tr>
<tr>
<td></td>
<td>375</td>
</tr>
<tr>
<td></td>
<td>375</td>
</tr>
<tr>
<td></td>
<td>375</td>
</tr>
<tr>
<td>Permissible exhaust back pressure</td>
<td>kW</td>
</tr>
<tr>
<td></td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>216</td>
</tr>
<tr>
<td></td>
<td>252</td>
</tr>
<tr>
<td></td>
<td>288</td>
</tr>
<tr>
<td></td>
<td>324</td>
</tr>
</tbody>
</table>

#### Exhaust gas data

<table>
<thead>
<tr>
<th></th>
<th>m³/h³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume flow (temperature turbocharger outlet) Mass flow</td>
<td>5,710</td>
</tr>
<tr>
<td>Temperature at turbine outlet</td>
<td>t/h</td>
</tr>
<tr>
<td></td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td>5.8</td>
</tr>
<tr>
<td>Heat content (190°C)</td>
<td>°C</td>
</tr>
<tr>
<td></td>
<td>375</td>
</tr>
<tr>
<td></td>
<td>375</td>
</tr>
<tr>
<td></td>
<td>375</td>
</tr>
<tr>
<td></td>
<td>375</td>
</tr>
<tr>
<td>Permissible exhaust back pressure</td>
<td>mbar</td>
</tr>
<tr>
<td></td>
<td>&lt; 30</td>
</tr>
</tbody>
</table>

#### Pumps

<table>
<thead>
<tr>
<th></th>
<th>m³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine driven pumps</td>
<td></td>
</tr>
<tr>
<td>HT circuit cooling water</td>
<td>10.9</td>
</tr>
<tr>
<td>LT circuit cooling water</td>
<td>15.7</td>
</tr>
<tr>
<td>Lube oil (4.5 bar)</td>
<td>18</td>
</tr>
<tr>
<td>External pumps</td>
<td></td>
</tr>
<tr>
<td>Diesel oil pump</td>
<td>0.32</td>
</tr>
<tr>
<td>Fuel oil supply pump</td>
<td>0.15</td>
</tr>
<tr>
<td>Fuel oil circulating pump</td>
<td>0.32</td>
</tr>
</tbody>
</table>

#### Starting air data

<table>
<thead>
<tr>
<th></th>
<th>Nm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air consumption per start, incl. air for jet assist</td>
<td>0.47</td>
</tr>
<tr>
<td>Air consumption per start, incl. air for jet assist</td>
<td>0.80</td>
</tr>
</tbody>
</table>

---

1) LT cooling water flow first through LT stage charge air cooler, then through lube oil cooler, water temperature outlet engine regulated by mechanical thermostat.

2) HT cooling water flow first through HT stage charge air cooler, then through water jacket and cylinder head, water temperature outlet engine regulated by mechanical thermostat.

3) Tolerance: + 10% for rating coolers, - 15% for heat recovery.

---

Fig. 4.06.02a: List of capacities for L16/24, 1,000 rpm, IMO Tier II

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**MAN Diesel**
### L16/24-TII GenSet Data

#### 5L: 100 kW/cyl., 6L-9L: 110 kW/Cyl. at 1,200 rpm

**Reference Condition: Tropic**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature</td>
<td>45°C</td>
</tr>
<tr>
<td>LT-water temperature inlet engine (from system)</td>
<td>38°C</td>
</tr>
<tr>
<td>Air pressure</td>
<td>bar</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>%</td>
</tr>
</tbody>
</table>

**Temperature basis**

<table>
<thead>
<tr>
<th>Setpoint HT cooling water engine outlet</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setpoint LT cooling water engine outlet</td>
<td>°C</td>
</tr>
<tr>
<td>Setpoint Lube oil inlet engine</td>
<td>°C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Cylinders</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine output</td>
<td>kW</td>
<td>500</td>
<td>660</td>
<td>770</td>
<td>880</td>
</tr>
<tr>
<td>Speed (rpm)</td>
<td></td>
<td>1,200</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Heat to be dissipated**

<table>
<thead>
<tr>
<th>Internal (inside engine)</th>
<th>Cooling water (C.W.) Cylinder</th>
<th>kW</th>
<th>100</th>
<th>132</th>
<th>154</th>
<th>177</th>
<th>199</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT circuit (lube oil + charge air cooler LT stage)</td>
<td>HT water flow at (38°C inlet)</td>
<td>m³/h</td>
<td>13.1</td>
<td>15.2</td>
<td>17.4</td>
<td>19.5</td>
<td>21.6</td>
</tr>
<tr>
<td></td>
<td>m³/h</td>
<td>19.3</td>
<td>20.7</td>
<td>24.2</td>
<td>27.7</td>
<td>31.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>m³/h</td>
<td>21</td>
<td>21</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>External (from engine to system)</td>
<td>LT water flow (at 40°C inlet)</td>
<td>m³/h</td>
<td>5.7</td>
<td>7.3</td>
<td>8.4</td>
<td>9.4</td>
<td>10.4</td>
</tr>
<tr>
<td></td>
<td>m³/h</td>
<td>19.1</td>
<td>20.7</td>
<td>24.2</td>
<td>27.7</td>
<td>31.1</td>
<td></td>
</tr>
</tbody>
</table>

**Air data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>°C</th>
<th>m³/h</th>
<th>kg/kWh</th>
<th>bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature of charge air at charge air cooler outlet</td>
<td></td>
<td>51</td>
<td>3.169</td>
<td>0.94</td>
</tr>
<tr>
<td>Air flow rate</td>
<td>m³/h</td>
<td>3,169</td>
<td>4,183</td>
<td>6.94</td>
</tr>
<tr>
<td>Charge air pressure</td>
<td>kg/kWh</td>
<td>6.94</td>
<td>6.94</td>
<td>6.94</td>
</tr>
<tr>
<td>Air required to dissipate heat radiation (engine) (t₂-t₁= 10°C)</td>
<td>m³/h</td>
<td>5,509</td>
<td>7,453</td>
<td>9,721</td>
</tr>
</tbody>
</table>

**Exhaust gas data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>°C</th>
<th>m³/h</th>
<th>kg/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume flow (temperature turbocharger outlet)</td>
<td>°C</td>
<td>6,448</td>
<td>8,511</td>
</tr>
<tr>
<td>Mass flow</td>
<td>t/h</td>
<td>9,209</td>
<td>11,348</td>
</tr>
<tr>
<td>Temperature at turbine outlet</td>
<td>°C</td>
<td>356</td>
<td>356</td>
</tr>
<tr>
<td>Heat content (190°C)</td>
<td>kW</td>
<td>356</td>
<td>356</td>
</tr>
<tr>
<td>Permissible exhaust back pressure</td>
<td>kW</td>
<td>356</td>
<td>356</td>
</tr>
</tbody>
</table>

**Pumps**

<table>
<thead>
<tr>
<th>Type</th>
<th>m³/h</th>
<th>kg/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Engine driven pumps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HT circuit cooling water</td>
<td>(2.5 bar)</td>
<td>m³/h</td>
</tr>
<tr>
<td>LT circuit cooling water</td>
<td>(2.5 bar)</td>
<td>m³/h</td>
</tr>
<tr>
<td>Lube oil (4.5 bar)</td>
<td>m³/h</td>
<td>21</td>
</tr>
<tr>
<td>b) External pumps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel oil pump</td>
<td>(5 bar at fuel oil inlet A1)</td>
<td>m³/h</td>
</tr>
<tr>
<td>Fuel oil supply pump</td>
<td>(4 bar discharge pressure)</td>
<td>m³/h</td>
</tr>
<tr>
<td>Fuel oil circulating pump</td>
<td>(6 bar at fuel oil inlet A1)</td>
<td>m³/h</td>
</tr>
</tbody>
</table>

**Starting air data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Nm³</th>
<th>Nm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air consumption per start, incl. air for jet assist (IR/TDI)</td>
<td>0.47</td>
<td>0.56</td>
</tr>
<tr>
<td>Air consumption per start, incl. air for jet assist (Gali)</td>
<td>0.80</td>
<td>0.96</td>
</tr>
</tbody>
</table>

---

1) LT cooling water flow first through LT stage charge air cooler, then through lube oil cooler, water temperature outlet engine regulated by mechanical thermostat.
2) HT cooling water flow first through HT stage charge air cooler, then through water jacket and cylinder head, water temperature outlet engine regulated by mechanical thermostat.
3) Tolerance: ± 10% for rating coolers, - 15% for heat recovery.
4) Basic values for layout of the coolers.
5) Under above mentioned reference conditions.
6) Tolerance: quantity +/- 5%, temperature +/- 20°C.
7) Under below mentioned temperature at turbine outlet and pressure according above mentioned reference conditions.
8) Tolerance of the pumps delivery capacities must be considered by the manufactures.

Fig. 4.06.02b: List of capacities for L16/24 1,200 rpm, IMO Tier II
L21/31-TII GenSet Data

Bore: 210 mm  Stroke: 310 mm

<table>
<thead>
<tr>
<th>Cyl. no</th>
<th>B (mm)</th>
<th>C (mm)</th>
<th>H (mm)</th>
<th>Dry weight GenSet (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 (900 rpm)</td>
<td>3,959</td>
<td>1,870</td>
<td>5,829</td>
<td>3,183</td>
</tr>
<tr>
<td>5 (1000 rpm)</td>
<td>3,959</td>
<td>1,870</td>
<td>5,829</td>
<td>3,183</td>
</tr>
<tr>
<td>6 (900 rpm)</td>
<td>4,314</td>
<td>2,000</td>
<td>6,314</td>
<td>3,183</td>
</tr>
<tr>
<td>6 (1000 rpm)</td>
<td>4,314</td>
<td>2,000</td>
<td>6,314</td>
<td>3,183</td>
</tr>
<tr>
<td>7 (900 rpm)</td>
<td>4,669</td>
<td>1,970</td>
<td>6,639</td>
<td>3,289</td>
</tr>
<tr>
<td>7 (1000 rpm)</td>
<td>4,669</td>
<td>1,970</td>
<td>6,639</td>
<td>3,289</td>
</tr>
<tr>
<td>8 (900 rpm)</td>
<td>5,024</td>
<td>2,250</td>
<td>7,274</td>
<td>3,289</td>
</tr>
<tr>
<td>8 (1000 rpm)</td>
<td>5,024</td>
<td>2,250</td>
<td>7,274</td>
<td>3,289</td>
</tr>
<tr>
<td>9 (900 rpm)</td>
<td>5,379</td>
<td>2,400</td>
<td>7,779</td>
<td>3,289</td>
</tr>
<tr>
<td>9 (1000 rpm)</td>
<td>5,379</td>
<td>2,400</td>
<td>7,779</td>
<td>3,289</td>
</tr>
</tbody>
</table>

P Free passage between the engines, width 600 mm and height 2,000 mm.
Q Min. distance between engines: 2,400 mm (without gallery) and 2,600 mm (with gallery)
* Depending on alternator
** Weight incl. standard alternator (based on a Uljanik alternator)
All dimensions and masses are approximate, and subject to changes without prior notice.

Fig. 4.07.01: Power and outline of L21/31, IMO Tier II
L21/31-TII GenSet Data

5L: 200 kW/cyl., 6L-9L: 220 kW/Cyl. at 1,000 rpm

Reference Condition: Tropic

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature</td>
<td>°C 45</td>
</tr>
<tr>
<td>LT-water temperature inlet engine (from system)</td>
<td>°C 38</td>
</tr>
<tr>
<td>Air pressure</td>
<td>bar 1</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>% 50</td>
</tr>
</tbody>
</table>

Temperature basis

Setpoint HT cooling water engine outlet 1) °C 79 nominal (Range of mechanical thermostatic element 77 to 85)
Setpoint LT cooling water engine outlet 2) °C 36 nominal (Range of mechanical thermostatic element 29 to 41)
Setpoint Lube oil inlet engine °C 66 nominal (Range of mechanical thermostatic element 63 to 72)

Number of Cylinders

<table>
<thead>
<tr>
<th>Cylinders</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine output kW</td>
<td>1,000</td>
<td>1,320</td>
<td>1,540</td>
<td>1,760</td>
<td>1,980</td>
</tr>
<tr>
<td>Speed rpm</td>
<td>1,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Heat to be dissipated 3)

- Cooling water (C.W.) Cylinder kW 176 233 272 310 349
- Charge air cooler; cooling water HT kW 294 370 418 462 504
- Charge air cooler; cooling water LT kW 163 205 232 258 284
- Lube oil (L.O.) cooler kW 180 237 277 316 356
- Heat radiation engine kW 56 74 86 98 110

Flow rates 4)

<table>
<thead>
<tr>
<th>Circuit</th>
<th>Flow rates m³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal (inside engine)</td>
<td></td>
</tr>
<tr>
<td>HT circuit (cylinder + charge air cooler HT stage) m³/h</td>
<td>61 61 61 61 61</td>
</tr>
<tr>
<td>LT circuit (lube oil + charge air cooler LT stage) m³/h</td>
<td>34 34 46 46 46</td>
</tr>
<tr>
<td>Lube oil m³/h</td>
<td></td>
</tr>
<tr>
<td>External (from engine to system)</td>
<td></td>
</tr>
<tr>
<td>HT water flow (at 40°C inlet) m³/h</td>
<td>10.7 13.5 15.4 17.1 18.8</td>
</tr>
<tr>
<td>LT water flow (at 38°C inlet) m³/h</td>
<td>61 61 61 61 61</td>
</tr>
</tbody>
</table>

Air data

| Temperature of charge air at charge air cooler outlet °C | 49 52 54 55 56 |
| Air flow rate m³/h | 6,548 8,644 10,084 11,525 12,965 |
| Charge air pressure bar | 7.17 7.17 7.17 7.17 7.17 |
| Air required to dissipate heat radiation (engine) (t₂-t₁=10°C) m³/h | 17,980 23,800 27,600 31,500 35,300 |

Exhaust gas data 6)

| Volume flow (temperature turbocharger outlet) m³/h | 13,162 17,324 20,360 23,217 26,075 |
| Mass flow t/h | 7.4 9.7 11.4 13.0 14.6 |
| Temperature at turbine outlet °C | 349 349 349 349 349 |
| Heat content (190°C) kW | 352 463 544 620 696 |
| Permissible exhaust back pressure mbar | < 30 |

Pumps

| a) Engine driven pumps | |
| HT circuit cooling water (2.5 bar) m³/h | 61 61 61 61 61 |
| LT circuit cooling water (2.5 bar) m³/h | 61 61 61 61 61 |
| Lube oil (4.5 bar) m³/h | 34 34 46 46 46 |
| b) External pumps 5) | |
| Fuel oil feed pump (4 bar) m³/h | 0.30 0.39 0.46 0.52 0.59 |
| Fuel booster pump (8 bar) m³/h | 0.89 1.18 1.37 1.57 1.76 |

Starting air data

| Air consumption per start, incl. air for jet assist (TDI) Nm³ | 1.0 1.2 1.4 1.6 1.8 |

1) LT cooling water flow first through LT stage charge air cooler, then through lube oil cooler, water temperature outlet engine regulated by mechanical thermostat
2) HT cooling water flow first through water jacket and cylinder head, then through HT stage charge air cooler, water temperature outlet engine regulated by mechanical thermostat
3) Tolerance: + 10% for rating coolers, - 15% for heat recovery
4) Basic values for layout of the coolers
5) under above mentioned reference conditions
6) Tolerance: quantity +/- 5%, temperature +/- 20°C
7) under above mentioned temperature at turbine outlet and pressure
8) Tolerance of the pumps delivery capacities must be considered by the manufactures

Fig. 4.07.02a: List of capacities for L21/31, 900 rpm, IMO Tier II
L23/30H-TII GenSet Data

Bore: 225 mm  Stroke: 300 mm

<table>
<thead>
<tr>
<th>No. of Cyls.</th>
<th>A (mm)</th>
<th>* B (mm)</th>
<th>* C (mm)</th>
<th>H (mm)</th>
<th>**Dry weight GenSet (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 (720 r/min)</td>
<td>3,369</td>
<td>2,155</td>
<td>5,524</td>
<td>2,383</td>
<td>18.0</td>
</tr>
<tr>
<td>5 (750 r/min)</td>
<td>3,369</td>
<td>2,155</td>
<td>5,524</td>
<td>2,383</td>
<td>18.0</td>
</tr>
<tr>
<td>6 (720 r/min)</td>
<td>3,738</td>
<td>2,265</td>
<td>6,004</td>
<td>2,383</td>
<td>19.7</td>
</tr>
<tr>
<td>6 (750 r/min)</td>
<td>3,738</td>
<td>2,265</td>
<td>6,004</td>
<td>2,383</td>
<td>19.7</td>
</tr>
<tr>
<td>6 (900 r/min)</td>
<td>3,738</td>
<td>2,265</td>
<td>6,004</td>
<td>2,815</td>
<td>21.0</td>
</tr>
<tr>
<td>7 (720 r/min)</td>
<td>4,109</td>
<td>2,395</td>
<td>6,504</td>
<td>2,815</td>
<td>21.4</td>
</tr>
<tr>
<td>7 (750 r/min)</td>
<td>4,109</td>
<td>2,395</td>
<td>6,504</td>
<td>2,815</td>
<td>21.4</td>
</tr>
<tr>
<td>7 (900 r/min)</td>
<td>4,109</td>
<td>2,395</td>
<td>6,504</td>
<td>2,815</td>
<td>22.8</td>
</tr>
<tr>
<td>8 (720 r/min)</td>
<td>4,475</td>
<td>2,480</td>
<td>6,959</td>
<td>2,815</td>
<td>23.5</td>
</tr>
<tr>
<td>8 (750 r/min)</td>
<td>4,475</td>
<td>2,480</td>
<td>6,959</td>
<td>2,815</td>
<td>23.5</td>
</tr>
<tr>
<td>8 (900 r/min)</td>
<td>4,475</td>
<td>2,340</td>
<td>6,815</td>
<td>2,815</td>
<td>24.5</td>
</tr>
</tbody>
</table>

P  Free passage between the engines, width 600 mm and height 2,000 mm
Q  Min. distance between engines: 2,250 mm
*  Depending on alternator
**  Weight includes a standard alternator, make A. van Kaick

All dimensions and masses are approximate and subject to change without prior notice.

Fig. 4.08.01: Power and outline of L23/30H, IMO Tier II
### L23/30H-TII GenSet Data

#### 5-8L23/30H: 130 kW/Cyl., 720 rpm or 135 kW/Cyl., 750 rpm

**Reference Condition : Tropic**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>45°C</td>
</tr>
<tr>
<td>LT-water temperature inlet (from system)</td>
<td>36°C</td>
</tr>
<tr>
<td>Air pressure</td>
<td>bar</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>%</td>
</tr>
</tbody>
</table>

**Temperature basis**

<table>
<thead>
<tr>
<th>Setpoint HT cooling water engine outlet</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coolant temperature (engine equipped with HT thermostatic valve)</td>
<td>82°C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Setpoint Lube oil inlet engine</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coolant temperature (190°C)</td>
<td>60°C (SAE30), 66°C (SAE40)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Cylinders</th>
<th>kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>650 / 675</td>
</tr>
<tr>
<td>6</td>
<td>780 / 810</td>
</tr>
<tr>
<td>7</td>
<td>910 / 945</td>
</tr>
<tr>
<td>8</td>
<td>1,040 / 1,080</td>
</tr>
</tbody>
</table>

**Heat to be dissipated**

1) Tolerance: + 10% for rating coolers, - 15% for heat recovery

2) LT cooling water flow parallel through 1 stage charge air cooler and through lube oil cooler and HT cooling water flow only through water jacket and cylinder head, water temperature outlet engine regulated by thermostat

3) Basic values for layout of the coolers

4) Under above mentioned reference conditions

5) Tolerance: quantity +/- 5%, temperature +/- 20°C

**Heat radiation engine kW**

182 219 257 294

**Heat to be dissipated**

**Air data**

<table>
<thead>
<tr>
<th>Temperature of charge air at charge air cooler outlet, max.</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control air inlet engine</td>
<td>45°C</td>
</tr>
<tr>
<td>Air pressure</td>
<td>bar</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>%</td>
</tr>
</tbody>
</table>

**Air flow rate**

<table>
<thead>
<tr>
<th>m³/h</th>
<th>kg/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,556</td>
<td>7.39</td>
</tr>
</tbody>
</table>

**Charge air pressure**

<table>
<thead>
<tr>
<th>m³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.39</td>
</tr>
</tbody>
</table>

**Air required to dissipate heat radiation (engine) (t₂-t₁=10°C)**

<table>
<thead>
<tr>
<th>m³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>8,749</td>
</tr>
</tbody>
</table>

**Exhaust gas data**

<table>
<thead>
<tr>
<th>m³/h</th>
<th>t/h</th>
<th>°C</th>
<th>kW</th>
<th>mbar</th>
</tr>
</thead>
<tbody>
<tr>
<td>9,047</td>
<td>5.1</td>
<td>342</td>
<td>234</td>
<td>&lt; 30</td>
</tr>
</tbody>
</table>

**Pumps**

<table>
<thead>
<tr>
<th>m³/h</th>
<th>m³/h</th>
<th>m³/h</th>
<th>m³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>36</td>
<td>55</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>m³/h</th>
<th>m³/h</th>
<th>m³/h</th>
<th>m³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.48</td>
<td>0.23</td>
<td>0.48</td>
<td>0.48</td>
</tr>
</tbody>
</table>

**Starting air system**

<table>
<thead>
<tr>
<th>Nm³</th>
<th>2.0</th>
</tr>
</thead>
</table>

**Nozzle cooling data**

<table>
<thead>
<tr>
<th>m³/h</th>
<th>0.66</th>
</tr>
</thead>
</table>

**Cooling water pumps for for "Internal Cooling Water System 1"**

<table>
<thead>
<tr>
<th>m³/h</th>
<th>m³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>42</td>
</tr>
</tbody>
</table>

**Cooling water pumps for for "Internal Cooling Water System 2"**

<table>
<thead>
<tr>
<th>m³/h</th>
<th>m³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>24</td>
</tr>
</tbody>
</table>

**Fuel oil supply pump**

<table>
<thead>
<tr>
<th>m³/h</th>
<th>m³/h</th>
<th>0.23</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.57</td>
<td>0.32</td>
<td></td>
</tr>
</tbody>
</table>

**Fuel oil circulating pump**

<table>
<thead>
<tr>
<th>m³/h</th>
<th>m³/h</th>
<th>0.48</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.57</td>
<td>0.67</td>
<td></td>
</tr>
</tbody>
</table>

**Starting air system**

<table>
<thead>
<tr>
<th>Nm²</th>
<th>2.0</th>
</tr>
</thead>
</table>

**Nozzle cooling data**

<table>
<thead>
<tr>
<th>m³/h</th>
<th>0.66</th>
</tr>
</thead>
</table>

1) Tolerance: + 10% for rating coolers, - 15% for heat recovery

2) LT cooling water flow parallel through 1 stage charge air cooler and through lube oil cooler and HT cooling water flow only through water jacket and cylinder head, water temperature outlet engine regulated by thermostat

3) Basic values for layout of the coolers

4) Under above mentioned reference conditions

5) Tolerance: quantity +/- 5%, temperature +/- 20°C

6) Under below mentioned temperature at turbine outlet and pressure according above mentioned reference conditions

7) Tolerance of the pumps delivery capacities must be considered by the manufactures

8) To compensate for built on pumps, ambient condition, calorific value and adequate circulations flow. The ISO fuel oil consumption is multiplied by 1.45.

Fig. 4.08.02a: List of capacities for L23/30H, 720/750 rpm, IMO Tier II
L23/30H-TII GenSet Data

6-8L23/30H: 160 kW/Cyl., 900 rpm

Reference Condition: Tropic

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature</td>
<td>°C</td>
</tr>
<tr>
<td>LT-water temperature inlet engine</td>
<td>°C</td>
</tr>
<tr>
<td>Air pressure</td>
<td>bar</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>%</td>
</tr>
</tbody>
</table>

Temperature basis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setpoint HT cooling water engine outlet</td>
<td>°C</td>
</tr>
<tr>
<td>Setpoint Lube oil inlet engine</td>
<td>°C</td>
</tr>
</tbody>
</table>

Number of Cylinders

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

Engine output

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>kW rpm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>960</td>
</tr>
<tr>
<td></td>
<td>1,120</td>
</tr>
<tr>
<td></td>
<td>1,280</td>
</tr>
</tbody>
</table>

Heat to be dissipated

<table>
<thead>
<tr>
<th>Component</th>
<th>kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling water (C.W.) Cylinder</td>
<td></td>
</tr>
<tr>
<td>Charge air cooler; cooling water HT</td>
<td></td>
</tr>
<tr>
<td>Charge air cooler; cooling water LT</td>
<td></td>
</tr>
<tr>
<td>Lube oil (L.O.) cooler</td>
<td></td>
</tr>
<tr>
<td>Heat radiation engine</td>
<td></td>
</tr>
</tbody>
</table>

Air data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature of charge air at charge air cooler outlet, max.</td>
<td>°C</td>
</tr>
<tr>
<td>Air flow rate</td>
<td>m³/h</td>
</tr>
<tr>
<td>Charge air pressure</td>
<td>bar</td>
</tr>
<tr>
<td>Air required to dissipate heat radiation (engine) (t₂-t₁=10°C)</td>
<td>m³/h</td>
</tr>
</tbody>
</table>

Exhaust gas data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume flow (temperature turbocharger outlet)</td>
<td>m³/h</td>
</tr>
<tr>
<td>Mass flow</td>
<td>t/h</td>
</tr>
<tr>
<td>Temperature at turbine outlet</td>
<td>°C</td>
</tr>
<tr>
<td>Heat content (190°C)</td>
<td>kW</td>
</tr>
<tr>
<td>Permissible exhaust back pressure</td>
<td>mbar</td>
</tr>
</tbody>
</table>

Pumps

<table>
<thead>
<tr>
<th>Pumps</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine driven pumps</td>
<td></td>
</tr>
<tr>
<td>Fuel oil feed pump</td>
<td>m³/h</td>
</tr>
<tr>
<td>HT cooling water pump</td>
<td>m³/h</td>
</tr>
<tr>
<td>LT cooling water pump</td>
<td>m³/h</td>
</tr>
<tr>
<td>Lube oil</td>
<td>m³/h</td>
</tr>
<tr>
<td>External pumps</td>
<td></td>
</tr>
<tr>
<td>Diesel oil pump</td>
<td>m³/h</td>
</tr>
<tr>
<td>Fuel oil supply pump</td>
<td>m³/h</td>
</tr>
<tr>
<td>Fuel oil circulating pump</td>
<td>m³/h</td>
</tr>
<tr>
<td>Cooling water pumps for for &quot;Internal Cooling Water System 1&quot;</td>
<td>m³/h</td>
</tr>
<tr>
<td>+ LT cooling water pump</td>
<td>m³/h</td>
</tr>
<tr>
<td>Cooling water pumps for for &quot;Internal Cooling Water System 2&quot;</td>
<td>m³/h</td>
</tr>
<tr>
<td>+ LT cooling water pump</td>
<td>m³/h</td>
</tr>
<tr>
<td>HT cooling water pump</td>
<td>m³/h</td>
</tr>
<tr>
<td>+ LT cooling water pump</td>
<td>m³/h</td>
</tr>
<tr>
<td>Lube oil pump</td>
<td>m³/h</td>
</tr>
</tbody>
</table>

Starting air system

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air consuption per start</td>
<td>Nm³</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
</tr>
</tbody>
</table>

Nozzle cooling data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle cooling data</td>
<td>m³/h</td>
</tr>
</tbody>
</table>

1) Tolerance: ±10% for rating coolers, - 15% for heat recovery
2) LT cooling water flow parallel through 1 stage charge air cooler and through lube oil cooler and HT cooling water flow only through water jacket and cylinder head, water temperature outlet engine regulated by thermostat
3) Basic values for layout of the coolers
4) Under above mentioned reference conditions
5) Tolerance: quantity +/- 5%, temperature +/- 20°C
6) Under below mentioned temperature at turbine outlet and pressure according above mentioned reference conditions
7) Tolerance of the pumps delivery capacities must be considered by the manufactures
8) To compensate for built on pumps, ambient condition, calorific value and adequate circulations flow. The ISO fuel oil consumption is multiplied by 1.45.

Fig. 4.08.02b: List of capacities for L23/30H, 900 rpm, IMO Tier II
L27/38-TII GenSet Data

Bore: 270 mm  Stroke: 380 mm

<table>
<thead>
<tr>
<th>No. of Cyls.</th>
<th>A (mm)</th>
<th>B (mm)</th>
<th>C (mm)</th>
<th>H (mm)</th>
<th><strong>Dry weight GenSet (t)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>5 (720 r/min)</td>
<td>4,346</td>
<td>2,486</td>
<td>6,832</td>
<td>3,712</td>
<td>42.3</td>
</tr>
<tr>
<td>5 (750 r/min)</td>
<td>4,346</td>
<td>2,486</td>
<td>6,832</td>
<td>3,712</td>
<td>42.3</td>
</tr>
<tr>
<td>6 (720 r/min)</td>
<td>4,791</td>
<td>2,766</td>
<td>7,557</td>
<td>3,712</td>
<td>45.8</td>
</tr>
<tr>
<td>6 (750 r/min)</td>
<td>4,791</td>
<td>2,766</td>
<td>7,557</td>
<td>3,712</td>
<td>46.1</td>
</tr>
<tr>
<td>7 (720 r/min)</td>
<td>5,236</td>
<td>2,766</td>
<td>8,002</td>
<td>3,899</td>
<td>52.1</td>
</tr>
<tr>
<td>7 (750 r/min)</td>
<td>5,236</td>
<td>2,766</td>
<td>8,002</td>
<td>3,899</td>
<td>52.1</td>
</tr>
<tr>
<td>8 (720 r/min)</td>
<td>5,681</td>
<td>2,986</td>
<td>8,667</td>
<td>3,899</td>
<td>56.3</td>
</tr>
<tr>
<td>8 (750 r/min)</td>
<td>5,681</td>
<td>2,986</td>
<td>8,667</td>
<td>3,899</td>
<td>58.3</td>
</tr>
<tr>
<td>9 (720 r/min)</td>
<td>6,126</td>
<td>2,986</td>
<td>9,112</td>
<td>3,899</td>
<td>63.9</td>
</tr>
<tr>
<td>9 (750 r/min)</td>
<td>6,126</td>
<td>2,986</td>
<td>9,112</td>
<td>3,899</td>
<td>63.9</td>
</tr>
</tbody>
</table>

P Free passage between the engines, width 600 mm and height 2,000 mm
Q Min. distance between engines: 2,900 mm (without gallery) and 3,100 mm (with gallery)
* Depending on alternator
** Weight includes a standard alternator
All dimensions and masses are approximate and subject to change without prior notice.

Fig. 4.09.01: Power and outline of L27/38, IMO Tier II
### L27/38-TII GenSet Data

**Reference Condition: Tropic**

<table>
<thead>
<tr>
<th></th>
<th>°C</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature</td>
<td></td>
<td>45</td>
</tr>
<tr>
<td>LT-water temperature inlet engine (from system)</td>
<td></td>
<td>38</td>
</tr>
<tr>
<td>Air pressure</td>
<td></td>
<td>bar</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>%</td>
<td>50</td>
</tr>
</tbody>
</table>

#### Temperature basis

| Setpoint HT cooling water engine outlet 1) | °C | 79 nominal (Range of mechanical thermostatic element 77 to 85) |
| Setpoint LT cooling water engine outlet 2) | °C | 35 nominal (Range of mechanical thermostatic element 29 to 41) |
| Setpoint Lube oil inlet engine            | °C | 66 nominal (Range of mechanical thermostatic element 63 to 72) |

<table>
<thead>
<tr>
<th>Number of Cylinders</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine output kW</td>
<td>2,100</td>
<td>2,450</td>
<td>2,800</td>
<td>3,150</td>
</tr>
<tr>
<td>Speed rpm</td>
<td></td>
<td>720</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Heat to be dissipated 3)

| Cooling water (C.W.) Cylinder kW | 315 | 368 | 421 | 473 |
| Charge air cooler; cooling water HT kW | 668 | 784 | 903 | 1,022 |
| Charge air cooler; cooling water LT kW | 175 | 200 | 224 | 247 |
| Lube oil (L.O.) cooler kW | 282 | 329 | 376 | 423 |
| Heat radiation engine kW | 70 | 81 | 93 | 104 |

#### Flow rates 4)

| HT circuit (cylinder + charge air cooler HT stage) m³/h | 58 | 58 | 58 | 58 |
| LT circuit (lube oil + charge air cooler LT stage) m³/h | 58 | 58 | 58 | 58 |
| Lube oil m³/h | 64 | 92 | 92 | 92 |
| External (from engine to system) HT water flow (at 40°C inlet) m³/h | 21.5 | 24.8 | 28.1 | 31.4 |
| LT water flow (at 38°C inlet) m³/h | 58 | 58 | 58 | 58 |

#### Air data

| Temperature of charge air at charge air cooler outlet °C | 50 | 53 | 55 | 56 |
| Air flow rate m³/h 5) | 12,792 | 14,924 | 17,056 | 19,188 |
| kg/kWh | 6.67 | 6.67 | 6.67 | 6.67 |
| Charge air pressure bar | 4.01 |        |    | |
| Air required to dissipate heat radiation (engine) (t₂-t₁= 10°C) m³/h | 22,682 | 26,247 | 30,135 | 33,699 |

#### Exhaust gas data 6)

| Volume flow (temperature turbocharger outlet) m³/h 7) | 27,381 | 31,944 | 36,508 | 41,071 |
| Mass flow t/h | 14.4 | 16.8 | 19.2 | 21.6 |
| Temperature at turbine outlet °C | 388 | 388 | 388 | 388 |
| Heat content (190°C) kW | 857 | 1,000 | 1,143 | 1,285 |
| Permissible exhaust back pressure mbar | < 30 |

#### Pumps

<table>
<thead>
<tr>
<th>a) Engine driven pumps</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>HT circuit cooling water (2.5 bar) m³/h</td>
<td>58</td>
</tr>
<tr>
<td>Lube oil (4.5 bar) m³/h</td>
<td>64</td>
</tr>
<tr>
<td>b) External pumps 8)</td>
<td></td>
</tr>
<tr>
<td>Diesel oil pump (5 bar at fuel oil inlet A1) m³/h</td>
<td>1.48</td>
</tr>
<tr>
<td>Fuel oil supply pump (4 bar discharge pressure) m³/h</td>
<td>0.71</td>
</tr>
<tr>
<td>Fuel oil circulating pump (8 bar at fuel oil inlet A1) m³/h</td>
<td>1.48</td>
</tr>
</tbody>
</table>

#### Starting air data

| Air consumption per start, incl. air for jet assist (IR/TDI) Nm³ | 2.9 | 3.3 | 3.8 | 4.3 |

---

1) LT cooling water flow first through LT stage charge air cooler, then through lube oil cooler, water temperature outlet engine regulated by mechanical thermostat.
2) HT cooling water flow first through HT stage charge air cooler, then through water jacket and cylinder head, water temperature outlet engine regulated by mechanical thermostat.
3) Tolerance: ± 10% for rating coolers, ± 15% for heat recovery.
4) Basic values for layout of the coolers.
5) Under above mentioned reference conditions.
6) Tolerance: quantity ± 5%, temperature ± 20°C.
7) Under below mentioned temperature at turbine outlet and pressure according above mentioned reference conditions.
8) Tolerance of the pumps delivery capacities must be considered by the manufactures.

---

Fig. 4.09.02a: List of capacities for L27/38, 720 rpm, IMO Tier II
L27/38-TII GenSet Data
6-9L27/38: 350 kW/cyl., 750 rpm, MGO

Reference Condition : Tropic

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature</td>
<td>°C</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LT-water temperature inlet engine (from system)</td>
<td>°C</td>
<td>38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air pressure</td>
<td>bar</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative humidity</td>
<td>%</td>
<td>50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Temperature basis

1) LT cooling water flow first through LT stage charge air cooler, then through lube oil cooler, water temperature outlet engine regulated by mechanical thermostat.

2) HT cooling water flow first through HT stage charge air cooler, then through water jacket and cylinder head, water temperature outlet engine regulated by mechanical thermostat.

3) Tolerance: +10% for rating coolers, -15% for heat recovery.

4) Basic values for layout of the coolers.

5) Under above mentioned reference conditions.

6) Tolerance: quantity +/- 5%, temperature +/- 20°C.

7) Under below mentioned temperature at turbine outlet and pressure according above mentioned reference conditions.

8) Tolerance of the pumps delivery capacities must be considered by the manufactures.

Fig. 4.09.02b: List of capacities for L27/38, 750 rpm, IMO Tier II
L28/32H-TII GenSet Data

<table>
<thead>
<tr>
<th>No. of Cyls.</th>
<th>A (mm)</th>
<th>* B (mm)</th>
<th>* C (mm)</th>
<th>H (mm)</th>
<th>**Dry weight GenSet (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 (720 r/min)</td>
<td>4,279</td>
<td>2,400</td>
<td>6,679</td>
<td>3,184</td>
<td>32.6</td>
</tr>
<tr>
<td>5 (750 r/min)</td>
<td>4,279</td>
<td>2,400</td>
<td>6,679</td>
<td>3,184</td>
<td>32.6</td>
</tr>
<tr>
<td>6 (720 r/min)</td>
<td>4,759</td>
<td>2,510</td>
<td>7,269</td>
<td>3,184</td>
<td>36.3</td>
</tr>
<tr>
<td>6 (750 r/min)</td>
<td>4,759</td>
<td>2,510</td>
<td>7,269</td>
<td>3,184</td>
<td>36.3</td>
</tr>
<tr>
<td>7 (720 r/min)</td>
<td>5,499</td>
<td>2,680</td>
<td>8,179</td>
<td>3,374</td>
<td>39.4</td>
</tr>
<tr>
<td>7 (750 r/min)</td>
<td>5,499</td>
<td>2,680</td>
<td>8,179</td>
<td>3,374</td>
<td>39.4</td>
</tr>
<tr>
<td>8 (720 r/min)</td>
<td>5,979</td>
<td>2,770</td>
<td>8,749</td>
<td>3,374</td>
<td>40.7</td>
</tr>
<tr>
<td>8 (750 r/min)</td>
<td>5,979</td>
<td>2,770</td>
<td>8,749</td>
<td>3,374</td>
<td>40.7</td>
</tr>
<tr>
<td>9 (720 r/min)</td>
<td>6,199</td>
<td>2,690</td>
<td>8,889</td>
<td>3,534</td>
<td>47.1</td>
</tr>
<tr>
<td>9 (750 r/min)</td>
<td>6,199</td>
<td>2,690</td>
<td>8,889</td>
<td>3,534</td>
<td>47.1</td>
</tr>
</tbody>
</table>

P Free passage between the engines, width 600 mm and height 2,000 mm
Q Min. distance between engines: 2,655 mm (without gallery) and 2,850 mm (with gallery)
* Depending on alternator
** Weight includes a standard alternator, make A. van Kaick
All dimensions and masses are approximate and subject to change without prior notice.

Fig. 4.10.01: Power and outline of L28/32H, IMO Tier II
MAN Diesel

L28/32H-TII GenSet Data

5L-9L: 220 kW/Cyl. at 750 rpm

**Reference Condition: Tropic**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature</td>
<td>45°C</td>
</tr>
<tr>
<td>LT water temperature inlet engine (from system)</td>
<td>38°C</td>
</tr>
<tr>
<td>Air pressure</td>
<td>1 bar</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>50%</td>
</tr>
</tbody>
</table>

**Number of Cylinders**

<table>
<thead>
<tr>
<th>Cylinders</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>9</td>
</tr>
</tbody>
</table>

**Engine output**

<table>
<thead>
<tr>
<th>Cylinders</th>
<th>kW</th>
<th>rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,100</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>1,320</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,540</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,760</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,980</td>
<td></td>
</tr>
</tbody>
</table>

**Heat to be dissipated**

<table>
<thead>
<tr>
<th>Component</th>
<th>kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling water (C.W.) Cylinder</td>
<td>245</td>
</tr>
<tr>
<td>Charge air cooler; cooling water HT</td>
<td>294</td>
</tr>
<tr>
<td>Charge air cooler; cooling water LT</td>
<td>343</td>
</tr>
<tr>
<td>Lube oil (L.O.) cooler</td>
<td>392</td>
</tr>
<tr>
<td>Heat radiation engine</td>
<td>442</td>
</tr>
</tbody>
</table>

**Flow rates**

<table>
<thead>
<tr>
<th>Component</th>
<th>m³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal (inside engine)</td>
<td></td>
</tr>
<tr>
<td>HT cooling water cylinder</td>
<td>37</td>
</tr>
<tr>
<td>LT cooling water lube oil cooler</td>
<td>45</td>
</tr>
<tr>
<td>LT cooling water lube oil cooler **</td>
<td>50</td>
</tr>
<tr>
<td>LT cooling water charge air cooler</td>
<td>55</td>
</tr>
</tbody>
</table>

**Air data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>°C</th>
<th>m³/h</th>
<th>kg/kWh</th>
<th>bar</th>
<th>m³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature of charge air at charge air cooler</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>55</td>
</tr>
<tr>
<td>Air flow rate</td>
<td>7,826</td>
<td>9,391</td>
<td>10,966</td>
<td>12,521</td>
<td>14,087</td>
</tr>
<tr>
<td>Charge air pressure</td>
<td>7.79</td>
<td>7.79</td>
<td>7.79</td>
<td>7.79</td>
<td>7.79</td>
</tr>
<tr>
<td>Air required to dissipate heat radiation (engine) (t₂-t₁=10°C)</td>
<td>8,749</td>
<td>10,693</td>
<td>12,313</td>
<td>14,257</td>
<td>15,878</td>
</tr>
</tbody>
</table>

**Exhaust gas data**

<table>
<thead>
<tr>
<th>Component</th>
<th>m³/h</th>
<th>t/h</th>
<th>°C</th>
<th>kW</th>
<th>mbar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume flow (temperature turbocharger outlet)</td>
<td>15,520</td>
<td>18,624</td>
<td>21,728</td>
<td>24,832</td>
<td>27,936</td>
</tr>
<tr>
<td>Mass flow</td>
<td>8.8</td>
<td>10.5</td>
<td>12.3</td>
<td>14.1</td>
<td>15.8</td>
</tr>
<tr>
<td>Temperature at turbine outlet</td>
<td>342</td>
<td>342</td>
<td>342</td>
<td>342</td>
<td>342</td>
</tr>
<tr>
<td>Heat content (190°C)</td>
<td>401</td>
<td>481</td>
<td>561</td>
<td>641</td>
<td>721</td>
</tr>
<tr>
<td>Permissible exhaust back pressure</td>
<td>mbar</td>
<td></td>
<td></td>
<td></td>
<td>&lt; 30</td>
</tr>
</tbody>
</table>

**Pumps**

<table>
<thead>
<tr>
<th>Component</th>
<th>m³/h</th>
<th>m³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine driven pumps</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Fuel oil feed pump</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>HT circuit cooling water</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>LT circuit cooling water</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>Lube oil</td>
<td>24</td>
<td>24</td>
</tr>
</tbody>
</table>

**Diesel oil pump**

<table>
<thead>
<tr>
<th>Component</th>
<th>m³/h</th>
<th>m³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>(4 bar at fuel oil inlet A1)</td>
<td>0.78</td>
<td>0.93</td>
</tr>
<tr>
<td>Fuel oil supply pump</td>
<td>0.37</td>
<td>0.45</td>
</tr>
<tr>
<td>Fuel oil circulating pump</td>
<td>0.37</td>
<td>0.52</td>
</tr>
<tr>
<td>(8 bar at fuel oil inlet A1)</td>
<td>0.78</td>
<td>0.93</td>
</tr>
<tr>
<td>HT circuit cooling water</td>
<td>37</td>
<td>50</td>
</tr>
<tr>
<td>LT circuit cooling water</td>
<td>45</td>
<td>65</td>
</tr>
<tr>
<td>LT circuit cooling water</td>
<td>45</td>
<td>65</td>
</tr>
<tr>
<td>Lube oil</td>
<td>65</td>
<td>73</td>
</tr>
</tbody>
</table>

**Fig. 4.10.02a: List of capacities for L28/32H, 750 rpm, IMO Tier II**

---

1) Tolerance: + 10% for rating coolers, - 15% for heat recovery
2) Basic values for layout of the coolers
3) Under above mentioned reference conditions
4) Tolerance: quantity +/- 5%, temperature +/- 20°C
5) Under below mentioned temperature at turbine outlet and pressure according above mentioned reference conditions
6) Tolerance of the pumps delivery capacities must be considered by the manufactures

* Only valid for engines equipped with internal basic cooling water system no. 1 and 2.
** Only valid for engines equipped with combined coolers, internal basic cooling water system no. 3
L28/32H-TII GenSet Data

5L-9L: 210 kW/Cyl. at 720 rpm

Reference Condition: Tropic

| Air temperature | °C | 45 |
| LT water temperature inlet engine (from system) | °C | 38 |
| Air pressure | bar | 1 |
| Relative humidity | % | 50 |

| Number of Cylinders | - | 5 | 6 | 7 | 8 | 9 |
| Engine output | kW | 1.050 | 1.260 | 1.470 | 1.680 | 1.890 |
| Speed | rpm | 720 |

Heat to be dissipated

| Cooling water (C.W.) Cylinder | kW | 234 | 281 | 328 | 375 | 421 |
| Charge air cooler; cooling water HT | kW | 0 | (Single stage charge air cooler) |
| Charge air cooler; cooling water LT | kW | 355 | 397 | 500 | 553 | 592 |
| Lube oil (L.O.) cooler | kW | 191 | 230 | 268 | 306 | 345 |
| Heat radiation engine | kW | 26 | 31 | 36 | 42 | 47 |

Flow rates

| Internal (inside engine) |
| HT cooling water cylinder | m³/h | 37 | 45 | 50 | 55 | 60 |
| LT cooling water lube oil cooler | m³/h | 7.8 | 9.4 | 11 | 12.7 | 14.4 |
| LT cooling water lube oil cooler | m³/h | 28 | 28 | 40 | 40 | 40 |
| LT cooling water charge air cooler | m³/h | 37 | 45 | 55 | 65 | 75 |

Air data

| Temperature of charge air at charge air cooler outlet | °C | 51 | 52 | 51 | 52 | 53 |
| Air flow rate | m³/h | 7.355 | 8,826 | 10,297 | 11,768 | 13,239 |
| kg/kWh | 7.67 | 7.67 | 7.67 | 7.67 | 7.67 |
| Charge air pressure | bar | 1 |
| Air required to dissipate heat radiation (engine) (t₂-t₁=10°C) | m³/h | 8,425 | 10,045 | 11,665 | 13,609 | 15,230 |

Exhaust gas data

| Volume flow (temperature turbocharger outlet) | m³/h | 14,711 | 17,653 | 20,595 | 23,537 | 26,479 |
| Mass flow | t/h | 8.3 | 9.9 | 11.6 | 13.2 | 14.9 |
| Temperature at turbine outlet | °C | 347 | 347 | 347 | 347 | 347 |
| Heat content (190°C) | kW | 389 | 467 | 545 | 623 | 701 |
| Permissible exhaust back pressure | mbar | < 30 |

Pumps

| Engine driven pumps |
| Fuel oil feed pump (5,5-7,5 bar) | m³/h | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| HT circuit cooling water (1,0-2,5 bar) | m³/h | 45 | 45 | 60 | 60 | 60 |
| LT circuit cooling water (1,0-2,5 bar) | m³/h | 45 | 60 | 75 | 75 | 75 |
| Lube oil (3,0-5,0 bar) | m³/h | 24 | 24 | 34 | 34 | 34 |
| Diesel oil pump (4 bar at fuel oil inlet A1) | m³/h | 0.74 | 0.89 | 1.04 | 1.19 | 1.34 |
| Fuel oil supply pump (4 bar discharge pressure) | m³/h | 0.36 | 0.43 | 0.50 | 0.57 | 0.64 |
| Fuel oil circulating pump (8 bar at fuel oil inlet A1) | m³/h | 0.74 | 0.89 | 1.04 | 1.19 | 1.34 |
| HT circuit cooling water (1,0-2,5 bar) | m³/h | 37 | 45 | 50 | 55 | 60 |
| LT circuit cooling water (1,0-2,5 bar) | m³/h | 45 | 54 | 65 | 77 | 89 |
| LT circuit cooling water (1,0-2,5 bar) | m³/h | 65 | 73 | 95 | 105 | 115 |
| Lube oil (3,0-5,0 bar) | m³/h | 22 | 23 | 25 | 27 | 28 |

1) Tolerance: + 10% for rating coolers, - 15% for heat recovery
2) Basic values for layout of the coolers
3) under above mentioned reference conditions
4) Tolerance: quantity +/- 5%, temperature +/- 20°C
5) Under below mentioned temperature at turbine outlet and pressure according above mentioned reference conditions
6) Tolerance of the pumps delivery capacities must be considered by the manufactures

* Only valid for engines equipped with internal basic cooling water system no. 1 and 2.
** Only valid for engines equipped with combined coolers, internal basic cooling water system no. 3

Fig. 4.10.02b: List of capacities for L28/32H, 720 rpm, IMO Tier II.
Installation Aspects
Space Requirements and Overhaul Heights

The latest version of most of the drawings of this section is available for download at www.marine.man.eu → 'Two-Stroke' → 'Installation Drawings'. First choose engine series, then engine type and select from the list of drawings available for download.

Space Requirements for the Engine

The space requirements stated in Section 5.02 are valid for engines rated at nominal MCR (L₁).

The additional space needed for engines equipped with PTO is stated in Chapter 4.

If, during the project stage, the outer dimensions of the turbocharger seem to cause problems, it is possible, for the same number of cylinders, to use turbochargers with smaller dimensions by increasing the indicated number of turbochargers by one, see Chapter 3.

Overhaul of Engine

The distances stated from the centre of the crankshaft to the crane hook are for the normal lifting procedure and the reduced height lifting procedure (involving tilting of main components). The lifting capacity of a normal engine room crane can be found in Fig. 5.04.01.

The area covered by the engine room crane shall be wide enough to reach any heavy spare part required in the engine room.

A lower overhaul height is, however, available by using the MAN B&W Double-Jib crane, built by Danish Crane Building A/S, shown in Figs. 5.04.02 and 5.04.03.

Please note that the distance ‘E’ in Fig. 5.02.01, given for a double-jib crane is from the centre of the crankshaft to the lower edge of the deck beam.

A special crane beam for dismantling the turbocharger must be fitted. The lifting capacity of the crane beam for dismantling the turbocharger is stated in Section 5.03.

The overhaul tools for the engine are designed to be used with a crane hook according to DIN 15400, June 1990, material class M and load capacity 1Am and dimensions of the single hook type according to DIN 15401, part 1.

The total length of the engine at the crankshaft level may vary depending on the equipment to be fitted on the fore end of the engine, such as adjustable counterweights, tuning wheel, moment compensators or PTO.
Space Requirement

Minimum access conditions around the engine to be used for an escape route is 600 mm.

The dimensions are given in mm, and are for guidance only. If the dimensions cannot be fulfilled, please contact MAN Diesel & Turbo or our local representative.

Fig. 5.02.01a: Space requirement for the engine, turbocharger on exhaust side, 4 59 122
The min. **engine room crane** height is ie. dependent on the choice of crane, see the actual heights “H1”, “H2” or “H3”.

The min. **engine room** height is dependent on “H1”, “H2”, “H3” or “E+D”.

Max. length of engine see the engine outline drawing

Length of engine with PTO see corresponding space requirement

---

![Fig. 5.02.01b: Space requirement for the engine](image-url)
Crane beam for overhaul of turbocharger

For the overhaul of a turbocharger, a crane beam with trolleys is required at each end of the turbocharger.

Two trolleys are to be available at the compressor end and one trolley is needed at the gas inlet end.

Crane beam no. 1 is for dismantling of turbocharger components.
Crane beam no. 2 is for transporting turbocharger components.
See Figs. 5.03.01a and 5.03.02.

The crane beams can be omitted if the main engine room crane also covers the turbocharger area.

The crane beams are used and dimensioned for lifting the following components:

- Exhaust gas inlet casing
- Turbocharger inlet silencer
- Compressor casing
- Turbine rotor with bearings

The crane beams are to be placed in relation to the turbocharger(s) so that the components around the gas outlet casing can be removed in connection with overhaul of the turbocharger(s).

The crane beam can be bolted to brackets that are fastened to the ship structure or to columns that are located on the top platform of the engine.

The lifting capacity of the crane beam for the heaviest component ‘W’, is indicated in Fig. 5.03.01b for the various turbocharger makes. The crane beam shall be dimensioned for lifting the weight ‘W’ with a deflection of some 5 mm only.

HB indicates the position of the crane hook in the vertical plane related to the centre of the turbocharger. HB and b also specifies the minimum space for dismantling.

For engines with the turbocharger(s) located on the exhaust side, EoD No. 4 59 122, the letter ‘a’ indicates the distance between vertical centrelines of the engine and the turbocharger.

The figures ‘a’ are stated on the ‘Engine and Gallery Outline’ drawing, Section 5.06.

*) Available on request

Fig. 5.03.01a: Required height and distance

Fig. 5.03.01b: Required height and distance and weight
Crane beam for turbochargers

Fig. 5.03.02: Crane beam for turbocharger
Crane beam for overhaul of air cooler
Overhaul/exchange of scavenge air cooler.

Valid for air cooler design for the following engines with more than one turbochargers mounted on the exhaust side.

1. Dismantle all the pipes in the area around the air cooler.
2. Dismantle all the pipes around the inlet cover for the cooler.
3. Take out the cooler insert by using the above placed crane beam mounted on the engine.
4. Turn the cooler insert to an upright position.
5. Dismantle the platforms below the air cooler.
6. Lower down the cooler insert between the gallery brackets and down to the engine room floor. Make sure that the cooler insert is supported, e.g. on a wooden support.
7. Move the air cooler insert to an area covered by the engine room crane using the lifting beam mounted below the lower gallery of the engine.
8. By using the engine room crane the air cooler insert can be lifted out of the engine room.

Fig.: 5.03.03: Crane beam for overhaul of air cooler, turbochargers located on exhaust side of the engine
Engine room crane

The crane hook travelling area must cover at least the full length of the engine and a width in accordance with dimension A given on the drawing (see cross-hatched area).

It is furthermore recommended that the engine room crane be used for transport of heavy spare parts from the engine room hatch to the spare part stores and to the engine. See example on this drawing.

The crane hook should at least be able to reach down to a level corresponding to the centre line of the crankshaft.

For overhaul of the turbocharger(s), trolley mounted chain hoists must be installed on a separate crane beam or, alternatively, in combination with the engine room crane structure, see separate drawing with information about the required lifting capacity for overhaul of turbochargers.

1) The lifting tools for the engine are designed to fit together with a standard crane hook with a lifting capacity in accordance with the figure stated in the table. If a larger crane hook is used, it may not fit directly to the overhaul tools, and the use of an intermediate shackle or similar between the lifting tool and the crane hook will affect the requirements for the minimum lifting height in the engine room (dimension B).

2) The hatched area shows the height where an MAN B&W Double-Jib Crane has to be used.

<table>
<thead>
<tr>
<th>Mass in kg including lifting tools</th>
<th>Crane capacity in tons selected in accordance with DIN and JIS standard capacities</th>
<th>Crane operating width in mm</th>
<th>Normal Crane Height to crane hook in mm for:</th>
<th>MAN B&amp;W Double-Jib Crane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder cover complete with exhaust valve</td>
<td>Cylinder liner with cooling jacket</td>
<td>Piston with rod and stuffing box</td>
<td>Normal crane</td>
<td>MAN B&amp;W Double-Jib Crane</td>
</tr>
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<td>4,175</td>
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<td>5.0</td>
<td>2x3.0</td>
</tr>
</tbody>
</table>

Fig. 5.04.01: Engine room crane
Overhaul with MAN B&W Double-Jib Crane

The MAN B&W Double-Jib crane is available from:

Danish Crane Building A/S
P.O. Box 54
Østerlandsvej 2
DK-9240 Nibe, Denmark
Telephone: + 45 98 35 31 33
Telefax: + 45 98 35 30 33
E-mail: dcb@dcb.dk

Fig. 5.04.02: Overhaul with Double-Jib crane
MAN B&W Double-Jib Crane

This crane is adapted to the special tool for low overhaul.

Dimensions are available on request.

Fig. 5.04.03: MAN B&W Double-Jib crane, option: 4 88 701
Engine Outline, Galleries and Pipe Connections

Engine outline

The total length of the engine at the crankshaft level may vary depending on the equipment to be fitted on the fore end of the engine, such as adjustable counterweights, tuning wheel, moment compensators or PTO, which are shown as alternatives in Section 5.06.

Engine masses and centre of gravity

The partial and total engine masses appear from Section 19.04, ‘Dispatch Pattern’, to which the masses of water and oil in the engine, Section 5.08, are to be added. The centre of gravity is shown in Section 5.07, in both cases including the water and oil in the engine, but without moment compensators or PTO.

Gallery outline

Section 5.06 show the gallery outline for engines rated at nominal MCR (L1).

Engine pipe connections

The positions of the external pipe connections on the engine are stated in Section 5.09, and the corresponding lists of counterflanges for pipes and turbocharger in Section 5.10.

The flange connection on the turbocharger gas outlet is rectangular, but a transition piece to a circular form can be supplied as an option: 4 60 601.
Centre of Gravity

For engines with two turbochargers*

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<th>No. of cylinders</th>
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<tr>
<td>Distance X mm</td>
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<td></td>
<td>-169</td>
<td></td>
</tr>
<tr>
<td>Distance Y mm</td>
<td></td>
<td></td>
<td>5,120</td>
<td>Available on request</td>
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<tr>
<td>Distance Z mm</td>
<td></td>
<td></td>
<td>2,883</td>
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All values stated are approximate.

* Data for engines with a different number of turbochargers is available on request.

Fig. 5.07: Centre of gravity, turbocharger located on exhaust side of engine
# Mass of Water and Oil

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<td>Mass of water</td>
<td>Mass of oil</td>
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<tr>
<td></td>
<td>Jacket cooling water kg</td>
<td>Scavenge air cooling water kg</td>
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<td>8</td>
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<td>676</td>
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*Fig. 5.08.01: Water and oil in engine*
Counterflanges, Connection D

MAN Type TCA33

MAN Type TCA44-99

MAN Diesel
Counterflanges, Connection D

**MAN Type TCR**

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<th>PCD</th>
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<th>O</th>
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**ABB Type A100/A200-L**

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### MHI Type MET

#### Series MB

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#### Series MA

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*Fig. 5.10.02: Turbocharger, exhaust outlet*
Counterflanges, Connection E

MAN Type TCA

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<th>Dia/JIS</th>
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ABB Type A100/A200-L

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---

Fig. 5.10.03: Venting of lubricating oil discharge pipe for turbochargers
### MHI Type MET MB

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### Connection EB

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Engine Seating and Holding Down Bolts

The latest version of most of the drawings of this section is available for download at www.marine.man.eu → ‘Two-Stroke’ → ‘Installation Drawings’. First choose engine series, then engine type and select ‘Engine seating’ in the general section of the list of drawings available for download.

Engine seating and arrangement of holding down bolts

The dimensions of the seating stated in Figs. 5.12.01 and 5.12.02 are for guidance only.

The engine is designed for mounting on epoxy chocks, EoD: 4 82 102, in which case the underside of the bedplate’s lower flanges has no taper.

The epoxy types approved by MAN Diesel & Turbo are:

- ‘Chockfast Orange PR 610 TCF’ from ITW Philadelphia Resins Corporation, USA
- ‘Durasin’ from Daemmstoff Industrie Korea Ltd
- ‘Epocast 36’ from H.A. Springer - Kiel, Germany
- ‘EPY’ from Marine Service Jaroszewicz S.C., Poland
- ‘Loctite Fixmaster Marine Chocking’, Henkel
Epoxy Chocks Arrangement

For details of chocks and bolts see special drawings.
For securing of supporting chocks see special drawing.

This drawing may, subject to the written consent of the actual engine builder concerned, be used as a basis for marking-off and drilling the holes for holding down bolts in the top plates, provided that:

1) The engine builder drills the holes for holding down bolts in the bedplate while observing the tolerated locations indicated on MAN B&W engine drawings for machining the bedplate.

2) The shipyard drills the holes for holding down bolts in the top plates while observing the tolerated locations given on the present drawing.

3) The holding down bolts are made in accordance with MAN B&W engine drawings of these bolts.

---

Fig. 5.12.01: Arrangement of epoxy chocks and holding down bolts

---

MAN B&W diesel engines are built by MAN Diesel.
Engine Seating Profile

Section A-A

This space to be kept free from pipes etc. along both sides of the engine in order to facilitate the overhaul work on holding down bolts, supporting chocks and side chocks.

Holding down bolts, option: 4 82 602 include:
1. Protecting cap
2. Spherical nut
3. Spherical washer
4. Distance pipe
5. Round nut
6. Holding down bolt

Fig. 5.12.02a: Profile of engine seating with vertical lubricating oil outlet
Side chock brackets, option: 4 82 622 includes:
1. Side chock brackets

Side chock liners, option: 4 82 620 includes:
2. Liner for side chock
3. Lock plate
4. Washer
5. Hexagon socket set screw

End chock bolts, option: 4 82 610 includes:
1. Stud for end chock bolt
2. Round nut
3. Round nut
4. Spherical washer
5. Spherical washer
6. Protecting cap

End chock liner, option: 4 82 612 includes:
7. Liner for end chock

End chock brackets, option: 4 82 614 includes:
8. End chock bracket
Engine Top Bracing

The so-called guide force moments are caused by the transverse reaction forces acting on the crossheads due to the connecting rod and crankshaft mechanism. When the piston of a cylinder is not exactly in its top or bottom position the gas force from the combustion, transferred through the connecting rod, will have a component acting on the crosshead and the crankshaft perpendicularly to the axis of the cylinder. Its resultant is acting on the guide shoe and together they form a guide force moment.

The moments may excite engine vibrations moving the engine top athwart ships and causing a rocking (excited by H-moment) or twisting (excited by X-moment) movement of the engine. For engines with less than seven cylinders, this guide force moment tends to rock the engine in the transverse direction, and for engines with seven cylinders or more, it tends to twist the engine.

The guide force moments are harmless to the engine except when resonance vibrations occur in the engine/double bottom system. They may, however, cause annoying vibrations in the superstructure and/or engine room, if proper countermeasures are not taken.

As a detailed calculation of this system is normally not available, MAN Diesel & Turbo recommends that top bracing is installed between the engine’s upper platform brackets and the casing side.

However, the top bracing is not needed in all cases. In some cases the vibration level is lower if the top bracing is not installed. This has normally to be checked by measurements, i.e. with and without top bracing.

If a vibration measurement in the first vessel of a series shows that the vibration level is acceptable without the top bracing, we have no objection to the top bracing being removed and the rest of the series produced without top bracing. It is our experience that especially the 7-cylinder engine will often have a lower vibration level without top bracing.

Without top bracing, the natural frequency of the vibrating system comprising engine, ship’s bottom, and ship’s side is often so low that resonance with the excitation source (the guide force moment) can occur close to the normal speed range, resulting in the risk of vibration.

With top bracing, such a resonance will occur above the normal speed range, as the natural frequencies of the double bottom/main engine system will increase. The impact of vibration is thus lowered.

The top bracing is normally installed on the exhaust side of the engine, but can alternatively be installed on the manoeuvring side. A combination of exhaust side and manoeuvring side installation is also possible.

The top bracing system is installed either as a mechanical top bracing or a hydraulic top bracing. Both systems are described below.

Mechanical top bracing

The mechanical top bracing comprises stiff connections between the engine and the hull.

The top bracing stiffener consists of a double bar tightened with friction shims at each end of the mounting positions. The friction shims allow the top bracing stiffener to move in case of displacements caused by thermal expansion of the engine or different loading conditions of the vessel. Furthermore, the tightening is made with a well-defined force on the friction shims, using disc springs, to prevent overloading of the system in case of an excessive vibration level.
The mechanical top bracing is to be made by the shipyard in accordance with MAN Diesel & Turbo instructions.

By a different pre-setting of the relief valve, the top bracing is delivered in a low-pressure version (26 bar) or a high-pressure version (40 bar).

The top bracing unit is designed to allow displacements between the hull and engine caused by thermal expansion of the engine or different loading conditions of the vessel.

**Hydraulic top bracing**

The hydraulic top bracing is an alternative to the mechanical top bracing used mainly on engines with a cylinder bore of 50 or more. The installation normally features two, four or six independently working top bracing units.

The top bracing unit consists of a single-acting hydraulic cylinder with a hydraulic control unit and an accumulator mounted directly on the cylinder unit.

The top bracing is controlled by an automatic switch in a control panel, which activates the top bracing when the engine is running. It is possible to programme the switch to choose a certain rpm range, at which the top bracing is active. For service purposes, manual control from the control panel is also possible.

When active, the hydraulic cylinder provides a pressure on the engine in proportion to the vibration level. When the distance between the hull and engine increases, oil flows into the cylinder under pressure from the accumulator. When the distance decreases, a non-return valve prevents the oil from flowing back to the accumulator, and the pressure rises. If the pressure reaches a preset maximum value, a relief valve allows the oil to flow back to the accumulator, hereby maintaining the force on the engine below the specified value.

---

**Fig. 5.13.01: Mechanical top bracing stiffener.**

Option: 4 83 112

**Fig. 5.13.02: Outline of a hydraulic top bracing unit.**

The unit is installed with the oil accumulator pointing either up or down. Option: 4 83 123
Mechanical Top Bracing

This symbol indicates that the top bracing is attached at point P.

This symbol indicates that the top bracing is attached at point Q.

Cylinder number

Turbocharger

Chain box

This symbol indicates that the top bracing is attached at point P.

This symbol indicates that the top bracing is attached at point Q.

Cylinder number

Turbocharger

Chain box
Horizontal distance between top bracing fix point and cyl. 1

<p>| | |</p>
<table>
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<td>a</td>
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<td>g</td>
<td>7,735</td>
</tr>
<tr>
<td>h</td>
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Horizontal vibrations on top of engine are caused by the guide force moments. For 4-7 cylinder engines the H-moment is the major excitation source and for larger cylinder numbers an X-moment is the major excitation source.

For engines with vibrations excited by an X-moment, bracing at the centre of the engine are of only minor importance.

Top bracing should only be installed on one side, either the exhaust side or the manoeuvring side. If top bracing has to be installed on manoeuvring side, please contact MAN Diesel & Turbo.

If the minimum built-in length can not be fulfilled, please contact MAN Diesel & Turbo or our local representative.

The complete arrangement to be delivered by the shipyard.

<table>
<thead>
<tr>
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Fig. 5.14: Mechanical top bracing arrangement
Hydraulic Top Bracing Arrangement

Hydraulic top bracing should be installed on one side, either the exhaust side (Alternative 1) or the camshaft side (Alternative 2).

<table>
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<tr>
<th>Turbocharger</th>
<th>Q</th>
<th>R</th>
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Fig. 5.15.01: Hydraulic top bracing data
As the rigidity of the casing structure to which the top bracing is attached is most important, it is recommended that the top bracing is attached directly into a deck.

Required rigidity of the casing side point A:

In the axial direction of the hydraulic top bracing:  
Force per bracing: 127 kN

Max. corresponding deflection of casing side: 0.51 mm

In the horizontal and vertical direction of the hydraulic top bracing:
Force per bracing: 22 kN

Max. corresponding deflection of casing side: 2.00 mm

Fig. 5.15.01: Hydraulic top bracing data
Components for Engine Control System

Installation of ECS in the Engine Control Room

The following items are to be installed in the ECR (Engine Control Room):

- 2 pcs EICU (Engine Interface Control Unit)
  (1 pcs only for ME-B engines)
- 1 pcs MOP A (Main Operating Panel)
  EC-MOP with touch display, 15”
  or
  Touch display, 15”
  PC unit with pointing device for MOP
- 1 pcs MOP B
  EC-MOP with touch display, 15”
  or
  Touch display, 15”
  PC unit with keyboard and pointing device
- 1 pcs PMI/CoCoS system software
  Display, 19”
  PC unit
- 1 pcs Printer (Yard supply)
- 1 pcs Ethernet Switch and VPN router
  with firewall

The EICU functions as an interface unit to ECR related systems such as AMS (Alarm and Monitoring System), RCS (Remote Control System) and Safety System. On ME-B engines the EICU also controls the HPS.

MOP A and B are redundant and are the operator’s interface to the ECS. Via both MOPs, the operator can control and view the status of the ECS. Via the PMI/CoCoS PC, the operator can view the status and operating history of the ECS and the engine.

The PMI Auto-tuning application is run on a standard PC. The PMI Auto-tuning system is used to optimize the combustion process with minimal operator attendance and improve the efficiency of the engine. See Section 18.02.

CoCoS-EDS ME Basic is included as part of the standard software package installed on the PMI/CoCoS PC. Optionally, the full version of CoCoS-EDS may be purchased separately. See Section 18.03.

Fig. 5.16.01 Network and PC components for the ME/ME-B Engine Control System
EC-MOP
- Integrated PC unit and touch display
  - Direct dimming control (0-100%)
  - USB connections at front
  - IP54 resistant front

MOP PC
- MOP control unit
- Without display

Main operating panel (Display)
- LCD (TFT) monitor 15" with touch display (calibrated)
  - Direct dimming control (0-100%)
  - USB connection at front
  - IP54 resistant front

Pointing device
- Keyboard model
  - UK version, 104 keys
  - USB connection
- Trackball mouse
  - USB connection

PMI/CoCos Display
- LCD (TFT) monitor 19"
  - Active matrix
  - Resolution 1,280x1,024, auto scaling
  - Direct dimming control (0-100%)
  - IP65 resistant front

PMI/CoCos PC
- Standard industry PC with MS Windows operating system, UK version

Router
- Ethernet switch and VPN router with firewall

Fig. 5.16.02 MOP PC equipment for the ME/ME-B Engine Control System
**Printer**
- Network printer, ink colour printer

**EICU Cabinet**
- Engine interface control cabinet for ME-ECS for installation in ECR (recommended) or ER

---

*Fig. 5.16.03: The network printer and EICU cabinet unit for the ME Engine Control System*

**Engine control room console**
- Recommended outline of Engine Control Room console with ME equipment

---

* Fig. 5.16.04: Example of Engine Control Room console

* Yard supply

Oil mist detector equipment depending on supplier/maker
BWM: Bearing Wear Monitoring
Shaftline Earthing Device

Scope and field of application

A difference in the electrical potential between the hull and the propeller shaft will be generated due to the difference in materials and to the propeller being immersed in sea water.

In some cases, the difference in the electrical potential has caused spark erosion on the thrust, main bearings and journals of the crankshaft of the engine.

In order to reduce the electrical potential between the crankshaft and the hull and thus prevent spark erosion, a highly efficient shaftline earthing device must be installed.

The shaftline earthing device should be able to keep the electrical potential difference below 50 mV DC. A shaft-to-hull monitoring equipment with a mV-meter and with an output signal to the alarm system must be installed so that the potential and thus the correct function of the shaftline earthing device can be monitored.

Note that only one shaftline earthing device is needed in the propeller shaft system.

Design description

The shaftline earthing device consists of two silver slip rings, two arrangements for holding brushes including connecting cables and monitoring equipment with a mV-meter and an output signal for alarm.

The slip rings should be made of solid silver or back-up rings of cobber with a silver layer all over. The expected life span of the silver layer on the slip rings should be minimum 5 years.

The brushes should be made of minimum 80% silver and 20% graphite to ensure a sufficient electrical conducting capability.

Resistivity of the silver should be less than 0.1μ Ohm x m. The total resistance from the shaft to the hull must not exceed 0.001 Ohm.

Cabling of the shaftline earthing device to the hull must be with a cable with a cross section not less than 45 mm². The length of the cable to the hull should be as short as possible.

Monitoring equipment should have a 4-20 mA signal for alarm and a mV-meter with a switch for changing range. Primary range from 0 to 50 mV DC and secondary range from 0 to 300 mV DC.

When the shaftline earthing device is working correctly, the electrical potential will normally be within the range of 10-50 mV DC depending of propeller size and revolutions.

The alarm set-point should be 80 mV for a high alarm. The alarm signals with an alarm delay of 30 seconds and an alarm cut-off, when the engine is stopped, must be connected to the alarm system.

Connection of cables is shown in the sketch, see Fig. 5.17.01.
Shaftline earthing device installations

The shaftline earthing device slip rings must be mounted on the foremost intermediate shaft as close to the engine as possible, see Fig. 5.17.02

Fig. 5.17.01: Connection of cables for the shaftline earthing device

Fig. 5.17.02: Installation of shaftline earthing device in an engine plant without shaft-mounted generator
When a generator is fitted in the propeller shaft system, where the rotor of the generator is part of the intermediate shaft, the shaftline earthing device must be mounted between the generator and the engine, see Fig. 5.17.03.

Fig. 5.17.03: Installation of shaftline earthing device in an engine plant with shaft-mounted generator
MAN Alpha Controllable Pitch Propeller and Alphatronic Propulsion Control

MAN Diesel & Turbo’s MAN Alpha Controllable Pitch propeller

On MAN Diesel & Turbo’s MAN Alpha VBS type Controllable Pitch (CP) propeller, the hydraulic servo motor setting the pitch is built into the propeller hub. A range of different hub sizes is available to select an optimum hub for any given combination of power, revolutions and ice class.

Standard blade/hub materials are Ni-Al-bronze. Stainless steel is available as an option. The propellers are based on ‘no ice class’ but are available up to the highest ice classes.

VBS type CP propeller designation and range

The VBS type CP propellers are designated according to the diameter of their hubs, i.e. ‘VBS2150’ indicates a propeller hub diameter of 2,150 mm.

The standard VBS type CP propeller programme, its diameters and the engine power range covered is shown in Fig. 5.18.01.

The servo oil system controlling the setting of the propeller blade pitch is shown in Fig.5.18.05.

Fig. 5.18.01: MAN Alpha type VBS Mk 5 Controllable Pitch (CP) propeller range. As standard the VBS Mk 5 versions are 4-bladed; 5-bladed versions are available on request.
Data Sheet for Propeller

Identification: _______________________________

For propeller design purposes please provide us with the following information:

1. S: ____________ mm
   W: ____________ mm
   I: ____________ mm (as shown above)

2. Stern tube and shafting arrangement layout

3. Propeller aperture drawing

4. Complete set of reports from model tank (resistance test, self-propulsion test and wake measurement). In case model test is not available the next page should be filled in.

5. Drawing of lines plan

6. Classification Society: __________
   Ice class notation: __________

7. Maximum rated power of shaft generator: kW

8. Optimisation condition for the propeller:
   To obtain the highest propeller efficiency please identify the most common service condition for the vessel.
   Ship speed: ________________ kn
   Engine service load: ____________ %
   Service/sea margin: ____________ %
   Shaft generator service load: __________ kW
   Draft: ________________ m

9. Comments:

Table 5.18.02b: Data sheet for propeller design purposes
Main Dimensions

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<tr>
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<td>m</td>
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</table>

Table 5.18.03: Data sheet for propeller design purposes, in case model test is not available this table should be filled in

Propeller clearance

To reduce pressure impulses and vibrations emitted from the propeller to the hull, MAN Diesel & Turbo recommends a minimum tip clearance as shown in Fig. 5.18.04.

For ships with slender aft body and favourable inflow conditions the lower values can be used, whereas full afterbody and large variations in wake field cause the upper values to be used.

In twin-screw ships the blade tip may protrude below the base line.

![Propeller clearance](image-url)
Servo oil system for VBS type CP propeller

The design principle of the servo oil system for MAN Diesel & Turbo’s MAN Alpha VBS type CP propeller is shown in Fig. 5.18.05.

The VBS system consists of a servo oil tank unit, the Hydraulic Power Unit, and a coupling flange with electrical pitch feedback box and oil distributor ring.

The electrical pitch feedback box continuously measures the position of the pitch feedback ring and compares this signal with the pitch order signal.

If deviation occurs, a proportional valve is actuated. Hereby high pressure oil is fed to one or the other side of the servo piston, via the oil distributor ring, until the desired propeller pitch has been reached.

The pitch setting is normally remote controlled, but local emergency control is possible.

Fig. 5.18.05: Servo oil system for MAN Alpha VBS type CP propeller
Hydraulic Power Unit for MAN Alpha CP propeller

The servo oil tank unit, the Hydraulic Power Unit for MAN Diesel & Turbo's MAN Alpha CP propeller shown in Fig. 5.18.06, consists of an oil tank with all other components top mounted to facilitate installation at yard.

Two electrically driven pumps draw oil from the oil tank through a suction filter and deliver high pressure oil to the proportional valve.

One of two pumps are in service during normal operation, while the second will start up at powerful manoeuvring.

A servo oil pressure adjusting valve ensures minimum servo oil pressure at any time hereby minimizing the electrical power consumption.

Maximum system pressure is set on the safety valve.

The return oil is led back to the tank via a thermostatic valve, cooler and paper filter.

The servo oil unit is equipped with alarms according to the Classification Society’s requirements as well as necessary pressure and temperature indicators.

If the servo oil unit cannot be located with maximum oil level below the oil distribution ring, the system must incorporate an extra, small drain tank complete with pump, located at a suitable level, below the oil distributor ring drain lines.

Fig. 5.18.06: Hydraulic Power Unit for MAN Alpha CP propeller, the servo oil tank unit
MAN Alphatronic 2000 Propulsion Control System

MAN Diesel & Turbo’s MAN Alphatronic 2000 Propulsion Control System (PCS) is designed for control of propulsion plants based on diesel engines with CP propellers. The plant could for instance include tunnel gear with PTO/PTI, PTO gear, multiple engines on one gearbox as well as multiple propeller plants.

As shown in Fig. 5.18.07, the propulsion control system comprises a computer controlled system with interconnections between control stations via a redundant bus and a hard wired back-up control system for direct pitch control at constant shaft speed.

The computer controlled system contains functions for:

- Machinery control of engine start/stop, engine load limits and possible gear clutches.
- Thrust control with optimization of propeller pitch and shaft speed. Selection of combinator, constant speed or separate thrust mode is possible. The rates of changes are controlled to ensure smooth manoeuvres and avoidance of propeller cavitation.
- A Load control function protects the engine against overload. The load control function contains a scavenge air smoke limiter, a load programme for avoidance of high thermal stresses in the engine, an automatic load reduction and an engineer controlled limitation of maximum load.
- Functions for transfer of responsibility between the local control stand, engine control room and control locations on the bridge are incorporated in the system.

Fig. 5.18.07: MAN Alphatronic 2000 Propulsion Control System
Propulsion control station on the main bridge

For remote control, a minimum of one control station located on the bridge is required.

This control station will incorporate three modules, as shown in Fig. 5.18.08:

- **Propulsion control panel** with push buttons and indicators for machinery control and a display with information of condition of operation and status of system parameters.

- **Propeller monitoring panel** with back-up instruments for propeller pitch and shaft speed.

- **Thrust control panel** with control lever for thrust control, an emergency stop button and push buttons for transfer of control between control stations on the bridge.

---

**Fig. 5.18.08: Main bridge station standard layout**
Renk PSC Clutch for auxiliary propulsion systems

The Renk PSC Clutch is a shaftline de-clutching device for auxiliary propulsion systems which meets the class notations for redundant propulsion.

The Renk PSC clutch facilitates reliable and simple ‘take home’ and ‘take away’ functions in two-stroke engine plants. It is described in Section 4.04.

Further information about MAN Alpha CP propeller

For further information about MAN Diesel & Turbo’s MAN Alpha Controllable Pitch (CP) propeller and the Alphatronic 2000 Remote Control System, please refer to our publications:

*CP Propeller – Product Information*

*Alphatronic 2000 PCS Propulsion Control System*

The publications are available at www.marine.man.eu → 'Propeller & Aft Ship'.
List of Capacities: Pumps, Coolers & Exhaust Gas
Calculation of List of Capacities and Exhaust Gas Data

Updated engine and capacities data is available from the CEAS program on www.marine.man.eu → ‘Two-Stroke’ → ‘CEAS Engine Calculations’.

This chapter describes the necessary auxiliary machinery capacities to be used for a nominally rated engine. The capacities given are valid for seawater cooling system and central cooling water system, respectively. For derated engine, i.e. with a specified MCR different from the nominally rated MCR point, the list of capacities will be different from the nominal capacities.

Furthermore, among others, the exhaust gas data depends on the ambient temperature conditions.

Based on examples for a derated engine, the way of how to calculate the derated capacities, freshwater production and exhaust gas amounts and temperatures will be described in details.

Nomenclature

In the following description and examples of the auxiliary machinery capacities, freshwater generator production and exhaust gas data, the below nomenclatures are used:

<table>
<thead>
<tr>
<th>Engine ratings</th>
<th>Point / Index</th>
<th>Power</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal MCR point</td>
<td>L_1</td>
<td>P_L_1</td>
<td>n_L_1</td>
</tr>
<tr>
<td>Specified MCR point</td>
<td>M</td>
<td>P_M</td>
<td>n_M</td>
</tr>
<tr>
<td>Service point</td>
<td>S</td>
<td>P_S</td>
<td>n_S</td>
</tr>
</tbody>
</table>

**Fig. 6.01.01: Nomenclature of basic engine ratings**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Cooler index</th>
<th>Flow index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q = Heat dissipation</td>
<td>air scavenge air cooler</td>
<td>sw seawater flow</td>
</tr>
<tr>
<td>V = Volume flow</td>
<td>lub lube oil cooler</td>
<td>cw cooling/central water flow</td>
</tr>
<tr>
<td>M = Mass flow</td>
<td>jw jacket water cooler</td>
<td>exh exhaust gas</td>
</tr>
<tr>
<td>T = Temperature</td>
<td>cent central cooler</td>
<td>fw freshwater</td>
</tr>
</tbody>
</table>

**Fig. 6.01.02: Nomenclature of coolers and volume flows, etc.**

Engine configurations related to SFOC

The engine type is available in the following version only with respect to the efficiency of the turbocharger:

**With high efficiency turbocharger**, which is the basic design and for which the lists of capacities Section 6.03 are calculated.
List of Capacities and Cooling Water Systems

The List of Capacities contain data regarding the necessary capacities of the auxiliary machinery for the main engine only, and refer to a nominally rated engine. Complying with IMO Tier II NOₓ limitations.

The heat dissipation figures include 10% extra margin for overload running except for the scavenge air cooler, which is an integrated part of the diesel engine.

Cooling Water Systems

The capacities given in the tables are based on tropical ambient reference conditions and refer to engines with high efficiency/conventional turbocharger running at nominal MCR (L₁) for:

- **Seawater cooling system**,  
  See diagram, Fig. 6.02.01 and nominal capacities in Fig. 6.03.01

- **Central cooling water system**,  
  See diagram, Fig. 6.02.02 and nominal capacities in Fig. 6.03.01

The capacities for the starting air receivers and the compressors are stated in Fig. 6.03.01.

Heat radiation and air consumption

The radiation and convection heat losses to the engine room is around 1% of the engine nominal power (kW in L₁).

The air consumption is approximately 98.2% of the calculated exhaust gas amount, ie. 
\[ M_{\text{air}} = M_{\text{exh}} \times 0.982. \]

Flanges on engine, etc.

The location of the flanges on the engine are shown in: ‘Engine pipe connections’, and the flanges are identified by reference letters stated in the ‘List of flanges”; both can be found in Chapter 5.

The diagrams use the ‘Basic symbols for piping’, whereas the symbols for instrumentation according to ‘ISO 1219-1’ and ‘ISO 1219-2’ and the instrumentation list found in Appendix A.

---

**Fig. 6.02.01: Diagram for seawater cooling system**

**Fig. 6.02.02: Diagram for central cooling water system**
List of Capacities for 5L70ME-C8.5-GI-TII at NMCR

<table>
<thead>
<tr>
<th></th>
<th>Seawater cooling</th>
<th>Central cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conventional TC</td>
<td>High eff. TC</td>
</tr>
<tr>
<td></td>
<td>1 x TQ7/7-21</td>
<td>1 x AT75-L</td>
</tr>
<tr>
<td></td>
<td>1 x MET7/1-MA</td>
<td>1 x AT75-L</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pumps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel oil circulation</td>
<td>m³/h</td>
<td>7.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.3</td>
</tr>
<tr>
<td>Fuel oil supply</td>
<td>m³/h</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.4</td>
</tr>
<tr>
<td>Jacket cooling</td>
<td>m³/h</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td></td>
<td>140</td>
</tr>
<tr>
<td>Seawater cooling *</td>
<td>m³/h</td>
<td>490</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500</td>
</tr>
<tr>
<td>Main lubrication *</td>
<td>m³/h</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td></td>
<td>320</td>
</tr>
<tr>
<td>Central cooling *</td>
<td>m³/h</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Scavenge air cooler(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat diss. app.</td>
<td>kW</td>
<td>6,320</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6,320</td>
</tr>
<tr>
<td>Central water flow</td>
<td>m³/h</td>
<td>310</td>
</tr>
<tr>
<td></td>
<td></td>
<td>310</td>
</tr>
<tr>
<td>Seawater flow</td>
<td></td>
<td>320</td>
</tr>
<tr>
<td></td>
<td></td>
<td>320</td>
</tr>
<tr>
<td>Lubricating oil cooler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat diss. app. *</td>
<td>kW</td>
<td>1,220</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,220</td>
</tr>
<tr>
<td>Lube oil flow *</td>
<td>m³/h</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td></td>
<td>320</td>
</tr>
<tr>
<td>Central water flow</td>
<td>m³/h</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td></td>
<td>180</td>
</tr>
<tr>
<td>Seawater flow</td>
<td></td>
<td>180</td>
</tr>
<tr>
<td></td>
<td></td>
<td>180</td>
</tr>
<tr>
<td>Jacket water cooler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat diss. app.</td>
<td>kW</td>
<td>2,360</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2,360</td>
</tr>
<tr>
<td>Jacket water flow</td>
<td>m³/h</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td></td>
<td>140</td>
</tr>
<tr>
<td>Central water flow</td>
<td>m³/h</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td></td>
<td>180</td>
</tr>
<tr>
<td>Seawater flow</td>
<td></td>
<td>180</td>
</tr>
<tr>
<td></td>
<td></td>
<td>180</td>
</tr>
<tr>
<td>Central cooler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat diss. app. *</td>
<td>kW</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Central water flow</td>
<td>m³/h</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Starting air system, 30.0 bar g, 12 starts</td>
<td>Fixed pitch propeller - reversible engine</td>
<td></td>
</tr>
<tr>
<td>Receiver volume</td>
<td>m³</td>
<td>2 x 6.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 x 6.5</td>
</tr>
<tr>
<td>Compressor cap.</td>
<td>m³</td>
<td>390</td>
</tr>
<tr>
<td></td>
<td></td>
<td>390</td>
</tr>
<tr>
<td>Starting air system, 30.0 bar g, 6 starts</td>
<td>Controllable pitch propeller - non-reversible engine</td>
<td></td>
</tr>
<tr>
<td>Receiver volume</td>
<td>m³</td>
<td>2 x 3.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 x 3.5</td>
</tr>
<tr>
<td>Compressor cap.</td>
<td>m³</td>
<td>210</td>
</tr>
<tr>
<td></td>
<td></td>
<td>210</td>
</tr>
<tr>
<td>Other values</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel oil heater</td>
<td>kW</td>
<td>129</td>
</tr>
<tr>
<td></td>
<td></td>
<td>129</td>
</tr>
<tr>
<td>Exh. gas temp. **</td>
<td>°C</td>
<td>251</td>
</tr>
<tr>
<td></td>
<td></td>
<td>251</td>
</tr>
<tr>
<td>Exh. gas amount **</td>
<td>kg/h</td>
<td>134,800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>134,800</td>
</tr>
<tr>
<td>Air consumption **</td>
<td>kg/h</td>
<td>33.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>33.4</td>
</tr>
</tbody>
</table>

* For main engine arrangements with built-on power take-off (PTO) of a MAN Diesel & Turbo recommended type and/or torsional vibration damper the engine’s capacities must be increased by those stated for the actual system.

** ISO based

For List of Capacities for derated engines and performance data at part load please visit http://www.mandieselturbo.com/ceas/LOC

Table 6.03.01e: Capacities for seawater and central systems as well as conventional and high efficiency turbochargers stated at NMCR
List of Capacities for 6L70ME-C8.5-GI-TII at NMCR

<table>
<thead>
<tr>
<th></th>
<th>Seawater cooling</th>
<th>Central cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conventional TC</td>
<td>High eff. TC</td>
</tr>
<tr>
<td>1 x TCD7-26</td>
<td>1 x A209-L</td>
<td>1 x MET13-MA</td>
</tr>
</tbody>
</table>

**Pumps**
- Fuel oil circulation m³/h: 8.8, 8.8, 8.8, 8.7, 8.7, 8.7
- Fuel oil supply m³/h: 5.3, 5.3, 5.3, 5.3, 5.3, 5.3
- Seawater cooling * m³/h: 580, 590, 600, 600, 600, 610
- Main lubrication oil * m³/h: 390, 390, 390, 400, 390, 390
- Central cooling * m³/h: 450, 450, 460, 460, 460, 470

**Scavenge air cooler(s)**
- Heat diss. app. kw: 7,580, 7,580, 7,580, 7,870, 7,870, 7,870
- Central water flow m³/h: 370, 370, 370, 380, 380, 380
- Seawater flow m³/h: 7,560, 7,560, 7,560, 7,850, 7,850, 7,850

**Lubricating oil cooler**
- Heat diss. app. * kw: 1,450, 1,500, 1,540, 1,470, 1,500, 1,540
- Lube oil flow * m³/h: 390, 390, 390, 400, 390, 390
- Central water flow m³/h: 180, 180, 190, 180, 190, 190
- Seawater flow m³/h: 210, 220, 230, 220, 220, 230

**Jacket water cooler**
- Heat diss. app. kw: 2,830, 2,830, 2,830, 2,830, 2,830
- Central water flow m³/h: 180, 180, 190, 180, 190
- Seawater flow m³/h: 210, 220, 230, 220, 230

**Central cooler**
- Heat diss. app. * kw: 11,860, 11,900, 11,940, 12,170, 12,190, 12,230
- Central water flow m³/h: 450, 450, 460, 460, 460, 470
- Seawater flow m³/h: 580, 580, 580, 590, 600, 600

**Starting air system, 30.0 bar g, 12 starts. Fixed pitch propeller - reversible engine**
- Receiver volume m³: 2 x 7.0, 2 x 7.0, 2 x 7.0, 2 x 7.0, 2 x 7.0
- Compressor cap. m³: 420, 420, 420, 420, 420

**Starting air system, 30.0 bar g, 6 starts. Controllable pitch propeller - non-reversible engine**
- Receiver volume m³: 2 x 3.5, 2 x 3.5, 2 x 3.5, 2 x 3.5, 2 x 3.5
- Compressor cap. m³: 2 x 3.5, 2 x 3.5, 2 x 3.5, 2 x 3.5, 2 x 3.5

**Other values**
- Fuel oil heater kw: 155, 155, 155, 154, 154
- Exh. gas temp. ** °C: 251, 251, 251, 231, 231
- Exh. gas amount ** kg/h: 161,760, 161,760, 161,760, 171,640, 171,640
- Air consumption ** kg/a: 40.4, 40.4, 40.4, 42.9, 42.9

* For main engine arrangements with built-on power take-off (PTO) of a MAN Diesel & Turbo recommended type and/or torsional vibration damper the engine’s capacities must be increased by those stated for the actual system

** ISO based

For List of Capacities for derated engines and performance data at part load please visit http://www.mandieselturbo.com/ceas/LCC

Table 6.03.01f: Capacities for seawater and central systems as well as conventional and high efficiency turbochargers stated at NMCR
### List of Capacities for 7L70ME-C8.5-GI-TII at NMCR

<table>
<thead>
<tr>
<th></th>
<th>Conventional TC</th>
<th>High eff. TC</th>
<th>Conventional TC</th>
<th>High eff. TC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 x TD48-21</td>
<td>1 x A185-L37</td>
<td>1 x MET3-MA</td>
<td>1 x TD48-21</td>
</tr>
<tr>
<td>Pumps</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel oil supply</td>
<td>m³/h</td>
<td>6.2</td>
<td>6.2</td>
<td>6.2</td>
</tr>
<tr>
<td>Fuel oil circulation</td>
<td>m³/h</td>
<td>10.2</td>
<td>10.2</td>
<td>10.2</td>
</tr>
<tr>
<td>Jacket cooling</td>
<td>m³/h</td>
<td>190</td>
<td>190</td>
<td>190</td>
</tr>
<tr>
<td>Seawater cooling *</td>
<td>m³/h</td>
<td>680</td>
<td>680</td>
<td>680</td>
</tr>
<tr>
<td>Main lubrication *</td>
<td>m³/h</td>
<td>460</td>
<td>460</td>
<td>460</td>
</tr>
<tr>
<td>Central cooling *</td>
<td>m³/h</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Scavenge air cooler(s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat diss. app.</td>
<td>kW</td>
<td>8,840</td>
<td>8,840</td>
<td>8,820</td>
</tr>
<tr>
<td>Central water flow</td>
<td>m³/h</td>
<td>8,840</td>
<td>8,840</td>
<td>8,820</td>
</tr>
<tr>
<td>Seawater flow</td>
<td>m³/h</td>
<td>9,180</td>
<td>9,180</td>
<td>9,180</td>
</tr>
<tr>
<td>Lubricating oil cooler</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat diss. app. *</td>
<td>kW</td>
<td>1,710</td>
<td>1,710</td>
<td>1,710</td>
</tr>
<tr>
<td>Lube oil flow *</td>
<td>m³/h</td>
<td>460</td>
<td>460</td>
<td>460</td>
</tr>
<tr>
<td>Central water flow</td>
<td>m³/h</td>
<td>450</td>
<td>450</td>
<td>450</td>
</tr>
<tr>
<td>Seawater flow</td>
<td>m³/h</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Jacket water cooler</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat diss. app.</td>
<td>kW</td>
<td>3,300</td>
<td>3,300</td>
<td>3,310</td>
</tr>
<tr>
<td>Jacket water flow</td>
<td>m³/h</td>
<td>3,300</td>
<td>3,300</td>
<td>3,310</td>
</tr>
<tr>
<td>Central water flow</td>
<td>m³/h</td>
<td>3,300</td>
<td>3,300</td>
<td>3,310</td>
</tr>
<tr>
<td>Seawater flow</td>
<td>m³/h</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Central cooler</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat diss. app. *</td>
<td>kW</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Central water flow</td>
<td>m³/h</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Seawater flow</td>
<td>m³/h</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Starting air system, 30.0 bar g, 12 starts. Fixed pitch propeller - reversible engine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receiver volume</td>
<td>m³</td>
<td>2 x 7.0</td>
<td>2 x 7.0</td>
<td>2 x 7.0</td>
</tr>
<tr>
<td>Compressor cap.</td>
<td>m³</td>
<td>420</td>
<td>420</td>
<td>420</td>
</tr>
<tr>
<td>Starting air system, 30.0 bar g, 6 starts. Controllable pitch propeller - non-reversible engine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receiver volume</td>
<td>m³</td>
<td>2 x 3.5</td>
<td>2 x 3.5</td>
<td>2 x 3.5</td>
</tr>
<tr>
<td>Compressor cap.</td>
<td>m³</td>
<td>210</td>
<td>210</td>
<td>210</td>
</tr>
<tr>
<td>Other values</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Fuel oil heater</td>
<td>kW</td>
<td>181</td>
<td>181</td>
<td>181</td>
</tr>
<tr>
<td>Exh. gas temp. **</td>
<td>°C</td>
<td>251</td>
<td>251</td>
<td>251</td>
</tr>
<tr>
<td>Exh. gas amount **</td>
<td>kg/ha</td>
<td>188,720</td>
<td>188,720</td>
<td>188,720</td>
</tr>
<tr>
<td>Air consumption **</td>
<td>kg/ha</td>
<td>46.7</td>
<td>46.7</td>
<td>46.7</td>
</tr>
</tbody>
</table>

* For main engine arrangements with built-on power take-off (PTO) of a MAN Diesel & Turbo recommended type and/or torsional vibration damper the engine’s capacities must be increased by those stated for the actual system.

** ISO based

For List of Capacities for derated engines and performance data at part load please visit http://www.mandieselturbo.com/ceas/LOC

Table 6.03.01g: Capacities for seawater and central systems as well as conventional and high efficiency turbochargers stated at NMCR
List of Capacities for 8L70ME-C8.5-GI-TII at NMCR

<table>
<thead>
<tr>
<th>Pumps</th>
<th>Seawater cooling</th>
<th>Central cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conventional TC</td>
<td>High eff. TC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fuel oil circulation m³/h</strong></td>
<td>11.7</td>
<td>11.7</td>
</tr>
<tr>
<td><strong>Fuel oil supply m³/h</strong></td>
<td>7.1</td>
<td>7.1</td>
</tr>
<tr>
<td><strong>Jacket cooling m³/h</strong></td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td><strong>Seawater cooling m³/h</strong></td>
<td>770</td>
<td>780</td>
</tr>
<tr>
<td><strong>Main lubrication * m³/h</strong></td>
<td>520</td>
<td>510</td>
</tr>
<tr>
<td><strong>Central cooling * m³/h</strong></td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scavenge air cooler(s)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heat diss. app. kW</strong></td>
<td>10,110</td>
<td>10,110</td>
</tr>
<tr>
<td>Central water flow m³/h</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Seawater flow m³/h</td>
<td>490</td>
<td>490</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lubricating oil cooler</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heat diss. app. * kW</strong></td>
<td>1,920</td>
<td>1,970</td>
</tr>
<tr>
<td>1,980</td>
<td>1,970</td>
<td>2,030</td>
</tr>
<tr>
<td><strong>Lube oil flow m³/h</strong></td>
<td>520</td>
<td>510</td>
</tr>
<tr>
<td>520</td>
<td>510</td>
<td>520</td>
</tr>
<tr>
<td><strong>Central water flow m³/h</strong></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Seawater flow m³/h</strong></td>
<td>280</td>
<td>290</td>
</tr>
<tr>
<td>300</td>
<td>290</td>
<td>290</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Jacket water cooler</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heat diss. app. kW</strong></td>
<td>3,780</td>
<td>3,780</td>
</tr>
<tr>
<td>3,780</td>
<td>3,780</td>
<td>3,780</td>
</tr>
<tr>
<td><strong>Jacket water flow m³/h</strong></td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>220</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td><strong>Central water flow m³/h</strong></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Seawater flow m³/h</strong></td>
<td>280</td>
<td>290</td>
</tr>
<tr>
<td>300</td>
<td>290</td>
<td>290</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Central cooler</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heat diss. app. * kW</strong></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Central water flow m³/h</strong></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Seawater flow m³/h</strong></td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Starting air system, 30.0 bar g, 12 starts. Fixed pitch propeller - reversible engine</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Receiver volume m³</strong></td>
<td>2 x 7.0</td>
<td>2 x 7.0</td>
</tr>
<tr>
<td>2 x 7.0</td>
<td>2 x 7.0</td>
<td>2 x 7.0</td>
</tr>
<tr>
<td><strong>Compressor cap. m³</strong></td>
<td>420</td>
<td>420</td>
</tr>
<tr>
<td>420</td>
<td>420</td>
<td>420</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Starting air system, 30.0 bar g, 6 starts. Controllable pitch propeller - non-reversible engine</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Receiver volume m³</strong></td>
<td>2 x 4.0</td>
<td>2 x 4.0</td>
</tr>
<tr>
<td>2 x 4.0</td>
<td>2 x 4.0</td>
<td>2 x 4.0</td>
</tr>
<tr>
<td><strong>Compressor cap. m³</strong></td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td>240</td>
<td>240</td>
<td>240</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other values</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel oil heater kW</strong></td>
<td>207</td>
<td>207</td>
</tr>
<tr>
<td>207</td>
<td>206</td>
<td>206</td>
</tr>
<tr>
<td><strong>Exh. gas temp. °C</strong></td>
<td>251</td>
<td>251</td>
</tr>
<tr>
<td>251</td>
<td>231</td>
<td>231</td>
</tr>
<tr>
<td><strong>Exh. gas amount kg/h</strong></td>
<td>215,680</td>
<td>215,680</td>
</tr>
<tr>
<td>215,680</td>
<td>228,850</td>
<td>228,850</td>
</tr>
<tr>
<td><strong>Air consumption kg/hr</strong></td>
<td>53.4</td>
<td>53.4</td>
</tr>
<tr>
<td>53.4</td>
<td>56.7</td>
<td>56.7</td>
</tr>
</tbody>
</table>

* For main engine arrangements with built-on power take-off (PTO) of a MAN Diesel & Turbo recommended type and/or torsional vibration damper the engine’s capacities must be increased by those stated for the actual system

** ISO based

For List of Capacities for derated engines and performance data at part load please visit http://www.mandieselturbo.com/ceas/LOC

Table 6.03.01h: Capacities for seawater and central systems as well as conventional and high efficiency turbochargers stated at NMCR
Auxiliary Machinery Capacities

The dimensioning of heat exchangers (coolers) and pumps for derated engines can be calculated on the basis of the heat dissipation values found by using the following description and diagrams. Those for the nominal MCR (L1), may also be used if wanted.

The nomenclature of the basic engine ratings and coolers, etc. used in this section is shown in Fig. 6.01.01 and 6.01.02.

Cooler heat dissipations

For the specified MCR (M) the following three diagrams in Figs. 6.04.01, 6.04.02 and 6.04.03 show reduction factors for the corresponding heat dissipations for the coolers, relative to the values stated in the ‘List of Capacities’ valid for nominal MCR (L1).

\[ Q_{\text{air}}\% = 100 \times \left( \frac{P_M}{P_{L1}} \right)^{1.68} \times \left( \frac{n_M}{n_{L1}} \right)^{-0.83} \]

Fig. 6.04.01: Scavenge air cooler, heat dissipation \( Q_{\text{air}}\% \) in point M, in % of the \( L_1 \) value \( Q_{\text{air}, L1} \)

\[ Q_{\text{jw}}\% = e^{-0.0811 \ln (n_{M}) + 0.8072 \ln (P_{M}) + 1.2614} \]

Fig. 6.04.02: Jacket water cooler, heat dissipation \( Q_{\text{jw}}\% \) in point M, in % of the \( L_1 \) value \( Q_{\text{jw}, L1} \)

\[ Q_{\text{lub}}\% = 67.3009 \ln (n_{M}) + 7.6304 \ln (P_{M}) - 245.0714 \]

Fig. 6.04.03: Lubricating oil cooler, heat dissipation \( Q_{\text{lub}}\% \) in point M, in % of the \( L_1 \) value \( Q_{\text{lub}, L1} \)
The derated cooler capacities may then be found by means of following equations:

\[ Q_{\text{air}, M} = Q_{\text{air}, L1} \times \left( \frac{Q_{\text{air} \%}}{100} \right) \]
\[ Q_{\text{jw}, M} = Q_{\text{jw}, L1} \times \left( \frac{Q_{\text{jw} \%}}{100} \right) \]
\[ Q_{\text{lub}, M} = Q_{\text{lub}, L1} \times \left( \frac{Q_{\text{lub} \%}}{100} \right) \]

and for a central cooling water system the central cooler heat dissipation is:

\[ Q_{\text{cent}, M} = Q_{\text{air}, M} + Q_{\text{jw}, M} + Q_{\text{lub}, M} \]

### Pump capacities

The pump capacities given in the ‘List of Capacities’ refer to engines rated at nominal MCR (L1). For lower rated engines, a marginal saving in the pump capacities is obtainable.

To ensure proper lubrication, the lubricating oil pump must remain unchanged.

In order to ensure reliable starting, the starting air compressors and the starting air receivers must also remain unchanged.

The jacket cooling water pump capacity is relatively low. Practically no saving is possible, and it is therefore unchanged.

### Seawater cooling system

The derated seawater pump capacity is equal to the sum of the below found derated seawater flow capacities through the scavenge air and lube oil coolers, as these are connected in parallel.

The seawater flow capacity for each of the scavenge air, lube oil and jacket water coolers can be reduced proportionally to the reduced heat dissipations found in Figs. 6.04.01, 6.04.02 and 6.04.03, respectively, i.e. as follows:

\[ V_{\text{sw,air}, M} = V_{\text{sw,air}, L1} \times \left( \frac{Q_{\text{air} \%}}{100} \right) \]
\[ V_{\text{sw,lub}, M} = V_{\text{sw,lub}, L1} \times \left( \frac{Q_{\text{lub} \%}}{100} \right) \]
\[ V_{\text{sw,jw}, M} = V_{\text{sw,lub}, M} \]

However, regarding the scavenge air cooler(s), the engine maker has to approve this reduction in order to avoid too low a water velocity in the scavenge air cooler pipes.

As the jacket water cooler is connected in series with the lube oil cooler, the seawater flow capacity for the latter is used also for the jacket water cooler.

### Central cooling water system

If a central cooler is used, the above still applies, but the central cooling water capacities are used instead of the above seawater capacities. The seawater flow capacity for the central cooler can be reduced in proportion to the reduction of the total cooler heat dissipation, i.e. as follows:

\[ V_{\text{cw,air}, M} = V_{\text{cw,air}, L1} \times \left( \frac{Q_{\text{air} \%}}{100} \right) \]
\[ V_{\text{cw,lub}, M} = V_{\text{cw,lub}, L1} \times \left( \frac{Q_{\text{lub} \%}}{100} \right) \]
\[ V_{\text{cw,jw}, M} = V_{\text{cw,jw}, M} \]
\[ V_{\text{cw,cent}, M} = V_{\text{cw,air}, M} + V_{\text{cw,lub}, M} \]
\[ V_{\text{sw,cent}, M} = V_{\text{sw,cent}, L1} \times \left( \frac{Q_{\text{cent} \%}}{100} \right) \]

### Pump pressures

Irrespective of the capacities selected as per the above guidelines, the below-mentioned pump heads at the mentioned maximum working temperatures for each system must be kept:

<table>
<thead>
<tr>
<th>Pump head bar</th>
<th>Max. working temp. ºC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel oil supply pump</td>
<td>4</td>
</tr>
<tr>
<td>Fuel oil circulating pump</td>
<td>6</td>
</tr>
<tr>
<td>Lubricating oil pump</td>
<td>4.3</td>
</tr>
<tr>
<td>Seawater pump</td>
<td>2.5</td>
</tr>
<tr>
<td>Central cooling water pump</td>
<td>2.5</td>
</tr>
<tr>
<td>Jacket water pump</td>
<td>3.0</td>
</tr>
</tbody>
</table>

### Flow velocities

For external pipe connections, we prescribe the following maximum velocities:

<table>
<thead>
<tr>
<th>Medium</th>
<th>Maximum Velocity m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine diesel oil</td>
<td>1.0 m/s</td>
</tr>
<tr>
<td>Heavy fuel oil</td>
<td>0.6 m/s</td>
</tr>
<tr>
<td>Lubricating oil</td>
<td>1.8 m/s</td>
</tr>
<tr>
<td>Cooling water</td>
<td>3.0 m/s</td>
</tr>
</tbody>
</table>
Calculation of List of Capacities for Derated Engine

Example 1:

**Pump and cooler capacities for a** derated 6L70ME-C8.5-GI-TII with 1 high efficiency MAN TCA77-26 turbocharger, high load, fixed pitch propeller and central cooling water system.

Nominal MCR, (L) \( P_{L1} \): 19.620 kW (100.0%) and 108.0 r/min (100.0%)

Specified MCR, (M) \( P_{M} \): 17.658 kW (90.0%) and 102.6 r/min (95.0%)

The method of calculating the reduced capacities for point M (\( n_{M\%} = 95.0\% \) and \( P_{M\%} = 90.0\% \)) is shown below.

The values valid for the nominal rated engine are found in the ‘List of Capacities’, Figs. 6.03.01 and 6.03.02, and are listed together with the result in the figure on the next page.

**Heat dissipation of scavenge air cooler**

Fig. 6.04.01 which approximately indicates a \( Q_{air\%} = 87.4\% \) heat dissipation, i.e.:

\[
Q_{air,M} = Q_{air,L1} \times \frac{Q_{air\%}}{100}
\]

\[
Q_{air,M} = 7.850 \times 0.874 = 6.861 \text{ kW}
\]

**Heat dissipation of jacket water cooler**

Fig. 6.04.02 indicates a \( Q_{jw\%} = 92.2\% \) heat dissipation, i.e.:

\[
Q_{jw,M} = Q_{jw,L1} \times \frac{Q_{jw\%}}{100}
\]

\[
Q_{jw,M} = 2.840 \times 0.922 = 2.618 \text{ kW}
\]

**Heat dissipation of lube oil cooler**

Fig. 6.04.03 indicates a \( Q_{lub\%} = 95.7\% \) heat dissipation, i.e.:

\[
Q_{lub,M} = Q_{lub,L1} \times \frac{Q_{lub\%}}{100}
\]

\[
Q_{lub,M} = 1.480 \times 0.957 = 1.416 \text{ kW}
\]

**Heat dissipation of central water cooler**

\[
Q_{cent,M} = Q_{air,M} + Q_{jw,M} + Q_{lub,M}
\]

\[
Q_{cent,M} = 6.861 + 2.618 + 1.416 = 10.895 \text{ kW}
\]

**Total cooling water flow through scavenge air coolers**

\[
V_{cw,air,M} = V_{cw,air,L1} \times \frac{Q_{air\%}}{100}
\]

\[
V_{cw,air,M} = 280 \times 0.874 = 245 \text{ m}^3/\text{h}
\]

**Cooling water flow through lubricating oil cooler**

\[
V_{cw,lub,M} = V_{cw,lub,L1} \times \frac{Q_{lub\%}}{100}
\]

\[
V_{cw,lub,M} = 180 \times 0.957 = 172 \text{ m}^3/\text{h}
\]

**Cooling water flow through central cooler**

(Central cooling water pump)

\[
V_{cw,cent,M} = V_{cw,air,M} + V_{cw,lub,M}
\]

\[
V_{cw,cent,M} = 245 + 172 = 417 \text{ m}^3/\text{h}
\]

**Cooling water flow through jacket water cooler**

(as for lube oil cooler)

\[
V_{cw,jw,M} = V_{cw,lub,M}
\]

\[
V_{cw,jw,M} = 172 \text{ m}^3/\text{h}
\]

**Seawater pump for central cooler**

As the seawater pump capacity and the central cooler heat dissipation for the nominal rated engine found in the ‘List of Capacities’ are 590 m\(^3\)/h and 12,170 kW the derated seawater pump flow equals:

\[
V_{sw,cent,M} = V_{sw,cent,L1} \times \frac{Q_{cent,L1}}{Q_{cent,M}}
\]

\[
= 590 \times 10.895 / 12.170 = 528 \text{ m}^3/\text{h}
\]
<table>
<thead>
<tr>
<th></th>
<th>Nominal rated engine (L₁)</th>
<th>Specified MCR (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>high efficiency</td>
<td>high efficiency</td>
</tr>
<tr>
<td></td>
<td>1 x MAN TCA88-21</td>
<td>1 x MAN TCA77-26</td>
</tr>
<tr>
<td>Shaft power at MCR</td>
<td>kW</td>
<td>19.620</td>
</tr>
<tr>
<td>Engine speed at MCR</td>
<td>r/min</td>
<td>108.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17.658</td>
</tr>
<tr>
<td></td>
<td></td>
<td>102.6</td>
</tr>
<tr>
<td><strong>Pumps:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel oil circulating</td>
<td>m³/h</td>
<td>8.7</td>
</tr>
<tr>
<td>Fuel oil supply</td>
<td>m³/h</td>
<td>5.3</td>
</tr>
<tr>
<td>Jacket cooling water</td>
<td>m³/h</td>
<td>160</td>
</tr>
<tr>
<td>Central cooling water</td>
<td>m³/h</td>
<td>460</td>
</tr>
<tr>
<td>Seawater</td>
<td>m³/h</td>
<td>590</td>
</tr>
<tr>
<td>Lubricating oil</td>
<td>m³/h</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>160</td>
</tr>
<tr>
<td></td>
<td></td>
<td>417</td>
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<td></td>
<td>528</td>
</tr>
<tr>
<td></td>
<td></td>
<td>390</td>
</tr>
<tr>
<td><strong>Coolers:</strong></td>
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<td></td>
</tr>
<tr>
<td>Scavenge air cooler</td>
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</tr>
<tr>
<td>Heat dissipation</td>
<td>kW</td>
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</tr>
<tr>
<td>Central cooling water flow</td>
<td>m³/h</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>6.861</td>
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<tr>
<td></td>
<td></td>
<td>245</td>
</tr>
<tr>
<td>Lub. oil cooler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat dissipation</td>
<td>kW</td>
<td>1.480</td>
</tr>
<tr>
<td>Lubricating oil flow</td>
<td>m³/h</td>
<td>400</td>
</tr>
<tr>
<td>Central cooling water flow</td>
<td>m³/h</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.416</td>
</tr>
<tr>
<td></td>
<td></td>
<td>390</td>
</tr>
<tr>
<td></td>
<td></td>
<td>172</td>
</tr>
<tr>
<td>Jacket water cooler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat dissipation</td>
<td>kW</td>
<td>2.840</td>
</tr>
<tr>
<td>Jacket cooling water flow</td>
<td>m³/h</td>
<td>160</td>
</tr>
<tr>
<td>Central cooling water flow</td>
<td>m³/h</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.618</td>
</tr>
<tr>
<td></td>
<td></td>
<td>160</td>
</tr>
<tr>
<td></td>
<td></td>
<td>172</td>
</tr>
<tr>
<td>Central cooler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat dissipation</td>
<td>kW</td>
<td>12.170</td>
</tr>
<tr>
<td>Central cooling water flow</td>
<td>m³/h</td>
<td>460</td>
</tr>
<tr>
<td>Seawater</td>
<td>m³/h</td>
<td>590</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.895</td>
</tr>
<tr>
<td></td>
<td></td>
<td>417</td>
</tr>
<tr>
<td></td>
<td></td>
<td>528</td>
</tr>
<tr>
<td>Fuel oil heater:</td>
<td>kW</td>
<td>153</td>
</tr>
<tr>
<td></td>
<td></td>
<td>137</td>
</tr>
<tr>
<td><strong>Gases at ISO ambient conditions</strong></td>
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<td></td>
</tr>
<tr>
<td>Exhaust gas amount</td>
<td>kg/h</td>
<td>171.100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>153.600</td>
</tr>
<tr>
<td>Exhaust gas temperature</td>
<td>°C</td>
<td>231</td>
</tr>
<tr>
<td></td>
<td></td>
<td>227</td>
</tr>
<tr>
<td>Air consumption</td>
<td>kg/s</td>
<td>46.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>41.9</td>
</tr>
<tr>
<td><strong>Starting air system:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 bar (gauge)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Reversible engine</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receiver volume (12 starts)</td>
<td>m³</td>
<td>2 x 7.0</td>
</tr>
<tr>
<td>Compressor capacity, total</td>
<td>m³/h</td>
<td>420</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 x 7.0</td>
</tr>
<tr>
<td><strong>Non-reversible engine</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receiver volume (6 starts)</td>
<td>m³</td>
<td>2 x 3.5</td>
</tr>
<tr>
<td>Compressor capacity, total</td>
<td>m³/h</td>
<td>210</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 x 3.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>210</td>
</tr>
<tr>
<td>Exhaust gas tolerances:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>temperature ±5 °C and amount</td>
<td></td>
<td></td>
</tr>
<tr>
<td>±15%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The air consumption and exhaust gas figures are expected and refer to 100% specified MCR, ISO ambient reference conditions and the exhaust gas back pressure 300 mm WC

The exhaust gas temperatures refer to after turbocharger

* Calculated in example 3, in this chapter
Freshwater Generator

If a freshwater generator is installed and is utilising the heat in the jacket water cooling system, it should be noted that the actual available heat in the jacket cooling water system is lower than indicated by the heat dissipation figures valid for nominal MCR (L1) given in the List of Capacities. This is because the latter figures are used for dimensioning the jacket water cooler and hence incorporate a safety margin which can be needed when the engine is operating under conditions such as, e.g. overload. Normally, this margin is 10% at nominal MCR.

Calculation Method

For a derated diesel engine, i.e. an engine having a specified MCR (M) different from L1, the relative jacket water heat dissipation for point M may be found, as previously described, by means of Fig. 6.04.02.

At part load operation, the actual jacket water heat dissipation will be reduced according to the curves for fixed pitch propeller (FPP) or for constant speed, controllable pitch propeller (CPP), respectively, in Fig. 6.04.04.

With reference to the above, the heat actually available for a derated diesel engine may then be found as follows:

1. Engine power equal to specified power M.
   
   For specified MCR (M) the diagram Fig. 6.04.02 is to be used, i.e. giving the percentage correction factor $Q_{jw\%}$ and hence for specified MCR power $P_M$:
   
   $$Q_{jw,M} = Q_{jw,L1} \times \frac{Q_{jw\%}}{100} \times 0.9 \ (0.88) \ \ [1]$$

2. Engine power lower than specified MCR power.
   
   For powers lower than the specified MCR power, the value $Q_{jw,M}$ found for point M by means of the above equation [1] is to be multiplied by the correction factor $k_p$ found in Fig. 6.04.04 and hence
   
   $$Q_{jw} = Q_{jw,M} \times k_p \ -15\%/0\% \ \ [2]$$

where

- $Q_{jw}$ = jacket water heat dissipation
- $Q_{jw,L1}$ = jacket water heat dissipation at nominal MCR (L1)
- $Q_{jw\%}$ = percentage correction factor from Fig. 6.04.02
- $Q_{jw,M}$ = jacket water heat dissipation at specified MCR power (M), found by means of equation [1]
- $k_p$ = part load correction factor from Fig. 6.04.04
- 0.9 = factor for safety margin of cooler, tropical ambient conditions

The heat dissipation is assumed to be more or less independent of the ambient temperature conditions, yet the safety margin/ambient condition factor of about 0.88 instead of 0.90 will be more accurate for ambient conditions corresponding to ISO temperatures or lower. The heat dissipation tolerance from -15% to 0% stated above is based on experience.
Jacket Cooling Water Temperature Control

When using a normal freshwater generator of the single-effect vacuum evaporator type, the freshwater production - based on the available jacket cooling water heat \( Q_{jw} \) - may, for guidance, be estimated as 0.03 t/24h per 1 kW heat, i.e.:

\[
M_{fw} = 0.03 \times Q_{jw} \text{ t/24h} -15\%/0\% \quad [3]
\]

where

\( M_{fw} \) is the freshwater production in tons per 24 hours

and

\( Q_{jw} \) is to be stated in kW

If necessary, all the actually available jacket cooling water heat may be used provided that a special temperature control system ensures that the jacket cooling water temperature at the outlet from the engine does not fall below a certain level. Such a temperature control system may consist, e.g., of a special by-pass pipe installed in the jacket cooling water system, see Fig. 6.04.05, or a special built-in temperature control in the freshwater generator, e.g., an automatic start/stop function, or similar.

If such a special temperature control is not applied, we recommend limiting the heat utilised to maximum 50% of the heat actually available at specified MCR, and only using the freshwater generator at engine loads above 50%. Considering the cooler margin of 10% and the minus tolerance of -15%, this heat corresponds to 50 x(1.00-0.15)x0.9 = 38% of the jacket water cooler capacity \( Q_{jw,M} \) used for dimensioning of the jacket water cooler.

Valve A: ensures that \( T_{jw} < 92^\circ \text{C} \)
Valve B: ensures that \( T_{jw} > 92 - 4^\circ \text{C} = 88^\circ \text{C} \)
Valve B and the corresponding by-pass may be omitted if, for example, the freshwater generator is equipped with an automatic start/stop function for too low jacket cooling water temperature.

If necessary, all the actually available jacket cooling water heat may be utilised provided that a special temperature control system ensures that the jacket cooling water temperature at the outlet from the engine does not fall below a certain level.

Fig. 6.04.05: Freshwater generators. Jacket cooling water heat recovery flow diagram
Calculation of Freshwater Production for Derated Engine

Example 2:

**Freshwater production from a derated 6L70ME-C8.5-GI-TII with 1 high efficiency MAN TCA77-26 turbocharger, high load and fixed pitch propeller.**

Based on the engine ratings below, this example will show how to calculate the expected available jacket cooling water heat removed from the diesel engine, together with the corresponding freshwater production from a freshwater generator.

The calculation is made for the service rating (S) of the diesel engine being 80% of the specified MCR.

Nominal MCR, (L)  \( P_{L1} \): 19.620 kW (100.0%) and 108,0 r/min (100.0%)

Specified MCR, (M)  \( P_{M} \): 17.658 kW (90.0%) and 102,6 r/min (95.0%)

Service rating, (S)  \( P_{S} \): 14.126 kW and 95,2 r/min,  \( P_S = 80,0\% \) of \( P_M \)

**Reference conditions**

- Air temperature \( T_{air} \) .............................................................. 20° C
- Scavenge air coolant temperature \( T_{CW} \) ........................................... 18° C
- Barometric pressure \( p_{bar} \) ...................................................... 1.013 mbar
- Exhaust gas back-pressure at specified MCR \( \Delta p_M \) ............ 300 mm WC

The expected available jacket cooling water heat at service rating is found as follows:

\[
Q_{jw,L1} = 2.840 \text{ kW from List of Capacities}
Q_{jw\%} = 92,2\% \text{ using 90.0\% power and 95.0\% speed for M in Fig. 6.04.02}
\]

By means of equation [1], and using factor 0,885 for actual ambient condition the heat dissipation in the SMCR point (M) is found:

\[
Q_{jw,M} = Q_{jw,L1} \times \frac{Q_{jw\%}}{100} \times 0,885
= 2.840 \times \frac{92,2}{100} \times 0,885 = 2.317 \text{ kW}
\]

By means of equation [2], the heat dissipation in the service point (S) i.e. for 80.0\% of specified MCR power, is found:

\[
k_p = 0,852 \text{ using 80.0\% in Fig. 6.04.04}
Q_{jw} = Q_{jw,M} \times k_p = 2.317 \times 0,852 = 1.974 \text{ kW}
\]

For the service point the corresponding expected obtainable freshwater production from a freshwater generator of the single effect vacuum evaporator type is then found from equation [3]:

\[
M_{fw} = 0,03 \times Q_{jw} = 0,03 \times 1.974 = 69,5 \text{ t/24h}
\]

-15%/0%
Exhaust Gas Amount and Temperature

Influencing factors

The exhaust gas data to be expected in practice depends, primarily, on the following three factors:

a) The specified MCR point of the engine (point M):

\[ P_M : \ \text{power in kW at specified MCR point} \]
\[ n_M : \ \text{speed in r/min at specified MCR point} \]

b) The ambient conditions, and exhaust gas back-pressure:

\[ T_{air} : \ \text{actual ambient air temperature, in °C} \]
\[ P_{bar} : \ \text{actual barometric pressure, in mbar} \]
\[ T_{CW} : \ \text{actual scavenge air coolant temperature, in °C} \]
\[ \Delta p_M : \ \text{exhaust gas back-pressure in mm WC at specified MCR} \]

c) The continuous service rating of the engine (point S), valid for fixed pitch propeller or controllable pitch propeller (constant engine speed):

\[ P_S : \ \text{continuous service rating of engine, in kW} \]

Calculation Method

To enable the project engineer to estimate the actual exhaust gas data at an arbitrary service rating, the following method of calculation may be used.

The partial calculations based on the above influencing factors have been summarised in equations [4] and [5].

\[ M_{exh} = M_{L1} \times \frac{P_M}{P_{L1}} \times \left(1 + \frac{\Delta m_{M6}}{100}\right) \times \left(1 + \frac{\Delta M_{amb}}{100}\right) \times \left(1 + \frac{\Delta m_{S6}}{100}\right) \times \frac{P_{S6}}{100} \ \text{kg/h} \quad +/-5\% \ [4] \]

\[ T_{exh} = T_{L1} + \Delta T_{m} + \Delta T_{amb} + \Delta T_{S} \ \text{°C} \quad -/+15 \ °C \ [5] \]

where, according to ‘List of capacities’, i.e. referring to ISO ambient conditions and 300 mm WC back-pressure and specified in L1:

\[ M_{L1} : \ \text{exhaust gas amount in kg/h at nominal MCR (L1)} \]
\[ T_{L1} : \ \text{exhaust gas temperature after turbocharger in °C at nominal MCR (L1)} \]

The partial calculations based on the influencing factors are described in the following:

a) Correction for choice of specified MCR point

When choosing a specified MCR point ‘M’ other than the nominal MCR point ‘L1’, the resulting changes in specific exhaust gas amount and temperature are found by using as input in diagrams the corresponding percentage values (of L1) for specified MCR power \( P_{M6} \) and speed \( n_{M6} \):

\[ P_{M6} = \frac{P_M}{P_{L1}} \times 100\% \]
\[ n_{M6} = \frac{n_M}{n_{L1}} \times 100\% \]
The change of specific exhaust gas amount, in % of the specific gas amount at nominal MCR (L1), is given by:

$$\Delta m_{M\%} = 14 \times \ln \left( \frac{P_M}{P_L} \right) - 24 \times \ln \left( \frac{n_M}{n_L} \right)$$

Fig. 6.04.07: Change of specific exhaust gas amount, $\Delta m_{M\%}$ in % of $L_1$ value

The change in exhaust gas temperature after the turbocharger relative to the L1 value, in °C, is given by:

$$\Delta T_M = 15 \times \ln \left( \frac{P_M}{P_L} \right) + 45 \times \ln \left( \frac{n_M}{n_L} \right)$$

Fig. 6.04.08: Change of exhaust gas temperature, $\Delta T_M$ in point M, in °C after turbocharger relative to $L_1$ value

b) Correction for actual ambient conditions and back-pressure

For ambient conditions other than ISO 3046-1:2002 (E) and ISO 15550:2002 (E), and back-pressure other than 300 mm WC at specified MCR point (M), the correction factors stated in the table in Fig. 6.04.09 may be used as a guide, and the corresponding relative change in the exhaust gas data may be found from equations [7] and [8], shown in Fig. 6.04.10.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Change</th>
<th>Change of exhaust gas temperature</th>
<th>Change of exhaust gas amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blower inlet temperature</td>
<td>+10°C</td>
<td>+16.0°C</td>
<td>-4.1%</td>
</tr>
<tr>
<td>Blower inlet pressure (barometric pressure)</td>
<td>+10 mbar</td>
<td>-0.1°C</td>
<td>+0.3%</td>
</tr>
<tr>
<td>Charge air coolant temperature (seawater temperature)</td>
<td>+10°C</td>
<td>+1.0°C</td>
<td>+1.9%</td>
</tr>
<tr>
<td>Exhaust gas back pressure at the specified MCR point</td>
<td>+100 mm WC</td>
<td>+5.0°C</td>
<td>-1.1%</td>
</tr>
</tbody>
</table>

Fig. 6.04.09: Correction of exhaust gas data for ambient conditions and exhaust gas back pressure
\[ \Delta M_{\text{amb}} = -0.41 \times (T_{\text{air}} - 25) + 0.03 \times (p_{\text{bar}} - 1000) + 0.19 \times (T_{\text{CW}} - 25) - 0.011 \times (\Delta p_M - 300) \% \]  
\[ \Delta T_{\text{amb}} = 1.6 \times (T_{\text{air}} - 25) - 0.01 \times (p_{\text{bar}} - 1000) + 0.1 \times (T_{\text{CW}} - 25) + 0.05 \times (\Delta p_M - 300) \degree C \]

where the following nomenclature is used:

- \( \Delta M_{\text{amb}} \% \): change in exhaust gas amount, in \% of amount at ISO conditions
- \( \Delta T_{\text{amb}} \): change in exhaust gas temperature, in \degree C compared with temperatures at ISO conditions

Fig. 6.04.10: Exhaust gas correction formula for ambient conditions and exhaust gas back pressure

\[ P_{\text{S\%}} = (P_{S} / P_{M}) \times 100\% \]

\[ \Delta m_{\text{S\%}} = 37 \times (P_{S} / P_{M})^3 - 87 \times (P_{S} / P_{M})^2 + 31 \times (P_{S} / P_{M}) + 19 \]

Fig. 6.04.11: Change of specific exhaust gas amount, \( \Delta m_{\text{S\%}} \) in \% at part load, and valid for FPP and CPP

\[ \Delta T_{S} = 280 \times (P_{S} / P_{M})^2 - 410 \times (P_{S} / P_{M}) + 130 \]

Fig. 6.04.12: Change of exhaust gas temperature, \( \Delta T_{S} \) in \degree C at part load, and valid for FPP and CPP

c) Correction for engine load

Figs. 6.04.11 and 6.04.12 may be used, as guidance, to determine the relative changes in the specific exhaust gas data when running at part load, compared to the values in the specified MCR point, i.e. using as input \( P_{\text{S\%}} = (P_{S} / P_{M}) \times 100\% \):

- \( \Delta m_{\text{S\%}} \): change in specific exhaust gas amount, in \% of specific amount at specified MCR point, see Fig. 6.04.11.
- \( \Delta T_{S} \): change in exhaust gas temperature, in \degree C, see Fig. 6.04.12.
Calculation of Exhaust Data for Derated Engine

Example 3:

**Expected exhaust gas data for a** derated 6L70ME-C8.5-GI-TII with 1 high efficiency MAN TCA77-26 turbocharger, high load and fixed pitch propeller.

Based on the engine ratings below, and by means of an example, this chapter will show how to calculate the expected exhaust gas amount and temperature at service rating, and for a given ambient reference condition different from ISO.

The calculation is made for the service rating (S) of the diesel engine being 80% of the specified MCR.

Nominal MCR, \( P_{L1} \): 19.620 kW (100.0%) and 108.0 r/min (100.0%)

Specified MCR, \( P_M \): 17.658 kW (90.0%) and 102.6 r/min (95.0%)

Service rating, \( P_S \): 14.126 kW and 95.2 r/min, \( P_S = 80\% \) of \( P_M \)

**Reference conditions**
- Air temperature \( T_{air} \) .............................................................. 20° C
- Scavenge air coolant temperature \( T_{CW} \) ............................................. 18° C
- Barometric pressure \( p_{bar} \) ...................................................... 1.013 mbar
- Exhaust gas back-pressure at specified MCR \( \Delta p_M \) .................. 300 mm WC

**a) Correction for choice of specified MCR point \( M \):**

\[
\begin{align*}
\Delta M_{amb\%} &= + 1.11\% \\
\Delta T_{amb} &= 1.6 \times (20 - 25) - 0.01 \times (1,013 - 1,000) \\
&+ 0.03 \times (1,013 - 1,000) \degree C \\
\Delta T_{amb} &= - 8.8 \degree C
\end{align*}
\]

**b) Correction for ambient conditions and back-pressure:**

By means of equations [7] and [8]:

\[
\begin{align*}
\Delta M_{amb\%} &= -0.24\% \\
\Delta T_{M} &= -3.9 \degree C
\end{align*}
\]

**c) Correction for the engine load:**

Service rating = 80% of specified MCR power

By means of Figs. 6.04.11 and 6.04.12:

\[
\begin{align*}
\Delta M_{S\%} &= + 7.1\% \\
\Delta T_{S} &= - 18.8 \degree C
\end{align*}
\]
Final calculation
By means of equations [4] and [5], the final result is found taking the exhaust gas flow $M_{L1}$ and temperature $T_{L1}$ from the ‘List of Capacities’:

$$
M_{L1} = 171.100 \text{ kg/h}
$$

$$
M_{exh} = 171.100 \times \frac{17.658}{19.620} \times (1 + \frac{-0.24}{100}) \times (1 + \frac{1.11}{100}) \times (1 + \frac{7.1}{100}) \times \frac{80}{100} = 133.083 \text{ kg/h}
$$

$$
M_{exh} = 133.100 \text{ kg/h ±15%}
$$

The exhaust gas temperature

$$
T_{L1} = 231 ^\circ \text{C}
$$

$$
T_{exh} = 231 - 3.9 - 8.8 - 18.8 = 199.5 ^\circ \text{C}
$$

$$
T_{exh} = 199.5 ^\circ \text{C ±5 ^\circ \text{C}}
$$

Exhaust gas data at specified MCR (ISO)
At specified MCR (M), the running point may be in equations [4] and [5] considered as a service point where $P_{SW} = 100$, $\Delta m_{sw} = 0.0$ and $\Delta T_{s} = 0.0$.

For ISO ambient reference conditions where $\Delta M_{amb} = 0.0$ and $\Delta T_{amb} = 0.0$, the corresponding calculations will be as follows:

$$
M_{exh,M} = 171.100 \times \frac{17.658}{19.620} \times (1 + \frac{-0.24}{100}) \times (1 + \frac{0.0}{100}) \times \frac{100.0}{100} = 153.614 \text{ kg/h}
$$

$$
M_{exh,M} = 153.600 \text{ kg/h ±15%}
$$

$$
T_{exh,M} = 231 - 3.9 + 0 + 0 = 227,1 ^\circ \text{C}
$$

$$
T_{exh,M} = 227,1 ^\circ \text{C ±5 ^\circ \text{C}}
$$

The air consumption will be:

$$
153.614 \times 0.982 \text{ kg/h} = 150.849 \text{ kg/h}
$$

$$
150.849 / 3,600 \text{ kg/s} = 41.9 \text{ kg/s}
$$
ME-GI Fuel Gas System

The dual fuel system of the ME-GI engine combines the regular ME/ME-B fuel system when running in fuel oil modes and the fuel gas system running in dual fuel mode. The ME/ME-B fuel system is described in Section 7.01, the fuel gas system on the engine is described here in 7.00 and the gas supply and auxiliary systems in Sections 7.07 - 7.09.

Fig. 7.00.01: The ME-GI engine and gas handling units
The ME-GI specific engine parts

The modified parts of the ME-GI engine comprise gas supply piping, gas block with accumulator and control valves on the (slightly modified) cylinder cover with gas injection valves.

A sealing oil system, delivering sealing oil to the window/shutdown and gas injection valves, separates the control oil and the gas.

Apart from these systems on the engine, the engine auxiliaries will comprise some new units, the most important ones being:

- If the supply of gas is natural gas (NG) or compressed natural gas (CNG) it require a high-pressure gas compressor, including a cooler, to raise the pressure to 300 bar, which is the maximum required pressure at the engine inlet
- If the supply of gas is liquid natural gas (LNG) it requires a Cryogenic HP Pump and vaporiser solution
- The ME-GI Engine Control System (ME-GI-ECS)
- Leakage detection and ventilation system, which ventilates the outer pipe of the double-wall piping completely, and incorporates leakage detection
- Flow switches
- Inert gas system, which enables purging of the fuel gas supply system and the gas system on the engine with inert gas
- Gas Valve Train (GVT)
- Gas blow-off silencers
- Heat traced and insulated gas supply pipes.
Gas piping on the engine

The layout of double-wall piping system for gas is shown in Fig. 7.00.02. The high-pressure gas from the compressor unit or the high-pressure pumps (vaporiser) flows through the main pipe and distributed via flexible chain pipes to each cylinder’s gas control block. The flexible chain pipes perform two important tasks:

- To separate each cylinder unit from each other in terms of gas dynamics, utilising the well-proven design philosophy of the ME engine’s fuel oil system
- Act as flexible connections between the engine structure and safeguarding against extra stresses in the gas supply and chain pipes caused by the inevitable differences in thermal expansion of the gas pipe system and the engine structure.

The large volume accumulator contains about 20 times the injection amount per stroke at MCR and performs two tasks:

- Supply the gas amount for injection at only a slight, but predetermined, pressure drop
- Form an important part of the safety system, see Section 18.08.

The gas injection valve is controlled by the control oil system. This, in principle, consists of the ME hydraulic control oil system and an ELGI valve, supplying high-pressure control oil to the gas injection valve, thereby controlling the timing and opening of the gas valve.

**Fig. 7.00.02: Layout of double-wall piping system for fuel gas**
The ME-GI fuel injection system

As can be seen in Fig. 7.00.03a, the fuel oil pressure booster, that pressurizes the supplied fuel oil (pilot oil) during gas fuel operation mode, is connected to the FIVA valve that controls the injection of fuel oil to the combustion chamber.

The 300 bar hydraulic oil also pressurizes the ELGI valve controlling the injection of the gas fuel.

By the engine control system, the engine can be operated in the various relevant modes: ‘gas operation’ with minimum pilot oil amount, ‘specified dual fuel operation’ (SDF) with injection of a fixed gas amount and the ‘fuel-oil-only mode’.

The system provides:
- Pressure, timing, rate shaping, main, pre- and post-injection
- Low pressure fuel supply
- Fuel return
- Measuring and limiting device, Pressure booster (800-900) bar
- Injection
- Position sensor
- FIVA valve
- ELGI valve
- 300 bar hydraulic oil, Common with exhaust valve actuator
- Gas

The system provides:

Gas operation is possible down to 10% load.

The minimum pilot oil amount in gas operation mode is 3% at MCR (in L), see Fig. 7.00.03b. In case the engine is derated, the pilot amount is relatively higher as calculated in CEAS, see Section 20.02.

Engine output with minimum pilot oil amount can be obtained even with an LCV of the fuel gas as low as 38 MJ/kg. Below 38 MJ/kg, a higher pilot oil amount might be required.

For guaranteed Specific Gas Consumption (SGC) on test bed, the minimum LCV is 50 MJ/kg with a tolerance of ±5%.
Condition of the fuel gas delivery to the engine

The following data is based on natural gas as fuel gas.

Temperature
Temp. inlet to engine......................... 45 ±10 °C

The temperature is specified with regards to the following parameters:
- To reduce condensation on the outer wall of the inner pipe for double wall piping
- In order that the performance of the engine is not adversely affected
- To reduce thermal loads on the gas piping itself
- To obtain a uniform gas density.

Quality of the fuel gas
Condensate-free, without oil/water droplets or mist, similar to the PNEUROP recommendation 6611 ‘Air Turbines’.

MAN Diesel & Turbo’s ‘Guiding fuel gas specification’ is listed in Table 7.00.04.

Flow

The maximum flow requirement is specified at 110% SMCR, 315 bar, with reference to an LCV value of 38,000kJ/kg.

Maximum flow requirement ....................... Refer to ‘List of Capacities’, or CEAS report
Minimum flow requirement ........................................... 0 kg/h

The maximum flow requirement must also be achievable close to the overhaul interval of the FGS system. In case of a specific LCV requirement, please inform MAN Diesel & Turbo.

Under certain circumstances, modification of the gas valves may be required to accommodate a special LCV lower than 38,000 kJ/kg.

### Table 7.00.04: Guiding fuel gas specification

<table>
<thead>
<tr>
<th>Designation</th>
<th>Unit</th>
<th>Limit – if any</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower heat value</td>
<td>MJ/kg</td>
<td>Minimum 38 if maximum gas fuel is to be obtained, below 38 higher pilot fuel oil amount might be required</td>
</tr>
<tr>
<td>Gas methane number</td>
<td></td>
<td>No limit</td>
</tr>
<tr>
<td>Methane content</td>
<td>% volume</td>
<td>No limit</td>
</tr>
<tr>
<td>Hydrogen sulphide (H₂S)</td>
<td>% volume</td>
<td>Max. 0.05</td>
</tr>
<tr>
<td>Hydrogen (H₂)</td>
<td>% volume</td>
<td>No limit</td>
</tr>
<tr>
<td>Water and hydrocarbon condensates</td>
<td>% volume</td>
<td>0</td>
</tr>
<tr>
<td>Ammonia</td>
<td>mg/Nm³</td>
<td>Max. 25</td>
</tr>
<tr>
<td>Chlorine + Flourines</td>
<td>mg/Nm³</td>
<td>Max. 50</td>
</tr>
<tr>
<td>Particles or solid content</td>
<td>mg/Nm³</td>
<td>Max. 50</td>
</tr>
<tr>
<td>Particles or solid size</td>
<td>μm</td>
<td>Max. 5</td>
</tr>
<tr>
<td>Gas inlet temperature</td>
<td>°C</td>
<td>Max. 45 ±10</td>
</tr>
<tr>
<td>Gas pressure</td>
<td></td>
<td>According to MAN Diesel &amp; Turbo specification</td>
</tr>
</tbody>
</table>
Sealing oil system

The sealing oil system is a pressurised hydraulic oil system, with a constant differential pressure kept at a higher level than the gas pressure, prevents gas from entering the hydraulic oil system.

The sealing oil is applied to the gas injection valves and the window/shutdown valve in the space between the gas on one side and the hydraulic oil on the other side. The sealing oil pump unit is connected to the gas block with double-walled pipes.

The sealing oil system consists of one pump and a safety block with an accumulator. The sealing oil system uses the low pressure oil supply and pressurises it to the operating pressure 20 – 25 bar higher than the gas pressure in order to prevent that the hydraulic oil is polluted with gas. The sealing oil system is installed on the engine.

The consumption of sealing oil is small, as calculated in CEAS, see Section 20.02. The sealing oil will be injected with the fuel gas into the combustion chamber.

The sealing oil system is shown in Fig.7.00.05.

Sealing pump motors

Three different electric motors can be used on the sealing oil pumps:

- Pump displacement mechanically limited to 9 ccm/rev.:
  - 7.4 kW, 1,450 rpm M3AA 132 M, 50 Hz
  - 8.6 kW, 1,750 rpm M3AA 132 M, 60 Hz

- Pump displacement 16 ccm/rev.:
  - 18.0 kW, 1,750 rpm M3AA 160 M, 60 Hz

Fig. 7.00.05: Sealing oil system control diagram
Pressurised Fuel Oil System

The system is so arranged that both diesel oil and heavy fuel oil can be used, see Fig. 7.01.01.

From the service tank the fuel is led to an electrically driven supply pump by means of which a pressure of approximately 4 bar can be maintained in the low pressure part of the fuel circulating system, thus avoiding gasification of the fuel in the venting box in the temperature ranges applied.

The venting box is connected to the service tank via an automatic deaerating valve, which will release any gases present, but will retain liquids.

From the low pressure part of the fuel system the fuel oil is led to an electrically-driven circulating pump, which pumps the fuel oil through a heater and a full flow filter situated immediately before the inlet to the engine.

The fuel injection is performed by the electronically controlled pressure booster located on the Hydraulic Cylinder Unit (HCU), one per cylinder, which also contains the actuator for the electronic exhaust valve activation.

The Cylinder Control Units (CCU) of the Engine Control System (described in Section 16.01) calculate the timing of the fuel injection and the exhaust valve activation.

To ensure ample filling of the HCU, the capacity of the electrically-driven circulating pump is higher than the amount of fuel consumed by the diesel engine. Surplus fuel oil is recirculated from the engine through the venting box.

To ensure a constant fuel pressure to the fuel injection pumps during all engine loads, a spring loaded overflow valve is inserted in the fuel oil system on the engine.

The fuel oil pressure measured on the engine (at fuel pump level) should be 7-8 bar, equivalent to a circulating pump pressure of 10 bar.

Fuel considerations

When the engine is stopped, the circulating pump will continue to circulate heated heavy fuel through the fuel oil system on the engine, thereby keeping the fuel pumps heated and the fuel valves deaerated. This automatic circulation of preheated fuel during engine standstill is the background for our recommendation: constant operation on heavy fuel.

In addition, if this recommendation was not followed, there would be a latent risk of diesel oil and heavy fuels of marginal quality forming incompatible blends during fuel change over or when operating in areas with restrictions on sulphur content in fuel oil due to exhaust gas emission control.

In special circumstances a change-over to diesel oil may become necessary – and this can be performed at any time, even when the engine is not running. Such a change-over may become necessary if, for instance, the vessel is expected to be inactive for a prolonged period with cold engine e.g. due to:

- docking
- stop for more than five days
- major repairs of the fuel system, etc.

The built-on overflow valves, if any, at the supply pumps are to be adjusted to 5 bar, whereas the external bypass valve is adjusted to 4 bar. The pipes between the tanks and the supply pumps shall have minimum 50% larger passage area than the pipe between the supply pump and the circulating pump.

If the fuel oil pipe ‘X’ at inlet to engine is made as a straight line immediately at the end of the engine, it will be necessary to mount an expansion joint. If the connection is made as indicated, with a bend immediately at the end of the engine, no expansion joint is required.
Fuel Oil System

No valve in drain pipe between engine and tank
32 mm Nominal bore
To HFO settling tank
Fuel oil drain tank
Overflow tank

---

Diesel oil

Heavy fuel oil

Heated pipe with insulation
a) Tracing fuel oil lines: Max. 150°C
b) Tracing drain lines: By jacket cooling water

The letters refer to the list of 'Counterflanges'

Fig. 7.01.01: Fuel oil system
**Drain of clean fuel oil from HCU, pumps, pipes**

The HCU Fuel Oil Pressure Booster has a leakage drain of clean fuel oil from the umbrella sealing through ‘AD’ to the fuel oil drain tank.

The flow rate in litres is approximately as listed in Table 7.01.02.

<table>
<thead>
<tr>
<th>Engine</th>
<th>Flow rate, litres/cyl. h. HFO 12 cSt</th>
</tr>
</thead>
<tbody>
<tr>
<td>K98ME/ME-C,</td>
<td>0.65</td>
</tr>
<tr>
<td>S90ME-C, K90ME/ME-C</td>
<td>0.55</td>
</tr>
<tr>
<td>G/S/K80ME-C</td>
<td>0.50</td>
</tr>
<tr>
<td>G/S/L70ME-C, S70ME-C-GI, S65ME-C/-GI</td>
<td>0.40</td>
</tr>
<tr>
<td>G/S/L60ME-C, S60ME-C-GI, S60ME-B</td>
<td>0.30</td>
</tr>
</tbody>
</table>

*Table 7.01.02: Approximate flow in HCU leakage drain.*

This drained clean oil will, of course, influence the measured SFOC, but the oil is not wasted, and the quantity is well within the measuring accuracy of the flowmeters normally used.

The main purpose of the drain ‘AD’ is to collect fuel oil from the fuel pumps. As a safety measure for the crew during maintenance, an overhaul drain from the umbrella leads clean fuel oil from the umbrella directly to drain ‘AF’. Also washing water from the cylinder cover and the baseplate is led to drain ‘AF’.

The drain oil is led to a sludge tank and can be pumped to the Heavy Fuel Oil service tank or to the settling tank.

The ‘AF’ drain is provided with a box for giving alarm in case of leakage in a high pressure pipe.

The size of the sludge tank is determined on the basis of the draining intervals, the classification society rules, and on whether it may be vented directly to the engine room.

Drains ‘AD’, ‘AF’ and the drain for overhaul are shown in Fig. 7.03.01.

**Drain of contaminated fuel etc.**

Leakage oil, in shape of fuel and lubricating oil contaminated with water, dirt etc. and collected by the HCU Base Plate top plate, is drained off through the bedplate drains ‘AE’.

Drain ‘AE’ is shown in Fig. 8.07.02.

**Heating of fuel drain pipes**

Owing to the relatively high viscosity of the heavy fuel oil, it is recommended that the drain pipes and the fuel oil drain tank are heated to min. 50 °C, but max. 100 °C.

The drain pipes between engine and tanks can be heated by the jacket water, as shown in Fig. 7.01.01 ‘Fuel oil system’ as flange ‘BD’.

**Fuel oil flow velocity and viscosity**

For external pipe connections, we prescribe the following maximum flow velocities:

- Marine diesel oil: 1.0 m/s
- Heavy fuel oil: 0.6 m/s

The fuel viscosity is influenced by factors such as emulsification of water into the fuel for reducing the NOx emission. This is further described in Section 7.06.

An emulsification arrangement for the main engine is described in our publication:

*Exhaust Gas Emission Control Today and Tomorrow*

Further information about fuel oil specifications is available in our publication:

*Guidelines for Fuels and Lubes Purchasing*

The publications are available at www.marine.man.eu → 'Two-Stroke' → 'Technical Papers'.
Fuel Oils

Marine diesel oil:

- Marine diesel oil ISO 8217, Class DMB
- British Standard 6843, Class DMB
- Similar oils may also be used

Heavy fuel oil (HFO)

Most commercially available HFO with a viscosity below 700 cSt at 50 °C (7,000 sec. Redwood I at 100 °F) can be used.

For guidance on purchase, reference is made to ISO 8217:2012, British Standard 6843 and to CIMAC recommendations regarding requirements for heavy fuel for diesel engines, fourth edition 2003, in which the maximum acceptable grades are RMH 700 and RMK 700. The above-mentioned ISO and BS standards supersede BSMA 100 in which the limit was M9.

The data in the above HFO standards and specifications refer to fuel as delivered to the ship, i.e. before on-board cleaning.

In order to ensure effective and sufficient cleaning of the HFO, i.e. removal of water and solid contaminants, the fuel oil specific gravity at 15 °C (60 °F) should be below 0.991, unless modern types of centrifuges with adequate cleaning abilities are used.

Higher densities can be allowed if special treatment systems are installed.

Current analysis information is not sufficient for estimating the combustion properties of the oil. This means that service results depend on oil properties which cannot be known beforehand. This especially applies to the tendency of the oil to form deposits in combustion chambers, gas passages and turbines. It may, therefore, be necessary to rule out some oils that cause difficulties.

Guiding heavy fuel oil specification

Based on our general service experience we have, as a supplement to the above mentioned standards, drawn up the guiding HFO specification shown below.

Heavy fuel oils limited by this specification have, to the extent of the commercial availability, been used with satisfactory results on MAN B&W two-stroke low speed diesel engines.

The data refers to the fuel as supplied i.e. before any on-board cleaning.

<table>
<thead>
<tr>
<th>Guiding specification (maximum values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density at 15 °C kg/m³</td>
</tr>
<tr>
<td>Kinematic viscosity cSt</td>
</tr>
<tr>
<td>at 100 °C</td>
</tr>
<tr>
<td>at 50 °C</td>
</tr>
<tr>
<td>Flash point °C</td>
</tr>
<tr>
<td>Pour point °C</td>
</tr>
<tr>
<td>Carbon residue % (m/m)</td>
</tr>
<tr>
<td>Ash % (m/m)</td>
</tr>
<tr>
<td>Total sediment potential % (m/m)</td>
</tr>
<tr>
<td>Water % (v/v)</td>
</tr>
<tr>
<td>Sulphur % (m/m)</td>
</tr>
<tr>
<td>Vanadium mg/kg</td>
</tr>
<tr>
<td>Aluminum + Silicon mg/kg</td>
</tr>
</tbody>
</table>

* Provided automatic clarifiers are installed

m/m = mass v/v = volume

If heavy fuel oils with analysis data exceeding the above figures are to be used, especially with regard to viscosity and specific gravity, the engine builder should be contacted for advice regarding possible fuel oil system changes.
Fuel Oil Pipes and Drain Pipes

The letters refer to list of ‘Counterflanges’

The item No. refer to ‘Guidance values automation’

Fig. 7.03.01: Fuel oil and drain pipes
Fuel Oil Pipe Insulation

Insulation of fuel oil pipes and fuel oil drain pipes should not be carried out until the piping systems have been subjected to the pressure tests specified and approved by the respective classification society and/or authorities, Fig. 7.04.01.

The directions mentioned below include insulation of hot pipes, flanges and valves with a surface temperature of the complete insulation of maximum 55 °C at a room temperature of maximum 38 °C. As for the choice of material and, if required, approval for the specific purpose, reference is made to the respective classification society.

Fuel oil pipes

The pipes are to be insulated with 20 mm mineral wool of minimum 150 kg/m³ and covered with glass cloth of minimum 400 g/m².

Fuel oil pipes and heating pipes together

Two or more pipes can be insulated with 30 mm wired mats of mineral wool of minimum 150 kg/m³ covered with glass cloth of minimum 400 g/m².

Flanges and valves

The flanges and valves are to be insulated by means of removable pads. Flange and valve pads are made of glass cloth, minimum 400 g/m², containing mineral wool stuffed to minimum 150 kg/m³.

Thickness of the pads to be:
Fuel oil pipes ........................................ 20 mm
Fuel oil pipes and heating pipes together .... 30 mm

The pads are to be fitted so that they lap over the pipe insulating material by the pad thickness. At flanged joints, insulating material on pipes should not be fitted closer than corresponding to the minimum bolt length.

Mounting

Mounting of the insulation is to be carried out in accordance with the supplier’s instructions.

Fig. 7.04.01: Details of fuel oil pipes insulation, option: 4 35 121. Example from 98-50 MC engine
Heat Loss in Piping

<table>
<thead>
<tr>
<th>Diameter (mm)</th>
<th>Insulation thickness</th>
<th>Temperature difference between pipe and room (°C)</th>
<th>Heat loss watt/meter pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>17</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>21</td>
<td>20</td>
<td>30</td>
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<td>20</td>
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<tr>
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</tr>
<tr>
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</tr>
<tr>
<td>273</td>
<td>20</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

Fig. 7.04.02: Heat loss/Pipe cover
Fuel Oil Pipe Heat Tracing

The steam tracing of the fuel oil pipes is intended to operate in two situations:

1. When the circulation pump is running, there will be a temperature loss in the piping, see Fig. 7.04.02. This loss is very small, therefore tracing in this situation is only necessary with very long fuel supply lines.

2. When the circulation pump is stopped with heavy fuel oil in the piping and the pipes have cooled down to engine room temperature, as it is not possible to pump the heavy fuel oil. In this situation the fuel oil must be heated to pumping temperature of about 50 ºC.

To heat the pipe to pumping level we recommend to use 100 watt leaking/meter pipe.

Fuel Oil and Lubricating Oil Pipe Spray Shields

To fulfill IMO regulations, fuel and oil pipes assemblies are to be secured by spray shields as shown.

To ensure tightness the spray shields are to be applied after pressure test of the pipe system. as shown in Fig. 7.04.04a and b.

To avoid leaks, the spray shields are to be installed after pressure testing of the pipe system.
Components for Fuel Oil System

Fuel oil centrifuges

The manual cleaning type of centrifuges are not to be recommended. Centrifuges must be self-cleaning, either with total discharge or with partial discharge.

Distinction must be made between installations for:

- Specific gravities < 0.991 (corresponding to ISO 8217 and British Standard 6843 from RMA to RMH, and CIMAC from A to H-grades)
- Specific gravities > 0.991 and (corresponding to CIMAC K-grades).

For the latter specific gravities, the manufacturers have developed special types of centrifuges, e.g.:

Alfa Laval.................................................. Alcap
Westfalia.................................................. Unitrol
Mitsubishi.............................................. E-Hidens II

The centrifuge should be able to treat approximately the following quantity of oil:

\[0.23 \text{ litres/kWh}\]

This figure includes a margin for:

- Water content in fuel oil
- Possible sludge, ash and other impurities in the fuel oil
- Increased fuel oil consumption, in connection with other conditions than ISO standard condition
- Purifier service for cleaning and maintenance.

The size of the centrifuge has to be chosen according to the supplier’s table valid for the selected viscosity of the Heavy Fuel Oil. Normally, two centrifuges are installed for Heavy Fuel Oil (HFO), each with adequate capacity to comply with the above recommendation.

A centrifuge for Marine Diesel Oil (MDO) is not a must. However, MAN Diesel & Turbo recommends that at least one of the HFO purifiers can also treat MDO.

If it is decided after all to install an individual purifier for MDO on board, the capacity should be based on the above recommendation, or it should be a centrifuge of the same size as that for HFO.

The Nominal MCR is used to determine the total installed capacity. Any derating can be taken into consideration in border-line cases where the centrifuge that is one step smaller is able to cover Specified MCR.

Fuel oil supply pump

This is to be of the screw or gear wheel type.

Fuel oil viscosity, specified.... up to 700 cSt at 50 °C
Fuel oil viscosity maximum..................\(1,000\) cSt
Pump head.................................................. 4 bar
Fuel oil flow ................................ see ‘List of Capacities’
Delivery pressure ................................... 4 bar
Working temperature ................................ 100 °C
Minimum temperature ......................... 50 °C

The capacity stated in ‘List of Capacities’ is to be fulfilled with a tolerance of: \(\pm 0\%\) to \(+15\%\) and shall also be able to cover the back-flushing, see ‘Fuel oil filter’.

Fuel oil circulating pump

This is to be of the screw or gear wheel type.

Fuel oil viscosity, specified.... up to 700 cSt at 50 °C
Fuel oil viscosity normal............................20 cSt
Fuel oil viscosity maximum..................\(1,000\) cSt
Fuel oil flow ................................ see ‘List of Capacities’
Pump head........................................... 6 bar
Delivery pressure .................................... 10 bar
Working temperature ............................. 150 °C

The capacity stated in ‘List of Capacities’ is to be fulfilled with a tolerance of: \(\pm 0\%\) to \(+15\%\) and shall also be able to cover the back-flushing, see ‘Fuel oil filter’.

Pump head is based on a total pressure drop in filter and preheater of maximum 1.5 bar.
Fuel Oil Heater

The heater is to be of the tube or plate heat exchanger type.

The required heating temperature for different oil viscosities will appear from the ‘Fuel oil heating chart’, Fig. 7.05.01. The chart is based on information from oil suppliers regarding typical marine fuels with viscosity index 70-80.

Since the viscosity after the heater is the controlled parameter, the heating temperature may vary, depending on the viscosity and viscosity index of the fuel.

Recommended viscosity meter setting is 10-15 cSt.

Fuel oil viscosity specified ... up to 700 cSt at 50°C
Fuel oil flow ........................................ see capacity of fuel oil circulating pump
Heat dissipation ............................... see ‘List of Capacities’
Pressure drop on fuel oil side ..........maximum 1 bar
Working pressure ..................................10 bar
Fuel oil inlet temperature .............. approx. 100 °C
Fuel oil outlet temperature ............. 150 °C
Steam supply, saturated ...................7 bar abs

To maintain a correct and constant viscosity of the fuel oil at the inlet to the main engine, the steam supply shall be automatically controlled, usually based on a pneumatic or an electrically controlled system.

Fig. 7.05.01: Fuel oil heating chart
Fuel oil filter

The filter can be of the manually cleaned duplex type or an automatic filter with a manually cleaned bypass filter.

If a double filter (duplex) is installed, it should have sufficient capacity to allow the specified full amount of oil to flow through each side of the filter at a given working temperature with a max. 0.3 bar pressure drop across the filter (clean filter).

If a filter with backflushing arrangement is installed, the following should be noted. The required oil flow specified in the 'List of capacities', i.e. the delivery rate of the fuel oil supply pump and the fuel oil circulating pump, should be increased by the amount of oil used for the backflushing, so that the fuel oil pressure at the inlet to the main engine can be maintained during cleaning.

In those cases where an automatically cleaned filter is installed, it should be noted that in order to activate the cleaning process, certain makers of filters require a greater oil pressure at the inlet to the filter than the pump pressure specified. Therefore, the pump capacity should be adequate for this purpose, too.

The fuel oil filter should be based on heavy fuel oil of: 130 cSt at 80 °C = 700 cSt at 50 °C = 7000 sec Redwood I/100 °F.

Fuel oil flow ......................... see ‘List of capacities’
Working pressure ........................................10 bar
Test pressure.......................... according to class rule
Absolute fineness.................................50 μm
Working temperature ................. maximum 150 °C
Oil viscosity at working temperature ........15 cSt
Pressure drop at clean filter........ maximum 0.3 bar
Filter to be cleaned at a pressure drop of .....................maximum 0.5 bar

Note:
Absolute fineness corresponds to a nominal fineness of approximately 35 μm at a retaining rate of 90%.

The filter housing shall be fitted with a steam jacket for heat tracing.

Fuel oil venting box

The design of the Fuel oil venting box is shown in Fig. 7.05.02. The size is chosen according to the maximum flow of the fuel oil circulation pump, which is listed in section 6.03.

![Fuel oil venting box diagram]

### Flow m³/h
<table>
<thead>
<tr>
<th>Q (max.)*</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>H1</th>
<th>H2</th>
<th>H3</th>
<th>H4</th>
<th>H5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3</td>
<td>150</td>
<td>32</td>
<td>15</td>
<td>100</td>
<td>600</td>
<td>171.3</td>
<td>1,000</td>
<td>550</td>
</tr>
<tr>
<td>2.1</td>
<td>150</td>
<td>40</td>
<td>15</td>
<td>100</td>
<td>600</td>
<td>171.3</td>
<td>1,000</td>
<td>550</td>
</tr>
<tr>
<td>5.0</td>
<td>200</td>
<td>65</td>
<td>15</td>
<td>100</td>
<td>600</td>
<td>171.3</td>
<td>1,000</td>
<td>550</td>
</tr>
<tr>
<td>8.4</td>
<td>400</td>
<td>80</td>
<td>15</td>
<td>150</td>
<td>1,200</td>
<td>333.5</td>
<td>1,800</td>
<td>1,100</td>
</tr>
<tr>
<td>11.5</td>
<td>400</td>
<td>90</td>
<td>15</td>
<td>150</td>
<td>1,200</td>
<td>333.5</td>
<td>1,800</td>
<td>1,100</td>
</tr>
<tr>
<td>19.5</td>
<td>400</td>
<td>125</td>
<td>15</td>
<td>150</td>
<td>1,200</td>
<td>333.5</td>
<td>1,800</td>
<td>1,100</td>
</tr>
<tr>
<td>29.4</td>
<td>500</td>
<td>150</td>
<td>15</td>
<td>150</td>
<td>1,500</td>
<td>402.4</td>
<td>2,150</td>
<td>1,350</td>
</tr>
<tr>
<td>43.0</td>
<td>500</td>
<td>200</td>
<td>15</td>
<td>150</td>
<td>1,500</td>
<td>402.4</td>
<td>2,150</td>
<td>1,350</td>
</tr>
</tbody>
</table>

* The maximum flow of the fuel oil circulation pump

### Flushing of the fuel oil system

Before starting the engine for the first time, the system on board has to be flushed in accordance with MAN Diesel & Turbos recommendations 'Flushing of Fuel Oil System' which is available on request.
Water In Fuel Emulsification

For MAN B&W ME-GI engines, Water in Fuel Emulsification is applicable only in fuel oil mode, not in gas mode.

The emulsification of water into the fuel oil reduces the NOx emission with about 1% per 1% water added to the fuel up to about 20% without modification of the engine fuel injection equipment.

A Water In Fuel emulsion (WIF) mixed for this purpose and based on Heavy Fuel Oil (HFO) is stable for a long time, whereas a WIF based on Marine Diesel Oil is only stable for a short period of time unless an emulsifying agent is applied.

As both the MAN B&W two-stroke main engine and the MAN GenSets are designed to run on emulsified HFO, it can be used for a common system.

It is supposed below, that both the main engine and GenSets are running on the same fuel, either HFO or a homogenised HFO-based WIF.

Special arrangements are available on request for a more sophisticated system in which the GenSets can run with or without a homogenised HFO-based WIF, if the main engine is running on that.

Please note that the fuel pump injection capacity shall be confirmed for the main engine as well as the GenSets for the selected percentage of water in the WIF.

Temperature and pressure

When water is added by emulsification, the fuel viscosity increases. In order to keep the injection viscosity at 10-15 cSt and still be able to operate on up to 700 cSt fuel oil, the heating temperature has to be increased to about 170 °C depending on the water content.

The higher temperature calls for a higher pressure to prevent cavitation and steam formation in the system. The inlet pressure is thus set to 13 bar.

In order to avoid temperature chock when mixing water into the fuel in the homogeniser, the water inlet temperature is to be set to 70-90 °C.

Safety system

In case the pressure in the fuel oil line drops, the water homogenised into the Water In Fuel emulsion will evaporate, damaging the emulsion and creating supply problems. This situation is avoided by installing a third, air driven supply pump, which keeps the pressure as long as air is left in the tank ‘S’, see Fig. 7.06.01.

Before the tank ‘S’ is empty, an alarm is given and the drain valve is opened, which will drain off the WIF and replace it with HFO or diesel oil from the service tank.

The drain system is kept at atmospheric pressure, so the water will evaporate when the hot emulsion enters the safety tank. The safety tank shall be designed accordingly.

Impact on the auxiliary systems

Please note that if the engine operates on Water In Fuel emulsion (WIF), in order to reduce the NOx emission, the exhaust gas temperature will decrease due to the reduced air / exhaust gas ratio and the increased specific heat of the exhaust gas.

Depending on the water content, this will have an impact on the calculation and design of the following items:
- Freshwater generators
- Energy for production of freshwater
- Jacket water system
- Waste heat recovery system
- Exhaust gas boiler
- Storage tank for freshwater

For further information about emulsification of water into the fuel and use of Water In Fuel emulsion (WIF), please refer to our publication titled:

Exhaust Gas Emission Control Today and Tomorrow

The publication is available at www.marine.man.eu → ‘Two-Stroke’ → ‘Technical Papers’.
Number of auxiliary engines, pumps, coolers, etc. are subject to alterations according to the actual plant specification.

The letters refer to the list of ‘Counterflanges’.

a) Tracing fuel oil lines: Max. 150 °C
b) Tracing fuel oil drain lines: Max. 90 °C, min. 50 °C for installations with jacket cooling water

Fig. 7.06.01: System for emulsification of water into the fuel common to the main engine and MAN GenSets
Gas Supply System

The ME-GI engine requires fuel gas at a load dependent pressure and a temperature as specified in Section 7.00. This requirement is met by a gas supply system consisting of:

- fuel gas supply (FGS) system, see examples in Section 7.08
- gas valve train for control of fuel gas flow to the engine
- auxiliary systems for leakage detection and ventilation as well as inert gas, see Section 7.09.

Fig. 7.07.01 shows the systems placed outside the engine room.

The detailed design of the gas supply, FGS, inert gas as well as the leakage detection and ventilation systems will normally be carried out by the individual shipyard/contractor, and is, therefore, not subject to the type approval of the engine.

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Fig. 7.07.01: Gas supply system for ME-GI placed outside the engine room
Gas Valve Train

The Gas Valve Train (GVT) is available as a single unit 'block component' from MAN Diesel & Turbo, option: 4 37 601. The GVT can, however, also be constructed using individual valves based on our recommendation below.

The block GVT can be supplied with double-wall piping through the entire GVT, option: 4 37 602, if it is required to install the GVT in machinery space.

Location of the GVT above or below the deck

Careful consideration must be given to the installation of the Gas Valve Train. It should preferably be placed outside the engine room as close to the engine as possible, e.g. on the deck in open spaces.

![Fig. 7.07.02a: Tank, FGSS and Gas Valve Train located on deck, enclosed](image1)

![Fig. 7.07.02b: Tank, FGSS and Gas Valve Train located on deck, open ventilated space](image2)
Installed on the deck, single-wall piping can be applied from the FGS to the GVT and then double-wall piping from the GVT to the ME-GI engine beneath the deck. In this case, it is possible to run the double-wall pipe ventilation from just after the GVT.

If it is preferred to install the GVT below deck, it is recommended to install it in a room next to the engine room.

The room where the GVT is installed must have separate ventilation providing 30 air changes per hour and a hydrocarbon (HC) sensor installed.

Figs. 7.07.02a, 02b, 02c and 02d show the four alternative locations of the GVT and the piping applied.

Fig. 7.07.02c: Tank, FGSS and Gas Valve Train located below deck

Fig. 7.07.02d: Gas Valve Train located in machinery space
Gas supply system key components

High-pressure filter

The purpose of the high-pressure (HP) filter is primarily to protect the gas valve train and ME-GI components from foreign particles that could damage the sealing of the gas valves.

Medium: Natural gas
Maximum working pressure: 350 bar
Maximum pressure drop: 10kPa
Temperature (max): 55 ºC
Flow: Refer to CEAS report for max. gas flow
Filter mesh size: ≤10 micron

Valves in the gas valve train

For design and/or purchase of the gas bleed and block valves in the gas valve train shown in Fig. 7.07.03, the general specification is as follows.

Medium: Natural Gas
Standard: PN 420
Temperature min: -40 ºC
Temperature max: 55 ºC
Actuation: Pneumatic, 6-8 bar

- Gas bleed valve
  Function: Fail to Open
  Opening time: <10 sec.
  Closing time: <10 sec.

- Block valves
  Function: Fail to Close
  Opening time: <10 sec.
  Closing time: <2 sec.

The valve control signal interface is shown in Fig. 16.02.03 ‘GI Extension Interface to External Systems’.

Fig. 7.07.03: Gas valve train control
Gas piping

For delivery of high-pressure gas to the ME-GI main engine, double-wall gas pipe can be used in both open and enclosed spaces and is required for interior piping.

Moreover, double-wall gas pipe requires ventilation in the annular space as described in Section 7.09.

Single-wall gas piping can only be used in exterior locations in free open space. In all other locations, double-wall gas piping is required.

Double-wall piping

Design guidelines:

Bosses must be fitted for every 5 meters for inspection of outer duct, inner pipe and supports. Bosses shall also be fitted next to every pipe bend on each side.

Inner pipe support must be placed with a distance of 1.8 m of each other to prevent natural frequency. On vertical piping, two supports must be placed in the horizontal pipe right before the bend to the vertical pipe.

Pipes to be cold-drawn in order to obtain a proper inner surface finish of the outer pipe.

Pipe installation must be able to absorb deflection from hull and engine due to heat and vibration, therefore flexible elements must be installed.

Leakage test is to be carried out at shop test and at commissioning of the vessel.

For more information contact MAN Diesel & Turbo, Copenhagen.

Outer pipe for double-wall piping

Design in accordance with IGF code, chapter 9.8. The tangential membrane stress of a straight pipe should not exceed the tensile strength divided by 1.5 (Rm/1.5) when subjected to the critical pressure. The pressure ratings of all other piping components should reflect the same level of strength as straight pipes.

Temperature range: .......................÷55°C to +60 °C

Total Pressure loss (max):
Must be constructed in a way to be compliant with MAN Diesel & Turbo’s ventilation specification, see Section 7.09, ‘General data for ventilation system’.

Critical pressure: ....................... 174 bar
(Based on 320 bar design pressure for inner pipe)

Material

The recommended material is Duplex EN 1.4462 or Stainless steel 316L (EN 1.4404). Selection of this material is based on corrosion resistance and required strength, resistance to cold exposure. Therefore long maintenance intervals can be offered with this material.

Duplex Steel EN 1.4462:
Ultimate tensile stress (UTS) ....................... 680 MPa
Yield stress ....................... 450 MPa

Stainless steel 316L (EN 1.4404):
Ultimate tensile stress (UTS) ....................... 500 MPa
Yield stress ....................... 200 MPa

Sizing of outer pipe

The table below provides pipe dimension guidelines based on standard pipe sizes for EN 1.4462, and in compliance with the above mentioned formula.

<table>
<thead>
<tr>
<th>Power range</th>
<th>Pipe OD</th>
<th>Thickness, t</th>
<th>NPS</th>
<th>Test pressure</th>
<th>Stress resulting from critical pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW</td>
<td>mm</td>
<td>mm</td>
<td>inch</td>
<td>Bar</td>
<td>Mpa</td>
</tr>
<tr>
<td>0-45</td>
<td>114,30</td>
<td>3,05</td>
<td>4</td>
<td>175</td>
<td>317</td>
</tr>
<tr>
<td>&gt;45</td>
<td>168,28</td>
<td>4,50</td>
<td>6</td>
<td>175</td>
<td>308</td>
</tr>
</tbody>
</table>
Inner pipe

The inner pipe in double-wall gas piping for delivery of high-pressure gas to the ME-GI main engine has the following specification:

Design pressure: .........................................320 bar
Temperature range: ......................÷55 °C to +60 °C
Total pressure loss (max) *): ............................5 bar
LHV: .......................................................... 50 MJ/kg

*) This refers to pressure loss from FGS flange to engine flange and only due to piping.

Design calculations for the pipe are performed using the above design assumptions, using the formula specified in chapters 5.2 and 5.3 of the IGC code for calculation of pipe thickness. Pipe strength for different pipe sizes is selected based on manufacturers information according to ASME B31.3.

For projects using gas with a specific LHV, the maximum total pressure loss requirement is unchanged, so a larger diameter pipe will be required to maintain pressure loss with a higher flow.

Total pressure loss

The total pressure loss from gas supply system to ME-GI main engine should be as low as possible, and calculated by the shipyard, where by:

\[ P_{\text{Total}} = P_{\text{Piping}} + P_{\text{GV1}} + P_{\text{Filter}} + P_{\text{Flowmeter}} \]

According to FGS design a maximum of 15 bar is allowed at 100 % SMCR. However, this requires additional energy from the FGS system so it is more desirable to improve the installation to reduce pressure loss to a minimum.

Material

The recommended material is Duplex EN 1.4462 up 1½” pipe dimension and Super Duplex EN 1.4410 up to 2½” pipe dimension.

Selection of this material is based on corrosion resistance, required strength, resistance to cold exposure, resistance to stress corrosion chloride cracking. Therefore long maintenance intervals can be offered with this material.

Piping should be cold-worked in order to reduce internal surface roughness.

Maximum surface roughness: ..................... 15 μm

Sizing of inner pipe

In order to dimension the piping, the guidelines provided in the table below can be used.

The pressure loss is calculated based on a length (stated in metres in the tables below) of piping from Fuel Gas Supply to the main engine inlet flange, including 20 bends.

Design using welded bends is recommended, with minimum radius as per DIN 13480-3, Chapter 6.2 and 6.3.

---

### Dimension guidelines based on standard pipe sizes for EN 1.4462

<table>
<thead>
<tr>
<th>Power range</th>
<th>Max flow</th>
<th>Pipe OD</th>
<th>Thickness, t</th>
<th>SCH</th>
<th>NPS</th>
<th>DN</th>
<th>Test pressure</th>
<th>Pressure loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MW Kg/h</td>
<td>mm</td>
<td>mm</td>
<td></td>
<td></td>
<td></td>
<td>50m bar</td>
<td>100m bar</td>
</tr>
<tr>
<td>0-15</td>
<td>2,100</td>
<td>33.40</td>
<td>3.88</td>
<td>40</td>
<td>1</td>
<td>25</td>
<td>480</td>
<td>1.5</td>
</tr>
<tr>
<td>15-30</td>
<td>4,000</td>
<td>42.16</td>
<td>4.85</td>
<td>80</td>
<td>1¼</td>
<td>32</td>
<td>480</td>
<td>1.4</td>
</tr>
<tr>
<td>30-45</td>
<td>6,000</td>
<td>48.26</td>
<td>5.08</td>
<td>80</td>
<td>1½</td>
<td>40</td>
<td>480</td>
<td>1.4</td>
</tr>
</tbody>
</table>

### Dimension guidelines based on standard pipe sizes for EN 1.4410

<table>
<thead>
<tr>
<th>Power range</th>
<th>Max flow</th>
<th>Pipe OD</th>
<th>t</th>
<th>SCH</th>
<th>NPS</th>
<th>DN</th>
<th>Test pressure</th>
<th>Pressure loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MW Kg/h</td>
<td>mm</td>
<td>mm</td>
<td></td>
<td></td>
<td></td>
<td>50m bar</td>
<td>100m bar</td>
</tr>
<tr>
<td>45-80</td>
<td>11,800</td>
<td>60.33</td>
<td>5.54</td>
<td>80</td>
<td>2</td>
<td>50</td>
<td>480</td>
<td>1.4</td>
</tr>
<tr>
<td>≥80</td>
<td>19,000</td>
<td>73.03</td>
<td>7.01</td>
<td>80</td>
<td>2¼</td>
<td>65</td>
<td>480</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Generating of fuel gas pressure

The pressure can be generated by the FGS in different ways depending on the storage condition of the gas. Some of the possibilities are:

- high-pressure gas compressor, including coolers, pulsation dampers, condensate separator etc.
- high-pressure cryogenic pump to deliver high pressure LNG to an evaporator
- a combination of the above solutions.

Examples of fuel gas supply systems is described in Section 7.08.

Control of the fuel gas supply system

A description of the ME-GI Engine Control System (ME-GI-ECS) is provided in Section 16.02.

The fuel gas pressure is to be controlled on the basis of the gas supply pressure set point, and the actual fuel gas load specified by the GI-ECS.

The control signal interface is shown in Fig. 16.02.03 'GI Extension Interface to External Systems' and the diagram of the gas valve train is shown in Fig. 7.07.03.

The gas supply pressure set point is expected to change from 200 bar to 300 bar dependent on engine load. The allowable deviation from the gas supply pressure set point is:

Deviation from set point (dynamic) ±5%

This requirement is to be fulfilled at a gas flow rate disturbance frequency of 0.1 Hz, and a gas flow rate variation (kg/s) relative to the gas flow rate at MCR of ±15%. This requirement has to be fulfilled also for the lowest calorific values of the gas.

Deviation from set point (static) ±1%

For using BOG from cargo tanks like LNG tankers, the FGS must be able to read the calorific value of the supplied gas to the main engine.

FGS pressure requirement guideline

The expected range of the gas pressure requirement for the FGS system is shown in Fig. 7.07.04. The gas supply pressure set point will be within the dotted area.

![Gas supply pressure set point range](image-url)
**Suction pressure for high pressure pump**

In case of application of high-pressure pump in the FGS system, sufficient positive pressure before the pump must be maintained in all conditions to avoid vaporisation of the LNG. Therefore, the pump suppliers NSPH requirement must be followed. See Fig. 7.07.05.

**Fig. 7.07.05: Suction pressure for high pressure pump**
Safety standards for the gas supply system

All equipment shall comply with but not necessarily be limited to the following:

a. Meet full class requirements for UMS notation and ACCU notation etc. (ABS, LRS and DNV)

b. Comply with current and draft International Gas Code (IGC) requirements

c. Comply with SOLAS and Flag State requirements for fire safety and detection systems

d. Other standards to be fulfilled:

- DNV Rules Part 6 Chapter 13 Gas Fuelled Engine Installations
- ABS applicable sections in their guidelines for propulsion and auxiliary for gas-fuelled ships
- ALPEMA SE 2000 or latest, Standards for Plate-fin Heat Exchangers
- ASME VIII div 1 Plate-fin Heat Exchangers
- ASME BPVC-VIII-3 Construction of High Pressure Vessels
- IEC 60092 Electrical installations in ships Certified according to ATEX directives.
Examples of Fuel Gas Supply Systems

Fuel gas supply systems preconditions

Bulker carriers, oil tankers and container vessels have requirements for the gas supply system different from LNG carriers.

LNG carriers have LNG onboard and the implication for this type of ship is to design an efficient fuel gas supply system, taking handling of boil-off gas (BOG) into consideration. The gas supply system should be able to handle the boil-off gas coming from the tanks and deliver it to the engine as well as to the dual fuel gensets. Furthermore, if the pressure in the tanks becomes too high, the gas supply system should be able to direct the BOG to the gas combustion unit (GCU) in order to protect the tanks.

For gas-fuelled bulkers, oil tankers and container vessels an LNG bunker tank is required. Therefore LNG bunker tanks are installed together with a fuel gas supply system delivering LNG to the ME-GI engine as well as to the dual fuel gensets. Here the implication is to make a ship design, which have sufficient space for putting up the tanks without losing any space for bulk, oil and containers. With LNG bunker tanks installed, however, no high-pressure compressors are required, thus the FGS consists of a high-pressure pump and vaporiser only, see Figs. 7.08.05a and b.

In short, different applications call for different gas supply systems and also operators and shipowners demand alternative solutions. Therefore, MAN Diesel and Turbo aims to have a number of different fuel gas supply systems prepared, tested and available for the MAN B&W ME-GI engine plants.

The three fuel gas supply solutions most commonly considered for the ME-GI engine are:

- LNG with high-pressure compressor
- LNG with cryogenic high-pressure pump
- CNG with high-pressure compressor.

The first two solutions can be combined with a reliquefaction system for boil-off gas as shown in Fig. 7.08.01.

![Diagram](image_url)

**Fig. 7.08.01: Three most commonly used gas supply systems**
Gas supply systems and reliquefaction plants

Table 7.08.02 lists fuel gas supply systems and reliquefaction plants for the MAN B&W ME-GI.

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Type / system name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burckhardt Compression AG</td>
<td>Laby®-GI compressor</td>
<td>Compressor system with two Laby®-GI compressors utilising the BOG from the ship storage tanks.</td>
</tr>
<tr>
<td>Cryostar SAS</td>
<td>Gas supply system with EcoRel reliquefaction plant</td>
<td>High-pressure liquid pump and vaporiser fed by condensate from a reliquefaction plant; surplus condensate is returned to the cargo tanks.</td>
</tr>
<tr>
<td>Daewoo Shipbuilding &amp; Marine Engineering Co., Hamworthy plc, Hyundai Heavy Industries Co., Mitsubishi Heavy Industries Ltd., TGE Marine AG</td>
<td>LNG high-pressure liquid pump</td>
<td>LNG from the cargo tanks supplied with the cargo pumps to the fuel gas supply system by means of a booster pump, a high-pressure pump and a heater unit.</td>
</tr>
<tr>
<td>Daewoo Shipbuilding &amp; Marine Engineering Co. + Burckhardt Compression AG</td>
<td>Laby®-GI compressor with partial reliquefaction and LNG high-pressure liquid pump</td>
<td>BOG evacuated from the LNG tanks by a three-stage centrifugal type BOG compressor with subsequent cooling after each stage.</td>
</tr>
<tr>
<td>Hamworthy plc</td>
<td>Mark III BOG reliquefaction system</td>
<td>BOG evacuated from the LNG tanks by a Laby®-GI compressor followed by two-stage centrifugal type BOG compressor with reliquefaction bypass.</td>
</tr>
<tr>
<td>Hamworthy plc + Burckhardt Compression AG</td>
<td>Mark III BOG reliquefaction system with Laby®-GI compressor</td>
<td>BOG compressor system with Laby®-GI compressors and cascade reliquefaction technology.</td>
</tr>
</tbody>
</table>

Table 7.08.02: Examples of fuel gas supply systems with and without reliquefaction plants

Capacities and dimensions of the FGS

For capacities and dimensions of the fuel gas supply system and reliquefaction plant (if installed), refer to the manufacturer's documentation.

Further information about fuel gas supply systems is available in our publication:

*ME-GI Dual Fuel MAN B&W Engines*

The publication is available at [www.marine.man.eu](http://www.marine.man.eu) → 'Two-Stroke' → 'Technical Papers'.


Low speed diesel engine with high pressure gas injection

Fig. 7.08.03: Combined reliquefaction plant and HP LNG pump supply system delivering high pressure fuel gas to the ME-GI engine (Cryostar SAS)

Fig. 7.08.04: Integrated compressor and reliquefaction system with Laby®-GI compressor (Hamworthy plc and Burckhardt Compression AG)
**Fig. 7.08.05a: Example of an FGS with high-pressure pump and vaporiser for LNG-fuelled merchant vessels. Vacuum-insulated LNG tanks, type C, best feasible for smaller vessels.**

**Fig. 7.08.05b: Example of an FGS with high-pressure pump and vaporiser for LNG-fuelled merchant vessels. Foam-insulated LNG tanks, type C, best feasible for medium-sized vessels.**
ME-GI Gas Supply Auxiliary Systems

The ME-GI gas supply auxiliary systems include:

- leakage detection and ventilation system, which ventilates the outer pipe of the double-wall piping completely and incorporates leakages detection
- inert gas system, which enables purging of the fuel gas system on the engine and the fuel gas supply system with inert gas
- gas return system (optional), receiving fuel gas returned from the engine when gas pipes are being depressurised.

Fig. 7.09.01 shows the gas supply auxiliary systems and how they are connected to the ME-GI engine.

**Capacities of the ME-GI auxiliary systems**

The capacities of the ME-GI gas supply auxiliary systems are listed in the CEAS report for the actual project see section 20.02.

---

**Fig. 7.09.01: ME-GI gas supply auxiliary systems**
Leakage detection and ventilation system

The purpose of the leakage detection and ventilation system is to ensure that the outer pipe of the double-wall gas pipe system is constantly ventilated by air. In this way securing gas leakages if any, to be detected and transported to a secure place outside the engine room the ventilation system is required where double wall piping is applied, in all enclosed areas on board the vessel.

General data for ventilation system

Medium: ................................................Ambient air
Minimum air supply inlet pressure: ...... 500 mBarg
(to be set at reduction valve)
Air supply quality: ......................... ISO 8573-1: 7 3 4
Pressure dewpoint Class 3 ≤ 20 °C

Ventilation air pressure must always be less atmospheric pressure, so a ventilation fan is also required to suck the supply air through the ventilation system from the air supply inlet cover.

Minimum ventilation air pressure: ..........÷10 mBarg
Temperature range: ......................÷20 °C to +55 °C

Venting air fan capacity

To decide the necessary capacity for the fan, the volume of the intermediate spaces of the pipe system must be calculated. The complete volume consists of:

- the volume of the annular spaces in the main pipes
- the volume of the annular space in the chain pipes
- the vented volume in the gas control block.

For further information regarding pipe sizes and venting volume in the gas block for a specific engine type, contact MAN Diesel & Turbo.

Based on the calculated volume, the capacity must ensure a minimum of 30 air changes per hour.

Fan requirements and installation guidelines

Ventilation is achieved by means of an electrically driven extractor fan on deck. The fan must work independently of any other fan installation in the engine room/power plant.

The electric fan motor as well as the starters have to be located outside the ventilated pipe and its connected ducting.

The fan has to be protected with a wire mesh (max 13 mm square mesh) in the outside opening which is also to be protected against rain/water entrance. In no case is the radial air gap between the impeller and the casing to be less than 0.1 times the diameter of the impeller shaft in way of the bearing but not less than 2 mm. It need not be more than 13 mm.

The parts of the rotating body and of the casing are to be made of spark free materiel and they are to have antistatic properties. The installation of the ventilation units is to made such as to ensure the bonding to the structure/hull of the unit themselves.

The ventilation inlet is to be located in open air away from ignition sources, and it is recommend to consider inlet and outlet as ATEX zone 1.

Venting air fan control

The fan is to be controlled from the GI-ECS, see Fig. 16.02.03 ‘GI Extension Interface to External Systems’, with reference to the signals going to and from ‘Double Wall Pipe Ventilation’.

Two flow switches must be installed in the venting air intake to monitor that air is flowing through the ventilation system and the pipes are vented sufficiently.
Leakage detection

To detect any gas leaks into the annular space in the double wall piping, two hydrocarbon (HC) sensors must be installed in the outlet of the ventilation system. The location of the flow switches and HC sensors is shown in Fig. 7.09.02.

Safety standards for the leakage detection and ventilation system

The leakage detection and ventilation system must comply with:

- all relevant classification requirements
- IEC 60092 Electrical Installations in Ships
- Certification according to ATEX directives.

![Diagram of leakage detection and ventilation system](image_url)

Fig. 7.09.02: Leakage detection and ventilation system for double-wall piping
Inert gas system

The inert gas system is required for purging of all fuel gas piping associated with the ME-GI installation. See the diagram of gas supply auxiliary systems Fig 7.09.01.

The inert gas for purging of the Fuel Gas Supply (FGS) system can either be supplied from a common inert gas system, or a separate stand alone system. This will depend on the individual installation.

A sufficient quantity of inert gas must be available on board before beginning to operate the engine on fuel gas.

General data for the inert gas system

Medium: .............................................................. N₂
Purging pressure: ...................................... 7 - 9 bar

Control of the inert gas system

The inert gas system is to be equipped with the interface signals described in Fig. 16.02.03 ‘GI Extension Interface to External Systems’, with reference to the signals going to and from ‘Inert Gas System’. When operating in ‘remote’ mode, the inert gas system is controlled by the GI control system.

Inert gas pipe connections

Please refer to Section 7.00 for estimating pipe dimensions based on engine power. The actual pipe dimensions must also be verified with Yard.

Safety requirements

For marine applications, the inert gas system is to be delivered with a Class approved product certificate.

Purging volume and storage capacity

The purging storage volume (or capacity) should also be designed for a number of consecutive starts on fuel gas. Our guideline is to design the system for 6 consecutive fuel gas starts.

In order to calculate the purging volume, the total volume of piping being purged must be calculated. The purging sequences are described in Table 7.09.03 with reference to Fig. 7.09.04.

Calculating the purging volume

The purge sequence is performed a maximum of 5 times, dependent on measurement by the HC sensors in the return pipe. Furthermore, the system must be purged before start in fuel gas mode.

Consequently a guideline for calculating the inert gas storage volume is:

\[
Purging volume = 6 \times 5 \times 2 \times (V_{sect \ 1} + V_{sect \ 2})
\]

the numbers meaning:

- 6 consecutive fuel gas starts
- 5 runs of purge sequence maximum
- 2 purges before start in fuel gas mode.
Chain pipe and accumulator volume is dependent on engine type, contact MAN Diesel & Turbo for further information.

If a common inert gas system is used to supply the FGS system too, the volume of this system must be added to the purging volume.

<table>
<thead>
<tr>
<th>ME-GI purge sequences</th>
<th>Piping route</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Purging accumulators $V_{\text{sect 1}}$</td>
<td>Inert gas unit – chain pipe – accumulator – purge valve – silencer</td>
</tr>
</tbody>
</table>

**Table 7.09.03: Purging sequence**

**Fig. 7.09.04: Piping routes for purging sequence**
**Vent silencer**

The vent silencer is needed because noise from venting valves can be expected to be in the region of 130 to 170 dB(A) Lw.

This description is made as a general specification and guideline for design and/or purchase of the vent silencer.

**Acoustic requirements**

Sound pressure level at 5 m distance: .....110 dB(A)

A chart of the allowable daily and occasional noise exposure zones is shown in Fig. 7.09.05.

**Safety requirements**

The vent silencer must comply with:

- Class requirements
- acoustic requirement in compliance with the IMO noise limits for seafarers.

The silencer design must secure that no gas is being trapped inside the silencer. Otherwise the function of the HC detector in the return pipe could be disturbed.

### Operating conditions

<table>
<thead>
<tr>
<th>Medium</th>
<th>Natural gas</th>
<th>Ethane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature, °C</td>
<td>+55 to +55</td>
<td>+89 to +55</td>
</tr>
<tr>
<td>Pressure upstream, bar</td>
<td>300</td>
<td>600</td>
</tr>
<tr>
<td>Mass flow rate, kg/s</td>
<td>See “Calculating the venting gas flow”</td>
<td></td>
</tr>
</tbody>
</table>

---

**Fig. 7.09.05: Allowable daily and occasional noise exposure zones**
Calculating the venting gas flow

The gas flow can be calculated from the Bird, Stewart and Lightfoot source-term model for choked gas flows from a pressurized gas system:

\[
t = \frac{\frac{2}{(k-1)} \times (F^{3-1})}{C_D \times \frac{(A/V)}{\{k \left(\frac{P_0}{d_0}\right) \times \left[\frac{2}{(k+1)}\right]^{a/3}\}}}
\]

where

\( t \) = the time since the flow started (when valve opens)
\( k \) = \( c_p/c_v \) of the gas (1.77 for methane at 300 bar, 45 °C)
\( F \) = the fraction of initial gas weight remaining in the system at any time \( t \)

\( a = \frac{1-k}{2} \)
\( C_D = \) coefficient of discharge, normally 0.72
\( A = \) cross sectional area of purge valve (805) in m²
\( V = \) system volume (piping volume from vent silencer to inert gas control valve (809) in m³)
\( P_0 = \) the initial gas pressure in the system, in Pa (30 MPa)
\( d_0 = \) the initial gas density in the system (195 kg/m³ for methane at 300 bar, 45 °C)

The pressure \( P \) at any fraction \( F : P = P_0 F^a \)

Example of pressure and mass flow at any given time for 100 l system volume and DN 50 valve is shown in Fig. 7.09.06.

![Gas condition during purging](image)

**Fig. 7.09.06: Gas condition during purging**

Gas return system

The optional gas return system, option: 4 37 611, enables emission-free gas solution by saving the fuel gas that is emitted to atmosphere during gas pipe emptying procedures.

The gas return system receives the remaining gas in the pipes and accumulators on engine side when fuel gas running is stopped and if the system is ready to receive gas. Otherwise, the gas is blown off to the atmosphere.
Lubricating Oil
Lubricating and Cooling Oil System

The lubricating oil is pumped from a bottom tank by means of the main lubricating oil pump to the lubricating oil cooler, a thermostatic valve and, through a full-flow filter, to the engine inlet RU, Fig. 8.01.01.

RU lubricates main bearings, thrust bearing, axial vibration damper, piston cooling, crosshead bearings, crankpin bearings. It also supplies oil to the Hydraulic Power Supply unit and to moment compensator and torsional vibration damper.

From the engine, the oil collects in the oil pan, from where it is drained off to the bottom tank, see Fig. 8.06.01a and b ‘Lubricating oil tank, with cofferdam’. By class demand, a cofferdam must be placed underneath the lubricating oil tank.

The engine crankcase is vented through ‘AR’ by a pipe which extends directly to the deck. This pipe has a drain arrangement so that oil condensed in the pipe can be led to a drain tank, see details in Fig. 8.07.01.

Drains from the engine bedplate ‘AE’ are fitted on both sides, see Fig. 8.07.02 ‘Bedplate drain pipes’.

For external pipe connections, we prescribe a maximum oil velocity of 1.8 m/s.

Lubrication of turbochargers

Turbochargers with slide bearings are normally lubricated from the main engine system. AB is outlet from the turbocharger, see Figs. 8.03.01 to 8.03.04.

Figs. 8.03.01 to 8.03.04 show the lube oil pipe arrangements for different turbocharger makes.

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* Venting for MAN or Mitsubishi turbochargers only

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Fig. 8.01.01 Lubricating and cooling oil system
Hydraulic Power Supply Unit

Hydraulic power for the ME hydraulic-mechanical system for activation of the fuel injection and the exhaust valve is supplied by the Hydraulic Power Supply (HPS) unit.

As hydraulic medium, normal lubricating oil is used, as standard taken from the engine’s main lubricating oil system and filtered in the HPS unit.

HPS connection to lubrication oil system

Internally on the engine, the system oil inlet RU is connected to the HPS unit which supplies the hydraulic oil to the Hydraulic Cylinder Units (HCUs). See Figs. 16.01.02a and 16.01.02b.

RW is the oil outlet from the automatic backflushing filter.

The hydraulic oil is supplied to the Hydraulic Cylinder Units (HCU) located at each cylinder, where it is diverted to the electronic Fuel Injection system, and to the electronic exhaust Valve Activation (FIVA) system, which perform the fuel injection and opens the exhaust valve. The exhaust valve is closed by the conventional ‘air spring’.

The electronic signals to the FIVA valves are given by the Engine Control System, see Chapter 16, Engine Control System (ECS).

HPS configurations

The HPS pumps are driven either mechanically by the engine (via a step-up gear from the crankshaft) or electrically.

With mechanically driven pumps, the HPS unit consists of:

- an automatic and a redundant filter
- three to five engine driven main pumps
- two electrically driven start-up pumps
- a safety and accumulator block

as shown in Fig. 8.02.01.

With electrically driven pumps, the HPS unit differs in having a total of three pumps which serve as combined main and start-up pumps.

The HPS unit is mounted on the engine no matter how its pumps are driven.

HPS unit types

Altogether, three HPS configurations are available:

- STANDARD mechanically driven HPS, EoD: 4 40 160, with mechanically driven main pumps and start-up pumps with capacity sufficient to deliver the start-up pressure only. The engine cannot run with all engine driven main pumps out of operation, whereas 66% engine load is available in case one main pump is out

- COMBINED mechanically driven HPS unit, EoD: 4 40 167 with electrically driven start-up pumps with back-up capacity. In this case, at least 15% engine power is available as back-up power if all engine driven pumps are out

- electrically driven HPS, EoD: 4 40 161, with 66% engine load available in case one pump is out.

The electric power consumption of the electrically driven pumps should be taken into consideration in the specification of the auxiliary machinery capacity.
Hydraulic Power Supply Unit, Engine Driven, and Lubricating Oil Pipes

The letters refer to list of “Counterflanges”
The item no. refer to “Guidance Values Automation”
The piping is delivered with and fitted onto the engine

Fig. 8.02.01: Engine driven hydraulic power supply unit and lubricating oil pipes
Lubricating Oil Pipes for Turbochargers

Fig. 8.03.01: MAN turbocharger type TCA

Fig. 8.03.03: Mitsubishi turbocharger type MET

Fig. 8.03.03: ABB turbocharger type A100L
Fig. 8.03.02: ABB turbocharger type TPL85B14-16 / TPL91B12

Fig. 8.03.02: ABB turbocharger type TPL65B12 - TPL85B12
Lubricating Oil Consumption, Centrifuges and List of Lubricating Oils

Lubricating oil consumption
The system oil consumption varies for different engine sizes and operational patterns. Typical consumptions are in the range from

negligible to 0.1 g/kWh

subject to load, maintenance condition and installed equipment like PTO.

Lubricating oil centrifuges
Automatic centrifuges are to be used, either with total discharge or partial discharge.

The nominal capacity of the centrifuge is to be according to the supplier’s recommendation for lubricating oil, based on the figure:

0.136 litre/kWh

The Nominal MCR is used as the total installed power.

Further information about lubricating oil qualities is available in our publication:

Guidelines for Fuels and Lubes Purchasing
The publication is available at www.marine.man.eu → ‘Two-Stroke’ → ‘Technical Papers’.

List of lubricating oils
The circulating oil (lubricating and cooling oil) must be of the rust and oxidation inhibited type of oil of SAE 30 viscosity grade.

In short, MAN Diesel and Turbo recommends the use of system oils with the following main properties:

- SAE 30 viscosity grade
- BN level 5-10
- adequately corrosion and oxidation inhibited
- adequate detergency and dispersancy.

The adequate dispersion and detergent properties are in order to keep the crankcase and piston cooling spaces clean of deposits.

Alkaline circulating oils are generally superior in this respect.

The major international system oil brands listed below have been tested in service with acceptable results. Some of the oils have also given satisfactory service results during long-term operation on MAN B&W engines running on heavy fuel oil (HFO).

<table>
<thead>
<tr>
<th>Company</th>
<th>Circulating oil SAE 30, BN 5-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aegean</td>
<td>Alfasy 305</td>
</tr>
<tr>
<td>BP</td>
<td>OE-HT 30</td>
</tr>
<tr>
<td>Castrol</td>
<td>CDX 30</td>
</tr>
<tr>
<td>Chevron</td>
<td>Veritas 800 Marine 30</td>
</tr>
<tr>
<td>ExxonMobil</td>
<td>Mobilgard 300</td>
</tr>
<tr>
<td>Gulf Oil Marine</td>
<td>GulfSea Superbear 3006</td>
</tr>
<tr>
<td>Lukoil</td>
<td>Navigo 6 SO</td>
</tr>
<tr>
<td>JX</td>
<td>Marine S30</td>
</tr>
<tr>
<td>Shell</td>
<td>Melina S 30</td>
</tr>
<tr>
<td>Sinopec</td>
<td>System Oil 3005</td>
</tr>
<tr>
<td>Total</td>
<td>Atlanta Marine D3005</td>
</tr>
</tbody>
</table>

Oils from other companies can be equally suitable. Further information can be obtained from the engine builder or MAN Diesel & Turbo, Copenhagen.
Components for Lubricating Oil System

Lubricating oil pump

The lubricating oil pump can be of the displacement wheel, or the centrifugal type:

Lubricating oil viscosity, specified...75 cSt at 50 °C
Lubricating oil viscosity........... maximum 400 cSt *
Lubricating oil flow .............. see 'List of capacities'
Design pump head.................................4.3 bar
Delivery pressure ..................................4.3 bar
Max. working temperature...............70 °C

* 400 cSt is specified, as it is normal practice when starting on cold oil, to partly open the bypass valves of the lubricating oil pumps, so as to reduce the electric power requirements for the pumps.

The flow capacity must be within a range from 100 to 112% of the capacity stated.

The pump head is based on a total pressure drop across cooler and filter of maximum 1 bar.

Referring to Fig. 8.01.01, the bypass valve shown between the main lubricating oil pumps may be omitted in cases where the pumps have a built-in bypass or if centrifugal pumps are used.

If centrifugal pumps are used, it is recommended to install a throttle valve at position ‘005’ to prevent an excessive oil level in the oil pan if the centrifugal pump is supplying too much oil to the engine.

During trials, the valve should be adjusted by means of a device which permits the valve to be closed only to the extent that the minimum flow area through the valve gives the specified lubricating oil pressure at the inlet to the engine at full normal load conditions. It should be possible to fully open the valve, e.g. when starting the engine with cold oil.

It is recommended to install a 25 mm valve (pos. 006), with a hose connection after the main lubricating oil pumps, for checking the cleanliness of the lubricating oil system during the flushing procedure. The valve is to be located on the underside of a horizontal pipe just after the discharge from the lubricating oil pumps.

Lubricating oil cooler

The lubricating oil cooler must be of the shell and tube type made of seawater resistant material, or a plate type heat exchanger with plate material of titanium, unless freshwater is used in a central cooling water system.

Lubricating oil viscosity, specified...75 cSt at 50 °C
Lubricating oil flow .............. see 'List of capacities'
Heat dissipation .................. see 'List of capacities'
Lubricating oil temperature, outlet cooler......45 °C
Working pressure on oil side....................4.3 bar
Pressure drop on oil side ..........maximum 0.5 bar
Cooling water flow ............... see 'List of capacities'
Cooling water temperature at inlet:
seawater.........................................................32 °C
freshwater.......................................................36 °C
Pressure drop on water side ......maximum 0.2 bar

The lubricating oil flow capacity must be within a range from 100 to 112% of the capacity stated.

The cooling water flow capacity must be within a range from 100 to 110% of the capacity stated.

To ensure the correct functioning of the lubricating oil cooler, we recommend that the seawater temperature is regulated so that it will not be lower than 10 °C.

The pressure drop may be larger, depending on the actual cooler design.

Lubricating oil temperature control valve

The temperature control system can, by means of a three-way valve unit, by-pass the cooler totally or partly.

Lubricating oil viscosity, specified....75 cSt at 50 °C
Lubricating oil flow .............. see 'List of capacities'
Temperature range, inlet to engine .......40 - 47 °C
Lubricating oil full flow filter

Lubricating oil flow .......... see ‘List of capacities’
Working pressure.................................4.3 bar
Test pressure.................................according to class rules
Absolute fineness.................................40 μm
Working temperature .......... approximately 45 °C
Oil viscosity at working temp. .......... 90 - 100 cSt
Pressure drop with clean filter .... maximum 0.2 bar
Filter to be cleaned
at a pressure drop ................ maximum 0.5 bar

* The absolute fineness corresponds to a nominal fineness of approximately 25 μm at a retaining rate of 90%.

The flow capacity must be within a range from 100 to 112% of the capacity stated.

The full-flow filter should be located as close as possible to the main engine.

If a double filter (duplex) is installed, it should have sufficient capacity to allow the specified full amount of oil to flow through each side of the filter at a given working temperature with a pressure drop across the filter of maximum 0.2 bar (clean filter).

If a filter with a back-flushing arrangement is installed, the following should be noted:

- The required oil flow, specified in the ‘List of capacities’, should be increased by the amount of oil used for the back-flushing, so that the lubricating oil pressure at the inlet to the main engine can be maintained during cleaning.

- If an automatically cleaned filter is installed, it should be noted that in order to activate the cleaning process, certain makes of filter require a higher oil pressure at the inlet to the filter than the pump pressure specified. Therefore, the pump capacity should be adequate for this purpose, too.
Flushing of lubricating oil components and piping system at the shipyard

During installation of the lubricating oil system for the main engine, it is important to minimise or eliminate foreign particles in the system. This is done as a final step onboard the vessel by flushing the lubricating oil components and piping system of the MAN B&W main engine types ME/ME-C/ME-B/-GI before starting the engine.

At the shipyard, the following main points should be observed during handling and flushing of the lubricating oil components and piping system:

- **Before and during installation**
  Components delivered from subsuppliers, such as pumps, coolers and filters, are expected to be clean and rust protected. However, these must be spot-checked before being connected to the piping system.

  All piping must be ‘finished’ in the workshop before mounting onboard, i.e. all internal welds must be ground and piping must be acid-treated followed by neutralisation, cleaned and corrosion protected.

  Both ends of all pipes must be closed/sealed during transport.

  Before final installation, carefully check the inside of the pipes for rust and other kinds of foreign particles.

  Never leave a pipe end uncovered during assembly.

- **Bunkering and filling the system**
  Tanks must be cleaned manually and inspected before filling with oil.

  When filling the oil system, MAN Diesel & Turbo recommends that new oil is bunkered through 6 μm fine filters, or that a purifier system is used. New oil is normally delivered with a cleanliness level of XX/23/19 according to ISO 4406 and, therefore, requires further cleaning to meet our specification.

- **Flushing the piping with engine bypass**
  When flushing the system, the first step is to bypass the main engine oil system. Through temporary piping and/or hosing, the oil is circulated through the vessel’s system and directly back to the main engine oil sump tank.

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**Fig. 8.05.01: Lubricating oil system with temporary hosing/piping for flushing at the shipyard**
If the system has been out of operation, unused for a long time, it may be necessary to spot-check for signs of corrosion in the system. Remove end covers, bends, etc., and inspect accordingly.

It is important during flushing to keep the oil warm, approx 60 °C, and the flow of oil as high as possible. For that reason it may be necessary to run two pumps at the same time.

**Filtering and removing impurities**

In order to remove dirt and impurities from the oil, it is essential to run the purifier system during the complete flushing period and/or use a bypass unit with a 6 μm fine filter and sump-to-sump filtration, see Fig. 8.05.01.

Furthermore, it is recommended to reduce the filter mesh size of the main filter unit to 10-25 μm (to be changed again after sea trial) and use the 6 μm fine filter already installed in the auto-filter for this temporary installation, see Fig. 8.05.01. This can lead to a reduction of the flushing time.

The flushing time depends on the system type, the condition of the piping and the experience of the yard. (15 to 26 hours should be expected).

**Cleanliness level, measuring kit and flushing log**

MAN Diesel & Turbo specifies ISO 4406 XX/16/13 as accepted cleanliness level for the ME/ME-C/ME-B/-GI hydraulic oil system, and ISO 4406 XX/19/15 for the remaining part of the lubricating oil system.

The amount of contamination contained in system samples can be estimated by means of the Pall Fluid Contamination Comparator combined with the Portable Analysis Kit, HPCA-Kit-0, which is used by MAN Diesel & Turbo. This kit and the Comparator included is supplied by Pall Corporation, USA, www.pall.com

It is important to record the flushing condition in statements to all inspectors involved. The MAN Diesel & Turbo Flushing Log form, which is available on request, or a similar form is recommended for this purpose.

**Flushing the engine oil system**

The second step of flushing the system is to flush the complete engine oil system. The procedure depends on the engine type and the condition in which the engine is delivered from the engine builder. For detailed information we recommend contacting the engine builder or MAN Diesel & Turbo.

**Inspection and recording in operation**

Inspect the filters before and after the sea trial.

During operation of the oil system, check the performance and behaviour of all filters, and note down any abnormal condition. Take immediate action if any abnormal condition is observed. For instance, if high differential pressure occurs at short intervals, or in case of abnormal back flushing, check the filters and take appropriate action.

Further information and recommendations regarding flushing, the specified cleanliness level and how to measure it, and how to use the NAS 1638 oil cleanliness code as an alternative to ISO 4406, are available from MAN Diesel & Turbo.
Lubricating oil outlet

A protecting ring position 1-4 is to be installed if required, by class rules, and is placed loose on the tanktop and guided by the hole in the flange.

In the vertical direction it is secured by means of screw position 4, in order to prevent wear of the rubber plate.

Fig. 8.05.02: Lubricating oil outlet
Lubricating Oil Tank

Outlet from the engine 400 mm having its bottom edge below the oil level (to obtain gas seal between crankcase and bottom tank)

125 mm air pipe

Oil outlet from turbocharger
See 'List of Counterflanges'

* Based on 50 mm thickness of supporting chocks

Fig. 8.06.01a: Lubricating oil tank, with cofferdam
Note:
When calculating the tank heights, allowance has not been made for the possibility that a quantity of oil in the lubricating oil system outside the engine may be returned to the bottom tank, when the pumps are stopped.

If the system outside the engine is so designed that an amount of the lubricating oil is drained back to the tank, when the pumps are stopped, the height of the bottom tank indicated in Table 8.06.01b has to be increased to include this quantity.

<table>
<thead>
<tr>
<th>Cylinder No.</th>
<th>Drain at cylinder No.</th>
<th>D0</th>
<th>D1</th>
<th>H0</th>
<th>H1</th>
<th>H2</th>
<th>H3</th>
<th>W</th>
<th>L</th>
<th>OL</th>
<th>Qm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>2-4</td>
<td>250</td>
<td>475</td>
<td>1,000</td>
<td>475</td>
<td>95</td>
<td>400</td>
<td>500</td>
<td>6,400</td>
<td>900</td>
<td>16.2</td>
</tr>
<tr>
<td>5</td>
<td>2-5</td>
<td>275</td>
<td>550</td>
<td>1,080</td>
<td>550</td>
<td>110</td>
<td>400</td>
<td>500</td>
<td>7,200</td>
<td>980</td>
<td>19.8</td>
</tr>
<tr>
<td>6</td>
<td>2-5</td>
<td>300</td>
<td>600</td>
<td>1,165</td>
<td>600</td>
<td>110</td>
<td>400</td>
<td>500</td>
<td>8,800</td>
<td>1,065</td>
<td>26.3</td>
</tr>
<tr>
<td>7</td>
<td>2-5-7</td>
<td>325</td>
<td>650</td>
<td>1,205</td>
<td>650</td>
<td>120</td>
<td>400</td>
<td>600</td>
<td>9,600</td>
<td>1,105</td>
<td>29.8</td>
</tr>
<tr>
<td>8</td>
<td>2-5-8</td>
<td>350</td>
<td>700</td>
<td>1,295</td>
<td>700</td>
<td>125</td>
<td>600</td>
<td>700</td>
<td>11,200</td>
<td>1,195</td>
<td>37.6</td>
</tr>
</tbody>
</table>

Table 8.06.01b: Lubricating oil tank, with cofferdam

If space is limited, however, other solutions are possible. Minimum lubricating oil bottom tank volume (m³) is:

<table>
<thead>
<tr>
<th>4 cyl.</th>
<th>5 cyl.</th>
<th>6 cyl.</th>
<th>7 cyl.</th>
<th>8 cyl.</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.2</td>
<td>19.8</td>
<td>24.2</td>
<td>28.2</td>
<td>32.7</td>
</tr>
</tbody>
</table>

Lubricating oil tank operating conditions

The lubricating oil bottom tank complies with the rules of the classification societies by operation under the following conditions:

<table>
<thead>
<tr>
<th>Angle of inclination, degrees</th>
<th>Athwartships</th>
<th>Fore and aft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static Dynamic</td>
<td>Static Dynamic</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>22.5</td>
<td>5</td>
</tr>
<tr>
<td>7.5</td>
<td></td>
<td>7.5</td>
</tr>
</tbody>
</table>
Crankcase Venting and Bedplate Drain Pipes

Fig. 8.07.01: Crankcase venting

Fig. 8.07.02: Bedplate drain pipes, aft-mounted HPS
Engine and Tank Venting to the Outside Air

Venting of engine plant equipment separately

The various tanks, engine crankcases and turbochargers should be provided with sufficient venting to the outside air.

MAN Diesel & Turbo recommends to vent the individual components directly to outside air above deck by separate venting pipes as shown in Fig. 8.07.03a.

It is not recommended to join the individual venting pipes in a common venting chamber as shown in Fig. 8.07.03b.

In order to avoid condensed oil (water) from blocking the venting, all vent pipes must be vertical or laid with an inclination.

Additional information on venting of tanks is available from MAN Diesel & Turbo, Copenhagen.

Fig. 8.07.03a: Separate venting of all systems directly to outside air above deck

Fig. 8.07.03b: Venting through a common venting chamber is not recommended
Hydraulic Oil Back-flushing

The special suction arrangement for purifier suction in connection with the ME engine (Integrated system).

The back-flushing oil from the self cleaning 6 μm hydraulic control oil filter unit built onto the engine is contaminated and it is therefore not expedient to lead it directly into the lubricating oil sump tank.

The amount of back-flushed oil is large, and it is considered to be too expensive to discard it. Therefore, we suggest that the lubricating oil sump tank is modified for the ME engines in order not to have this contaminated lubricating hydraulic control oil mixed up in the total amount of lubricating oil. The lubricating oil sump tank is designed with a small 'back-flushing hydraulic control oil drain tank' to which the back-flushed hydraulic control oil is led and from which the lubricating oil purifier can also suck.

This is explained in detail below and the principle is shown in Fig. 8.08.01. Three suggestions for the arrangement of the drain tank in the sump tank are shown in Fig. 8.08.02 illustrates another suggestion for a back-flushing oil drain tank.

The special suction arrangement for the purifier is consisting of two connected tanks (lubricating oil sump tank and back-flushing oil drain tank) and of this reason the oil level will be the same in both tanks, as explained in detail below.

The oil level in the two tanks will be equalizing through the 'branch pipe to back-flushing oil drain tank', see Fig. 8.08.01. As the pipes have the same diameters but a different length, the resistance is larger in the 'branch pipe to back-flushing oil drain tank', and therefore the purifier will suck primarily from the sump tank.

The oil level in the sump tank and the back-flushing oil drain tank will remain to be about equal because the tanks are interconnected at the top.

When hydraulic control oil is back-flushed from the filter, it will give a higher oil level in the back-flushing hydraulic control oil drain tank and the purifier will suck from this tank until the oil level is the same in both tanks. After that, the purifier will suck from the sump tank, as mentioned above.

This special arrangement for purifier suction will ensure that a good cleaning effect on the lubrication oil is obtained.

If found profitable the back-flushed lubricating oil from the main lubricating oil filter (normally a 50 or 40 μm filter) can also be returned into the special back-flushing oil drain tank.

![Fig. 8.08.01: Back-flushing servo oil drain tank](image1)

![Fig. 8.08.02: Alternative design for the back-flushing servo oil drain tank](image2)
Separate System for Hydraulic Control Unit

As an option, the engine can be prepared for the use of a separate hydraulic control oil system Fig. 8.09.01.

The separate hydraulic control oil system can be built as a unit, or be built streamlined in the engine room with the various components placed and fastened to the steel structure of the engine room.

The design and the dimensioning of the various components are based on the aim of having a reliable system that is able to supply low-pressure oil to the inlet of the engine-mounted high-pressure hydraulic control oil pumps at a constant pressure, both at engine stand-by and at various engine loads.

Cleanliness of the hydraulic control oil

The hydraulic control oil must fulfill the same cleanliness level as for our standard integrated lube/cooling/hydraulic-control oil system, i.e. ISO 4406 XX/16/13 equivalent to NAS 1638 Class 7.

Information and recommendations regarding flushing, the specified cleanliness level and how to measure it, and how to use the NAS 1638 oil cleanliness code as an alternative to ISO 4406, are available from MAN Diesel & Turbo.

Control oil system components

The hydraulic control oil system comprises:
1. Hydraulic control oil tank
2. Hydraulic control oil pumps (one for stand-by)
3. Pressure control valve
4. Hydraulic control oil cooler, water-cooled by the low temperature cooling water
5. Three-way valve, temperature controlled
6. Hydraulic control oil filter, duplex type or automatic self-cleaning type
7. Hydraulic control oil fine filter with pump
8. Temperature indicator
9. Pressure indicator
10. Level alarms
11. Valves and cocks
12. Piping

Hydraulic control oil tank

The tank can be made of mild steel plate or be a part of the ship structure.

The tank is to be equipped with flange connections and the items listed below:
- Oil filling pipe
- Outlet pipe for pump suctions
- Return pipe from engine
- Drain pipe
- Vent pipe.

The hydraulic control oil tank is to be placed at least 1 m below the hydraulic oil outlet flange, RZ.

Hydraulic control oil pump

The pump must be of the displacement type (e.g. gear wheel or screw wheel pump).

The following data is specified in Table 8.09.02:
- Pump capacity
- Pump head
- Delivery pressure
- Working temperature
- Oil viscosity range.

Pressure control valve

The valve is to be of the self-operating flow controlling type, which bases the flow on the pre-defined pressure set point. The valve must be able to react quickly from the fully-closed to the fully-open position ($t_{max} = 4$ sec), and the capacity must be the same as for the hydraulic control oil low-pressure pumps. The set point of the valve has to be within the adjustable range specified in a separate drawing.

The following data is specified in Table 8.09.02:
- Flow rate
- Adjustable differential pressure range across the valve
- Oil viscosity range.
Hydraulic control oil cooler

The cooler must be of the plate heat exchanger or shell and tube type.

The following data is specified in Table 8.09.02:
- Heat dissipation
- Oil flow rate
- Oil outlet temperature
- Maximum oil pressure drop across the cooler
- Cooling water flow rate
- Water inlet temperature
- Maximum water pressure drop across the cooler.

Temperature controlled three-way valve

The valve must act as a control valve, with an external sensor.

The following data is specified in Table 8.09.02:
- Capacity
- Adjustable temperature range
- Maximum pressure drop across the valve.

Hydraulic control oil filter

The filter is to be of the duplex full flow type with manual change over and manual cleaning or of the automatic self cleaning type.

A differential pressure gauge is fitted onto the filter.

The following data is specified in Table 8.09.02:
- Filter capacity
- Maximum pressure drop across the filter
- Filter mesh size (absolute)
- Oil viscosity
- Design temperature.

Off-line hydraulic control oil fine filter / purifier

Shown in Fig. 8.09.01, the off-line fine filter unit or purifier must be able to treat 15-20% of the total oil volume per hour.

The fine filter is an off-line filter and removes metallic and non-metallic particles larger than 0.8 μm as well as water and oxidation residues. The filter has a pertaining pump and is to be fitted on the top of the hydraulic control oil tank.

A suitable fine filter unit is:

For oil volume <10,000 litres:
HDU 27/-MZ-Z with a pump flow of 15-20% of the total oil volume per hour.

For oil volume >10,000 litres:
HDU 27/-GP-DZ with a pump flow of 15-20% of the total oil volume per hour.

Temperature indicator

The temperature indicator is to be of the liquid straight type.

Pressure indicator

The pressure indicator is to be of the dial type.

Level alarm

The hydraulic control oil tank has to have level alarms for high and low oil level.

Piping

The pipes can be made of mild steel.

The design oil pressure is to be 10 bar.

The return pipes are to be placed vertical or laid with a downwards inclination of minimum 15°.
Fig. 8.09.01: Hydraulic control oil system, manual filter
Cylinder Lubrication
Cylinder Lubricating Oil System

The cost of the cylinder lubricating oil is one of the largest contributions to total operating costs, next to the fuel oil cost. Another aspect is that the lubrication rate has a great influence on the cylinder condition, and thus on the overhauling schedules and maintenance costs.

It is therefore of the utmost importance that the cylinder lubricating oil system as well as its operation is optimised.

Cylinder oils

In short, MAN Diesel and Turbo recommends the use of cylinder oils with the following main properties:

- SAE 50 viscosity grade
- high detergency
- BN 100 for high-sulphur fuel
- BN 40 for low-sulphur fuel.

A BN 100 cylinder oil is to be used as the default choice of oil and it may be used on all fuel types. However, in case of the engine running on fuel with sulphur content lower than 1.5% for more than 2 weeks, we recommend to change to a lower BN cylinder oil such as a BN 40.

Two-tank cylinder oil supply system

Fig. 9.01.01 shows a cylinder oil supply system with separate tanks for cylinder oils with high and low BN.

Cylinder oil feed rate (dosage)

Adjustment of the cylinder oil dosage to the sulphur content in the fuel being burnt is further explained in Section 9.02.

Further information about cylinder lubrication on different fuel types is available in our publication: Operation on Low-Sulphur Fuels

The publication is available at www.marine.man.eu → 'Two-Stroke' → 'Technical Papers'.
List of cylinder oils

The major international cylinder oil brands listed below have been tested in service with acceptable results. Some of the oils have also given satisfactory service results during long-term operation on MAN B&W engines running on heavy fuel oil (HFO).

<table>
<thead>
<tr>
<th>Company</th>
<th>Cylinder oil name, SAE 50</th>
<th>BN level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aegean</td>
<td>Alfacylo 540 LS</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Alfacylo 100 HS</td>
<td>100</td>
</tr>
<tr>
<td>BP</td>
<td>CL-DX 405</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Energol CL 100 ACC</td>
<td>100</td>
</tr>
<tr>
<td>Castrol</td>
<td>Clytech 40SX</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Clytech CL 100 ACC</td>
<td>100</td>
</tr>
<tr>
<td>Chevron</td>
<td>Taro Special HT LS 40</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Taro Special HT 100</td>
<td>100</td>
</tr>
<tr>
<td>ExxonMobil</td>
<td>Mobilgard L540</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Mobilgard 5100</td>
<td>100</td>
</tr>
<tr>
<td>Gulf Oil Marine</td>
<td>GulfSea Cylcare DCA 5040H</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>GulfSea Cylcare 50100</td>
<td>100</td>
</tr>
<tr>
<td>JX Nippon Oil &amp; Energy</td>
<td>Marine C405</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>MC-1005-8 (internal code)</td>
<td>100</td>
</tr>
<tr>
<td>Lukoil</td>
<td>Navigo 40 MCL</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Navigo 100 MCL</td>
<td>100</td>
</tr>
<tr>
<td>Shell</td>
<td>Alexia S6</td>
<td>100</td>
</tr>
<tr>
<td>Sinopec</td>
<td>Marine Cylinder Oil 5040</td>
<td>40</td>
</tr>
<tr>
<td>Total</td>
<td>Talusia LS 40</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Talusia Universal 100</td>
<td>100</td>
</tr>
</tbody>
</table>

Oils from other companies can be equally suitable. Further information can be obtained from the engine builder or MAN Diesel & Turbo, Copenhagen.
MAN B&W Alpha Cylinder Lubrication System

The MAN B&W Alpha cylinder lubrication system, see Figs. 9.02.02a and 9.02.02b, is designed to supply cylinder oil intermittently, e.g. every four engine revolutions with electronically controlled timing and dosage at a defined position.

The cylinder lubricating oil is pumped from the cylinder oil storage tank to the service tank, the size of which depends on the owner’s and the yard’s requirements, - it is normally dimensioned for minimum two days’ cylinder lubricating oil consumption.

Cylinder lubricating oil is fed to the Alpha cylinder lubrication system by gravity from the service tank.

The storage tank and the service tank may alternatively be one and the same tank.

The oil fed to the injectors is pressurised by means of the Alpha Lubricator which is placed on the HCU and equipped with small multi-piston pumps.

The oil pipes fitted on the engine is shown in Fig. 9.02.04.

The whole system is controlled by the Cylinder Control Unit (CCU) which controls the injection frequency on the basis of the engine-speed signal given by the tacho signal and the fuel index.

Prior to start-up, the cylinders can be pre-lubricated and, during the running-in period, the operator can choose to increase the lubricating oil feed rate to a max. setting of 200%.

The MAN B&W Alpha Cylinder Lubricator is preferably to be controlled in accordance with the Alpha ACC (Adaptive Cylinder oil Control) feed rate system.

The yard supply should be according to the items shown in Fig. 9.02.02a within the broken line. With regard to the filter and the small box, please see Fig. 9.02.05.
Alpha Adaptive Cylinder Oil Control (Alpha ACC)

It is a well-known fact that the actual need for cylinder oil quantity varies with the operational conditions such as load and fuel oil quality. Consequently, in order to perform the optimal lubrication – cost-effectively as well as technically – the cylinder lubricating oil dosage should follow such operational variations accordingly.

The Alpha lubricating system offers the possibility of saving a considerable amount of cylinder lubricating oil per year and, at the same time, to obtain a safer and more predictable cylinder condition.

Alpha ACC (Adaptive Cylinder-oil Control) is the lubrication mode for MAN B&W two-stroke engines, i.e. lube oil dosing proportional to the engine load and proportional to the sulphur content in the fuel oil being burnt.

Working principle

The feed rate control should be adjusted in relation to the actual fuel quality and amount being burnt at any given time.

The following criteria determine the control:

• The cylinder oil dosage shall be proportional to the sulphur percentage in the fuel
• The cylinder oil dosage shall be proportional to the engine load (i.e. the amount of fuel entering the cylinders)
• The actual feed rate is dependent of the operating pattern and determined based on engine wear and cylinder condition.

The implementation of the above criteria will lead to an optimal cylinder oil dosage.

Specific minimum dosage with Alpha ACC

The recommendations are valid for all plants, whether controllable pitch or fixed pitch propellers are used. The specific minimum dosage at lower-sulphur fuels is set at 0.6 g/kWh. After a running-in period of 500 hours, the feed rate sulphur proportional factor is 0.20 - 0.34 g/kWh × S%. The actual ACC factor will be based on cylinder condition, and preferably a cylinder oil feed rate sweep test should be applied.

Examples of average cylinder oil consumption based on calculations of the average worldwide sulphur content used on MAN B&W two-stroke engines are shown in Fig. 9.02.01a and b.

![Fig. 9.02.01a: ACC = 0.20 g/kWh × S% and BN100 cylinder oil – average consumption less than 0.65 g/kWh](image1)

![Fig. 9.02.01b: ACC = 0.26 g/kWh × S% and BN100 cylinder oil – average consumption less than 0.7 g/kWh](image2)

Further information on cylinder oil as a function of fuel oil sulphur content, alkalinity of lubricating oil and operating pattern as well as assessing the engine wear and cylinder condition is available from MAN Diesel & Turbo, Copenhagen.
Cylinder Oil Pipe Heating

In case of low engine room temperature, it can be difficult to keep the cylinder oil temperature at 45 °C at the MAN B&W Alpha Lubricator, mounted on the hydraulic cylinder.

Therefore the cylinder oil pipe from the small tank, see Figs. 9.02.02a and 9.02.02b, in the vessel and of the main cylinder oil pipe on the engine is insulated and electrically heated.

The engine builder is to make the insulation and heating on the main cylinder oil pipe on the engine. Moreover, the engine builder is to mount the junction box and the thermostat on the engine. See Fig. 9.02.03.

The ship yard is to make the insulation of the cylinder oil pipe in the engine room. The heating cable supplied by the engine builder is to be mounted from the small tank to the junction box on the engine. See Figs. 9.02.02a and 9.02.02b.

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**Fig. 9.02.02a:** Cylinder lubricating oil system with dual service tanks for two different TBN cylinder oils
Fig. 9.02.02b: Cylinder lubricating oil system. Example from 80/70/65ME-C engines

Fig. 9.02.03: Electric heating of cylinder oil pipes

* The number of cylinder lubricating points depends on the actual engine type
Fig. 9.02.04: Cylinder lubricating oil pipes

The letters refer to list of ‘Counterflanges’
The item No refer to ‘Guidance Values Automation’
Fig. 9.02.05: Suggestion for small heating box with filter
Piston Rod Stuffing
Box Drain Oil
Stuffing Box Drain Oil System

For engines running on heavy fuel, it is important that the oil drained from the piston rod stuffing boxes is not led directly into the system oil, as the oil drained from the stuffing box is mixed with sludge from the scavenge air space.

The performance of the piston rod stuffing box on the engines has proved to be very efficient, primarily because the hardened piston rod allows a higher scraper ring pressure.

The amount of drain oil from the stuffing boxes is about 5 - 10 litres/24 hours per cylinder during normal service. In the running-in period, it can be higher.

The relatively small amount of drain oil is led to the general oily waste drain tank or is burnt in the incinerator, Fig. 10.01.01. (Yard’s supply).

![Diagram of Stuffing Box Drain Oil System]

*Fig. 10.01.01: Stuffing box drain oil system*
Central Cooling Water System
Central Cooling

The water cooling can be arranged in several configurations, the most common system choice being a central cooling water system.

**Advantages of the central cooling system:**

- Only one heat exchanger cooled by seawater, and thus, only one exchanger to be overhauled
- All other heat exchangers are freshwater cooled and can, therefore, be made of a less expensive material
- Few non-corrosive pipes to be installed
- Reduced maintenance of coolers and components
- Increased heat utilisation.

**Disadvantages of the central cooling system:**

- Three sets of cooling water pumps (seawater, central water and jacket water.
- Higher first cost.

For information on the alternative Seawater Cooling System, see Chapter 12.

An arrangement common for the main engine and MAN Diesel & Turbo auxiliary engines is available on request.

For further information about common cooling water system for main engines and auxiliary engines please refer to our publication:

*Uni-concept Auxiliary Systems for Two-Stroke Main Engines and Four-Stroke Auxiliary Engines*

The publication is available at www.marine.man.eu → 'Two-Stroke' → 'Technical Papers'.
Central Cooling Water System

The central cooling water system is characterised by having only one heat exchanger cooled by seawater, and by the other coolers, including the jacket water cooler, being cooled by central cooling water.

In order to prevent too high a scavenge air temperature, the cooling water design temperature in the central cooling water system is normally 36 °C, corresponding to a maximum seawater temperature of 32 °C.

Our recommendation of keeping the cooling water inlet temperature to the main engine scavenge air cooler as low as possible also applies to the central cooling system. This means that the temperature control valve in the central cooling water circuit is to be set to minimum 10 °C, whereby the temperature follows the outboard seawater temperature when central cooling water temperature exceeds 10 °C.

For external pipe connections, we prescribe the following maximum water velocities:

- Jacket water: 3.0 m/s
- Central cooling water: 3.0 m/s
- Seawater: 3.0 m/s

Regarding the lubricating oil coolers, this valve should be adjusted so that the inlet temperature of the cooling water is not below 10 °C.

Air pockets, if any, in the pipe line between the pumps, must be vented to the expansion tank.

The letters refer to list of ‘Counterflanges’, Fig. 5.10.01
The item No. refer to ‘Guidance values automation’
Components for Central Cooling Water System

Seawater cooling pumps

The pumps are to be of the centrifugal type.

Seawater flow....................... see ‘List of Capacities’
Pump head..................................2.5 bar
Test pressure..........................according to class rules
Working temperature, normal ..........0-32 °C
Working temperature maximum 50 °C

The flow capacity must be within a range from 100 to 110% of the capacity stated.

The differential pressure of the pumps is to be determined on the basis of the total actual pressure drop across the cooling water system.

Central cooling water pumps

The pumps are to be of the centrifugal type.

Central cooling water flow... see ‘List of Capacities’
Pump head...............................2.5 bar
Delivery pressure .....................depends on location of expansion tank
Test pressure.........................according to class rules
Working temperature....................80 °C
Design temperature...................100 °C

The flow capacity must be within a range from 100 to 110% of the capacity stated.

The ‘List of Capacities’ covers the main engine only. The differential pressure provided by the pumps is to be determined on the basis of the total actual pressure drop across the cooling water system.

Central cooler

The cooler is to be of the shell and tube or plate heat exchanger type, made of seawater resistant material.

Heat dissipation..................... see ‘List of Capacities’
Central cooling water flow ...... see ‘List of Capacities’
Central cooling water temperature, outlet........36 °C
Pressure drop on central cooling side....max. 0.2 bar
Seawater flow.......................... see ‘List of Capacities’
Seawater temperature, inlet...............32 °C
Pressure drop on seawater side..............maximum 0.2 bar

The pressure drop may be larger, depending on the actual cooler design.

The heat dissipation and the seawater flow figures are based on MCR output at tropical conditions, i.e. a seawater temperature of 32 °C and an ambient air temperature of 45 °C.

Overload running at tropical conditions will slightly increase the temperature level in the cooling system, and will also slightly influence the engine performance.

Central cooling water thermostatic valve

The low temperature cooling system is to be equipped with a three-way valve, mounted as a mixing valve, which by-passes all or part of the fresh water around the central cooler.

The sensor is to be located at the outlet pipe from the thermostatic valve and is set so as to keep a temperature level of minimum 10 °C.
Jacket water system

Due to the central cooler the cooling water inlet temperature is about 4 °C higher for this system compared to the seawater cooling system. The input data are therefore different for the scavenge air cooler, the lube oil cooler and the jacket water cooler.

The heat dissipation and the central cooling water flow figures are based on an MCR output at tropical conditions, i.e. a maximum seawater temperature of 32 °C and an ambient air temperature of 45 °C.

Jacket water cooling pump

The pumps are to be of the centrifugal type.
Jacket water flow ............... see ‘List of Capacities’
Pump head ...................................................3.0 bar
Delivery pressure ...............depends on location of expansion tank
Test pressure.....................according to class rules
Working temperature ..................... 80 °C
Design temperature..................100 °C

The flow capacity must be within a range from 100 to 110% of the capacity stated.

The stated of capacities cover the main engine only. The pump head of the pumps is to be determined on the basis of the total actual pressure drop across the cooling water system.

Scavenge air cooler

The scavenge air cooler is an integrated part of the main engine.

Heat dissipation ..........................see ‘List of Capacities’
Central cooling water flow .......see ‘List of Capacities’
Central cooling temperature, inlet ...............36 °C
Pressure drop on FW-LT water side .... approx. 0.5 bar

Lubricating oil cooler

See Chapter 8 ‘Lubricating Oil’.

Cooling water pipes

Diagrams of cooling water pipes are shown in Figs. 12.03.01.

Jacket water cooler

The cooler is to be of the shell and tube or plate heat exchanger type.

Heat dissipation ................ see ‘List of Capacities’
Jacket water flow ............... see ‘List of Capacities’
Jacket water temperature, inlet .....................80 °C
Pressure drop on jacket water side ..........max. 0.2 bar
Central cooling water flow ... see ‘List of Capacities’
Central cooling water temperature, inlet ................ approx. 42 °C
Pressure drop on Central cooling water side ................ max. 0.2 bar

The other data for the jacket cooling water system can be found in Chapter 12.

For further information about a common cooling water system for main engines and MAN Diesel & Turbo auxiliary engines, please refer to our publication:

*Uni-concept Auxiliary Systems for Two-Stroke Main Engines and Four-Stroke Auxiliary Engines*

The publication is available at www.marine.man.eu → ‘Two-Stroke’ → 'Technical Papers'.
Seawater
Cooling System
Seawater Systems

The water cooling can be arranged in several configurations, the most simple system choices being seawater and central cooling water system:

- A seawater cooling system and a jacket cooling water system

The advantages of the seawater cooling system are mainly related to first cost, viz:

- Only two sets of cooling water pumps (seawater and jacket water)
- Simple installation with few piping systems.

Whereas the disadvantages are:

- Seawater to all coolers and thereby higher maintenance cost
- Expensive seawater piping of non-corrosive materials such as galvanised steel pipes or Cu-Ni pipes.
Seawater Cooling System

The seawater cooling system is used for cooling, the main engine lubricating oil cooler, the jacket water cooler and the scavenge air cooler, see Fig. 12.02.01.

The lubricating oil cooler for a PTO step-up gear should be connected in parallel with the other coolers. The capacity of the seawater pump is based on the outlet temperature of the seawater being maximum 50 °C after passing through the coolers – with an inlet temperature of maximum 32 °C (tropical conditions), i.e. a maximum temperature increase of 18 °C.

The valves located in the system fitted to adjust the distribution of cooling water flow are to be provided with graduated scales.

The inter-related positioning of the coolers in the system serves to achieve:

- The lowest possible cooling water inlet temperature to the lubricating oil cooler in order to obtain the cheapest cooler. On the other hand, in order to prevent the lubricating oil from stiffening in cold services, the inlet cooling water temperature should not be lower than 10 °C.

- The lowest possible cooling water inlet temperature to the scavenge air cooler, in order to keep the fuel oil consumption as low as possible.

The letters refer to list of ‘Counterflanges’

*Fig. 12.02.01: Seawater cooling system*
Cooling Water Pipes

Fig. 12.03.01a: Cooling water pipes for engines with two or more turbochargers

The letters refer to list of ‘Counterflanges’. The item No. refer to ‘Guidance Values Automation’

* Calculated valve from PT8440/844X if possible
n Refer to number of air coolers

Fig. 12.03.01b: Cooling water cooling pipes with waste heat recovery for engines with two or more turbochargers
Components for Seawater Cooling System

Seawater cooling pump

The pumps are to be of the centrifugal type.

Seawater flow ..................... see ‘List of Capacities’
Pump head ................................................... 2.5 bar
Test pressure .......................... according to class rule
Working temperature .................. maximum 50 °C

The flow capacity must be within a range from 100 to 110% of the capacity stated.

Scavenge air cooler

The scavenge air cooler is an integrated part of the main engine.

Heat dissipation ..................... see ‘List of Capacities’
Seawater flow .......................... see ‘List of Capacities’
Seawater temperature, for seawater cooling inlet, max. ..................... 32 °C
Pressure drop on cooling water side .......... between 0.1 and 0.5 bar

The heat dissipation and the seawater flow are based on an MCR output at tropical conditions, i.e. seawater temperature of 32 °C and an ambient air temperature of 45 °C.

Lubricating oil cooler

See Chapter 8 ‘Lubricating Oil’.

Seawater thermostatic valve

The temperature control valve is a three-way valve which can recirculate all or part of the seawater to the pump’s suction side. The sensor is to be located at the seawater inlet to the lubricating oil cooler, and the temperature level must be a minimum of +10 °C.

Seawater flow ..................... see ‘List of Capacities’
Temperature range, adjustable within ......................... +5 to +32 °C

Seawater thermostat

The cooler is to be of the shell and tube or plate heat exchanger type, made of seawater resistant material.

Heat dissipation ..................... see ‘List of Capacities’
Jacket water flow .......................... see ‘List of Capacities’
Jacket water temperature, inlet  ..................... 80 °C
Pressure drop on jacket water side ................. maximum 0.2 bar
Seawater flow ..................... see ‘List of Capacities’
Seawater temperature, inlet ..................... 38 °C
Pressure drop on seawater side .................. maximum 0.2 bar

The heat dissipation and the seawater flow are based on an MCR output at tropical conditions, i.e. seawater temperature of 32 °C and an ambient air temperature of 45 °C.

Jacket water cooler

Seawater thermostat

The cooler is to be of the shell and tube or plate heat exchanger type, made of seawater resistant material.

Pressure drop on jacket water side ................. maximum 0.2 bar
Seawater flow ..................... see ‘List of Capacities’
Seawater temperature, inlet ..................... 38 °C
Pressure drop on seawater side .................. maximum 0.2 bar

The heat dissipation and the seawater flow are based on an MCR output at tropical conditions, i.e. seawater temperature of 32 °C and an ambient air temperature of 45 °C.

Seawater thermostat
Jacket Cooling Water System

The jacket cooling water system is used for cooling the cylinder liners, cylinder covers and exhaust valves of the main engine and heating of the fuel oil drain pipes, see Fig. 12.05.01.

The jacket water pump draws water from the jacket water cooler outlet and delivers it to the engine.

At the inlet to the jacket water cooler there is a thermostatically controlled regulating valve, with a sensor at the engine cooling water outlet, which keeps the main engine cooling water outlet at a temperature between 88 and 92 °C.

The engine jacket water must be carefully treated, maintained and monitored so as to avoid corrosion, corrosion fatigue, cavitation and scale formation. It is recommended to install a preheater if preheating is not available from the auxiliary engines jacket cooling water system.

The venting pipe in the expansion tank should end just below the lowest water level, and the expansion tank must be located at least 15 m above the top of the exhaust valves.

The freshwater generator, if installed, may be connected to the seawater system if the generator does not have a separate cooling water pump. The generator must be coupled in and out slowly over a period of at least 3 minutes.

In case it is possible to utilise more than 50% of the heat available, we recommend to install a thermostatic valve at the freshwater generator inlet, adjusted to keep a minimum cooling water outlet temperature of 88 °C.

For external pipe connections, we prescribe the following maximum water velocities:

- Jacket water: 3.0 m/s
- Seawater: 3.0 m/s

The letters refer to list of 'Counterflanges'

Fig. 12.05.01: Jacket cooling water system
Jacket Cooling Water Pipes

The letters refer to list of ‘Counterflanges’
The item No. refer to ‘Guidance values automation’

Fig. 12.06.01: Jacket cooling water pipes
Components for Jacket Cooling Water System

Jacket water cooling pump
The pumps are to be of the centrifugal type.

Jacket water flow ............... see ‘List of Capacities’
Pump head.........................................................3.0 bar
Delivery pressure ............... depends on position
of expansion tank
Test pressure....................... according to class rule
Working temperature, ............. 80 °C, max. 100 °C

The flow capacity must be within a range from
100 to 110% of the capacity stated.

The stated capacities cover the main engine only.
The pump head of the pumps is to be determined
based on the total actual pressure drop across
the cooling water system.

Freshwater generator
If a generator is installed in the ship for produc-
tion of freshwater by utilising the heat in the jacket
water cooling system it should be noted that the
actual available heat in the jacket water system is
lower than indicated by the heat dissipation figures
given in the ‘List of Capacities’. This is because
the latter figures are used for dimensioning the
jacket water cooler and hence incorporate a safety
margin which can be needed when the engine is
operating under conditions such as, e.g. overload.
Normally, this margin is 10% at nominal MCR.

The calculation of the heat actually available at
specified MCR for a derated diesel engine is stat-
ed in Chapter 6 ‘List of Capacities’.

For illustration of installation of fresh water gen-
erator see Fig. 12.05.01.

Jacket water thermostatic valve
The temperature control system is equipped with
a three-way valve mounted as a diverting valve,
which by-pass all or part of the jacket water
around the jacket water cooler.

The sensor is to be located at the outlet from the
main engine, and the temperature level must be
adjustable in the range of 70-90 °C.

Jacket water preheater
When a preheater, see Fig. 12.05.01, is installed in
the jacket cooling water system, its water flow, and
thus the preheater pump capacity, should be about
10% of the jacket water main pump capacity.

Based on experience, it is recommended that the
pressure drop across the preheater should be
approx. 0.2 bar. The preheater pump and main
pump should be electrically interlocked to avoid
the risk of simultaneous operation.

The preheater capacity depends on the required
preheating time and the required temperature
increase of the engine jacket water. The tempera-
ture and time relations are shown in Fig. 12.08.01.

In general, a temperature increase of about 35 °C
(from 15 °C to 50 °C) is required, and a preheating
time of 12 hours requires a preheater capacity of
about 1% of the engine’s nominal MCR power.

Deaerating tank
Design and dimensions of the deaerating tank
are shown in Fig. 12.07.01 ‘Deaerating tank’ and
the corresponding alarm device is shown in Fig.
12.07.02 ‘Deaerating tank, alarm device’.

Expansion tank
The total expansion tank volume has to be ap-
proximate 10% of the total jacket cooling water
amount in the system.

Fresh water treatment
MAN Diesel & Turbo’s recommendations for treat-
ment of the jacket water/freshwater are available
on request.
Deaerating tank

![Deaerating tank diagram]

**Fig. 12.07.01: Deaerating tank, option: 4 46 640**

**Deaerating tank dimensions**

<table>
<thead>
<tr>
<th></th>
<th>0.05 m³</th>
<th>0.16 m³</th>
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<tbody>
<tr>
<td>Tank size</td>
<td>120 m³/h</td>
<td>300 m³/h</td>
</tr>
<tr>
<td>Max. jacket water capacity</td>
<td>120 m³/h</td>
<td>300 m³/h</td>
</tr>
<tr>
<td>Max. nominal diameter</td>
<td>125 200</td>
<td>200</td>
</tr>
<tr>
<td>A</td>
<td>600</td>
<td>800</td>
</tr>
<tr>
<td>B</td>
<td>125</td>
<td>210</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>D</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>E</td>
<td>300</td>
<td>500</td>
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<td>F</td>
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<td>1,195</td>
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<td>G</td>
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<td>350</td>
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<td>øH</td>
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<td>520</td>
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<tr>
<td>øJ</td>
<td>ND 50</td>
<td>ND 80</td>
</tr>
<tr>
<td>øK</td>
<td>ND 32</td>
<td>ND 50</td>
</tr>
</tbody>
</table>

ND: Nominal diameter

Working pressure is according to actual piping arrangement.

In order not to impede the rotation of water, the pipe connection must end flush with the tank, so that no internal edges are protruding.

![Deaerating tank alarm device diagram]

**Fig. 12.07.02: Deaerating tank, alarm device, option: 4 46 645**

**Expansion tank**

![Expansion tank diagram]
Temperature at Start of Engine

In order to protect the engine, some minimum temperature restrictions have to be considered before starting the engine and, in order to avoid corrosive attacks on the cylinder liners during starting.

The temperature and speed/load restrictions vary with type of propeller as explained below.

Fixed pitch propeller plants

• Normal start of engine:

Normally, a minimum engine jacket water temperature of 50 °C is recommended before the engine may be started and run up gradually from 80% to 90% of specified MCR speed (SMCR rpm) during 30 minutes.

For running up between 90% and 100% of SMCR rpm, it is recommended that the speed be increased slowly over a period of 60 minutes.

• Start of cold engine:

In exceptional circumstances where it is not possible to comply with the above-mentioned recommendation, a minimum of 20 °C can be accepted before the engine is started and run up slowly to 80% of SMCR rpm.

Before exceeding 80% SMCR rpm, a minimum jacket water temperature of 50 °C should be obtained before the above described normal start load-up procedure may be continued.

Controllable pitch propeller plants

• Normal start of engine:

Normally, a minimum engine jacket water temperature of 50 °C is recommended before the engine may be started and run up gradually from 50% to 75% of specified MCR load (SMCR power) during 30 minutes.

For running up between 75% and 100% of SMCR power, it is recommended that the load be increased slowly over a period of 60 minutes.

• Start of cold engine:

In exceptional circumstances where it is not possible to comply with the above-mentioned recommendation, a minimum of 20 °C can be accepted before the engine is started and run up slowly to 50% of SMCR power.

Before exceeding 50% SMCR power, a minimum jacket water temperature of 50 °C should be obtained before above described normal start load-up procedure may be continued.

Jacket water warming-up time

The time period required for increasing the jacket water temperature from 20 °C to 50 °C will depend on the amount of water in the jacket cooling water system, and the engine load.

Note:
The above considerations for start of cold engine are based on the assumption that the engine has already been well run-in.
Preheating of diesel engine

Preheating during standstill periods

During short stays in port (i.e. less than 4-5 days), it is recommended that the engine is kept preheated, the purpose being to prevent temperature variation in the engine structure and corresponding variation in thermal expansions and possible leakages.

The jacket cooling water outlet temperature should be kept as high as possible and should – before starting up – be increased to at least 50 °C, either by means of cooling water from the auxiliary engines, or by means of a built-in preheater in the jacket cooling water system, or a combination.

![Fig. 12.08.01: Jacket water preheater, example](image)
Heating of LNG

The LNG for fuel gas supply must be heated to 45 °C ±10 as specified in MAN Diesel & Turbo’s ‘Guiding fuel gas specification’, see Section 7.00.

Subject to the availability on the actual engine plant, a number of waste heat sources could be utilised for heating of the LNG including:

- jacket cooling water
- scavenger air cooling water
- steam.

Capacity of the high-pressure LNG heater

The required capacity of the LNG heater is listed in the CEAS report for the actual project, see Section 20.02.

High-pressure LNG heater

Suitable for the fuel gas supply pressure, a shell and tube type heat exchanger is typically used. As an example, the key specification is:

- Tube side
  Medium: ........................................LNG/NG
  Temperature, inlet: .......................approx. 55 °C
  Material: ........................................AISI 316L

- Shell side
  Medium: ........................................Water/glycol (WG)
  Temperature, outlet: .................... 45 °C ±10
  Material: .......................................Carbon steel

For more information on LNG heating solutions, contact MAN Diesel & Turbo, Copenhagen.

Fig. 12.09.01: Example of high-pressure LNG heater installation
Starting and Control Air
Starting and Control Air Systems

The starting air of 30 bar is supplied by the starting air compressors to the starting air receivers and from these to the main engine inlet 'A'.

Through a reduction station, filtered compressed air at 7 bar is supplied to the control air for exhaust valve air springs, through engine inlet 'B'.

Through a reduction valve, compressed air is supplied at 10 bar to 'AP' for turbocharger cleaning (soft blast), and a minor volume used for the fuel valve testing unit.

Through a reduction valve, compressed air is supplied at 1.5 bar to the leakage detection and ventilation system for the double-wall gas piping.

Please note that the air consumption for control air, safety air, turbocharger cleaning, sealing air for exhaust valve, for fuel valve testing unit and venting of gas pipes are momentary requirements of the consumers.

The components of the starting and control air systems are further described in Section 13.02.

For information about a common starting air system for main engines and MAN Diesel & Turbo auxiliary engines, please refer to our publication:

*Uni-concept Auxiliary Systems for Two-Stroke Main Engines and Four-Stroke Auxiliary Engines*

The publication is available at www.marine.man.eu → 'Two-Stroke' → 'Technical Papers'.

---

*Fig. 13.01.01: Starting and control air systems*

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*The letters refer to list of 'Counterflanges’

*) Pipe a nominal dimension: DN150 mm*
Components for Starting Air System

Starting air compressors

The starting air compressors are to be of the water-cooled, two-stage type with intercooling.

More than two compressors may be installed to supply the total capacity stated.

Air intake quantity:
Reversible engine,
for 12 starts ...................... see ‘List of capacities’
Non-reversible engine,
for 6 starts ......................... see ‘List of capacities’
Delivery pressure ...................... 30 bar

Starting air receivers

The volume of the two receivers is:
Reversible engine,
for 12 starts ...................... see ‘List of capacities’ *
Non-reversible engine,
for 6 starts ......................... see ‘List of capacities’ *
Working pressure ...................... 30 bar
Test pressure ...................... according to class rule

* The volume stated is at 25 °C and 1,000 mbar

Reduction station for control and safety air

In normal operating, each of the two lines supplies one engine inlet. During maintenance, three isolating valves in the reduction station allow one of the two lines to be shut down while the other line supplies both engine inlets, see Fig. 13.01.01.

Reduction ...................... from 30-10 bar to 7 bar (Tolerance ±10%)
Flow rate, free air .......... 2,100 Normal liters/min equal to 0.035 m³/s
Filter, fineness ...................... 40 μm

Reduction valve for turbocharger cleaning etc

Reduction ...................... from 30-10 bar to 7 bar
(Tolerance ±10%)
Flow rate, free air .......... 2,600 Normal liters/min
equal to 0.043 m³/s

Reduction valve for venting air for gas piping

Reduction ...................... from 30-10 bar to 1.5 bar
(Tolerance ±10%)
Flow rate, free air .......... 900 Normal liters/min
equal to 0.015 m³/s

The consumption of compressed air for control air, exhaust valve air springs and safety air as well as air for turbocharger cleaning, fuel valve testing and venting of gas piping is covered by the capacities stated for air receivers and compressors in the list of capacities.

Starting and control air pipes

The piping delivered with and fitted onto the main engine is shown in the following figures in Section 13.03:
Fig. 13.03.01 Starting air pipes
Fig. 13.03.02 Air spring pipes, exhaust valves

Turning gear

The turning wheel has cylindrical teeth and is fitted to the thrust shaft. The turning wheel is driven by a pinion on the terminal shaft of the turning gear, which is mounted on the bedplate.

Engagement and disengagement of the turning gear is effected by displacing the pinion and terminal shaft axially. To prevent the main engine from starting when the turning gear is engaged, the turning gear is equipped with a safety arrangement which interlocks with the starting air system.

The turning gear is driven by an electric motor with a built-in gear and brake. Key specifications of the electric motor and brake are stated in Section 13.04.
Starting and Control Air Pipes

The starting air pipes, Fig. 13.03.01, contain a main starting valve (a ball valve with actuator), a non-return valve, a solenoid valve and a starting valve. The main starting valve is controlled by the Engine Control System. Slow turning before start of engine, EoD: 4 50 140, is included in the basic design.

The Engine Control System regulates the supply of control air to the starting valves in accordance with the correct firing sequence and the timing.

Please note that the air consumption for control air, turbocharger cleaning and for fuel valve testing unit are momentary requirements of the consumers. The capacities stated for the air receivers and compressors in the ‘List of Capacities’ cover all the main engine requirements and starting of the auxiliary engines.

For information about a common starting air system for main engines and auxiliary engines, please refer to our publication:

Unic-concept Auxiliary Systems for Two-Stroke Main Engines and Four-Stroke Auxiliary Engines

The publication is available at www.marine.man.eu → 'Two-Stroke' → 'Technical Papers'.

The letters refer to list of ‘Counterflanges’
The item Nos. refer to ‘Guidance values automation’
The piping is delivered with and fitted onto the engine

Fig. 13.03.01: Starting air pipes
Exhaust Valve Air Spring Pipes

The exhaust valve is opened hydraulically by the Fuel Injection Valve Actuator (FIVA) system which is activated by the Engine Control System, and the closing force is provided by an ‘air spring’ which leaves the valve spindle free to rotate.

The compressed air is taken from the control air supply, see Fig. 13.03.02.

The item Nos. refer to ‘Guidance values automation’
The piping is delivered with and fitted onto the engine

*Fig. 13.03.02: Air spring pipes for exhaust valves*
Electric Motor for Turning Gear

MAN Diesel & Turbo delivers a turning gear with built-in disc brake, option 4 80 101. Two basic executions are available for power supply frequencies of 60 and 50 Hz respectively. Nominal power and current consumption of the motors are listed below.

Turning gear with electric motor of other protection or insulation classes can be ordered, option 4 80 103. Information about the alternative executions is available on request.

Electric motor and brake, voltage.... 3 x 440-480 V
Electric motor and brake, frequency..............60 Hz
Protection, electric motor / brake ..................IP 54
Insulation class ................................................. F

Electric motor and brake, voltage..... 3 x 380-415 V
Electric motor and brake, frequency..............50 Hz
Protection, electric motor / brake ..................IP 54
Insulation class ................................................. F

<table>
<thead>
<tr>
<th>Number of cylinders</th>
<th>Electric motor</th>
<th>Nominal power, kW</th>
<th>Normal current, A</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-7</td>
<td>Data is available on request</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>4.8</td>
<td>8.1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of cylinders</th>
<th>Electric motor</th>
<th>Nominal power, kW</th>
<th>Normal current, A</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-7</td>
<td>Data is available on request</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>8.1</td>
<td></td>
</tr>
</tbody>
</table>
Scavenge Air
Scavenge Air System

Scavenge air is supplied to the engine by one or more turbochargers, located on the exhaust side of the engine.

The compressor of the turbocharger draws air from the engine room, through an air filter, and the compressed air is cooled by the scavenge air cooler, one per turbocharger. The scavenge air cooler is provided with a water mist catcher, which prevents condensate water from being carried with the air into the scavenge air receiver and to the combustion chamber.

The scavenge air system (see Figs. 14.01.01 and 14.02.01) is an integrated part of the main engine.

The engine power figures and the data in the list of capacities are based on MCR at tropical conditions, i.e. a seawater temperature of 32 °C, or freshwater temperature of 36 °C, and an ambient air inlet temperature of 45 °C.

Fig. 14.01.01: Scavenge Air System
Auxiliary Blowers

The engine is provided with a minimum of two electrically driven auxiliary blowers, the actual number depending on the number of cylinders as well as the turbocharger make and amount.

The auxiliary blowers are integrated in the reversing chamber below the scavenge air cooler. Between the scavenge air cooler and the scavenge air receiver, non-return valves are fitted which close automatically when the auxiliary blowers start supplying the scavenge air.

Auxiliary blower operation

The auxiliary blowers start operating consecutively before the engine is started and will ensure complete scavenging of the cylinders in the starting phase, thus providing the best conditions for a safe start.

During operation of the engine, the auxiliary blowers will start automatically whenever the blower inlet pressure drops below a preset pressure, corresponding to an engine load of approximately 25-35%.

The blowers will continue to operate until the blower inlet pressure again exceeds the preset pressure plus an appropriate hysteresis (i.e. taking recent pressure history into account), corresponding to an engine load of approximately 30-40%.

Emergency running

If one of the auxiliary blowers is out of function, the other auxiliary blower will function in the system, without any manual adjustment of the valves being necessary.

Fig. 14.02.01: Scavenge air system, integrated blower
Control of the Auxiliary Blowers

The control system for the auxiliary blowers is integrated in the Engine Control System. The auxiliary blowers can be controlled in either automatic (default) or manual mode.

In automatic mode, the auxiliary blowers are started sequentially at the moment the engine is commanded to start. During engine running, the blowers are started and stopped according to preset scavenge air pressure limits.

When the engine stops, the blowers are stopped after 10 minutes to prevent overheating of the blowers. When a start is ordered, the blower will be started in the normal sequence and the actual start of the engine will be delayed until the blowers have started.

In manual mode, the blowers can be controlled individually from the ECR (Engine Control Room) panel irrespective of the engine condition.

Referring to Fig. 14.02.02, the Auxiliary Blower Starter Panels control and protect the Auxiliary Blower motors, one panel with starter per blower.

The starter panels with starters for the auxiliary blower motors are not included, they can be ordered as an option: 455 653. (The starter panel design and function is according to MAN Diesel & Turbo’s diagram, however, the physical layout and choice of components has to be decided by the manufacturer).

Heaters for the blower motors are available as an option: 455 155.

Scavenge air cooler requirements

The data for the scavenge air cooler is specified in the description of the cooling water system chosen.

For further information, please refer to our publication titled:

MAN Diesel & Turbo Influence of Ambient Temperature Conditions

The publication is available at www.marine.man.eu → 'Two-Stroke' → 'Technical Papers'.

Fig. 14.02.02: Diagram of auxiliary blower control system
Scavenge Air Pipes

The item No. refer to ‘Guidance Values Automation’

*) Option, see Fig. 15.02.05: Soft blast cleaning of turbine side

*Fig. 14.03.01: Scavenge air pipes*
Electric Motor for Auxiliary Blower

The number of auxiliary blowers in a propulsion plant may vary depending on the actual amount of turbochargers as well as space requirements.

For engines with Dynamic Positioning (DP) mode in manoeuvring system, option: 4 06 111, larger electric motors are required. This is in order to avoid start and stop of the blowers inside the load range specified for dynamic positioning. The actual load range is to be decided between the owner and the yard.

For typical engine configurations, the installed size of the electric motors for auxiliary blowers are listed in Table 14.04.01.

Engine plants with waste heat recovery exhaust gas bypass and engines with low- and part-load exhaust gas bypass may require less blower capacity, please contact MAN Diesel & Turbo, Copenhagen.

<table>
<thead>
<tr>
<th>Number of cylinders</th>
<th>Number of turbochargers</th>
<th>Number of auxiliary blowers</th>
<th>Installed power/blower kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1</td>
<td>2</td>
<td>65</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>2</td>
<td>75</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>2</td>
<td>75</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>2</td>
<td>86</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>2</td>
<td>99</td>
</tr>
</tbody>
</table>

The installed power of the electric motors are based on a voltage supply of 3x440V at 60Hz.

The electric motors are delivered with and fitted onto the engine.

*Table 14.04.01: Electric motor for auxiliary blower*
Scavenge Air Cooler Cleaning System

The air side of the scavenge air cooler can be cleaned by injecting a grease dissolving media through ‘AK’ to a spray pipe arrangement fitted to the air chamber above the air cooler element.

Drain from water mist catcher

Sludge is drained through ‘AL’ to the drain water collecting tank and the polluted grease dissolvent returns from ‘AM’, through a filter, to the chemical cleaning tank. The cleaning must be carried out while the engine is at standstill.

Dirty water collected after the water mist catcher is drained through ‘DX’ and led to the bilge tank via an open funnel, see Fig. 14.05.02.

The ‘AL’ drain line is, during running, used as a permanent drain from the air cooler water mist catcher. The water is led through an orifice to prevent major losses of scavenge air.

The system is equipped with a drain box with a level switch, indicating any excessive water level.

The piping delivered with and fitted on the engine is shown in Fig 14.05.01.

Auto Pump Overboard System

It is common practice on board to lead drain water directly overboard via a collecting tank. Before pumping the drain water overboard, it is recommended to measure the oil content. If above 15ppm, the drain water should be lead to the clean bilge tank / bilge holding tank.

If required by the owner, a system for automatic disposal of drain water with oil content monitoring could be built as outlined in Fig. 14.05.02.

With two or more air cooler
The letters refer to list of ‘Counterflanges’
The item no refer to ‘Guidance values automation’

Fig. 14.05.01: Air cooler cleaning pipes
Auto Pump Overboard System

Fig. 14.05.02: Suggested automatic disposal of drain water, if required by owner (not a demand from MAN Diesel & Turbo)

Air Cooler Cleaning Unit

The letters refer to list of ‘Counterflanges’

<table>
<thead>
<tr>
<th>No. of cylinders</th>
<th>5-7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical tank capacity, m³</td>
<td>0.6</td>
<td>0.9</td>
</tr>
<tr>
<td>Circulation pump capacity at 3 bar, m³/h</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Fig. 14.05.03: Air cooler cleaning system with Air Cooler Cleaning Unit, option: 4 55 665
Scavenge Air Box Drain System

The scavenge air box is continuously drained through ‘AV’ to a small pressurised drain tank, from where the sludge is led to the sludge tank. Steam can be applied through ‘BV’, if required, to facilitate the draining. See Fig. 14.06.01.

The continuous drain from the scavenge air box must not be directly connected to the sludge tank owing to the scavenge air pressure.

The pressurised drain tank must be designed to withstand full scavenge air pressure and, if steam is applied, to withstand the steam pressure available.

The system delivered with and fitted on the engine is shown in Fig. 14.07.03 Scavenge air space, drain pipes.

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**Fig. 14.06.01: Scavenge air box drain system**

---

### No. of cylinders:

<table>
<thead>
<tr>
<th>No. of cylinders:</th>
<th>5-6</th>
<th>7-9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain tank capacity, m³</td>
<td>0.5</td>
<td>0.7</td>
</tr>
</tbody>
</table>

The letters refer to list of ‘Counterflanges’
Fire Extinguishing System for Scavenge Air Space

Fire in the scavenge air space can be extinguished by steam, this being the basic solution, or, optionally, by water mist or CO₂.

The external system, pipe and flange connections are shown in Fig. 14.07.01 and the piping fitted onto the engine in Fig. 14.07.02.

In the Extent of Delivery, the fire extinguishing system for scavenge air space is selected by the fire extinguishing agent:

- basic solution: 4 55 140 Steam
- option: 4 55 142 Water mist
- option: 4 55 143 CO₂

The key specifications of the fire extinguishing agents are:

Steam fire extinguishing for scavenge air space
Steam test pressure: 15 bar
Steam quantity, approx.: 4.3 kg/cyl.

Water mist fire extinguishing for scavenge air space
Freshwater test pressure: 10 bar
Freshwater quantity, approx.: 3.4 kg/cyl.

CO₂ fire extinguishing for scavenge air space
CO₂ test pressure: 150 bar
CO₂ quantity, approx.: 8.5 kg/cyl.

The letters refer to list of 'Counterflanges'

Fig. 14.07.01: Fire extinguishing system for scavenge air space
Fire Extinguishing Pipes in Scavenge Air Space

Extinguishing agent:
- CO2
- Steam or Freshwater

Drain pipe, bedplate
(Only for steam or freshwater)

Scavenge Air Space, Drain Pipes

The letters refer to list of ‘Counterflanges’

Fig. 14.07.02: Fire extinguishing pipes in scavenge air space

Fig. 14.07.03: Scavenge air space, drain pipes
Exhaust Gas
Exhaust Gas System

The exhaust gas is led from the cylinders to the exhaust gas receiver where the fluctuating pressures from the cylinders are equalised and from where the gas is led further on to the turbocharger at a constant pressure. See fig. 15.01.01.

Compensators are fitted between the exhaust valve housings and the exhaust gas receiver and between the receiver and the turbocharger. A protective grating is placed between the exhaust gas receiver and the turbocharger. The turbocharger is fitted with a pick-up for monitoring and remote indication of the turbocharger speed.

The exhaust gas receiver and the exhaust pipes are provided with insulation, covered by steel plating.

Turbocharger arrangement and cleaning systems

The turbochargers are located on the exhaust side of the engine.

The engine is designed for the installation of the MAN turbocharger type TCA, option: 4 59 101, ABB turbocharger type A-L, option: 4 59 102, or MHI turbocharger type MET, option: 4 59 103.

All makes of turbochargers are fitted with an arrangement for water washing of the compressor side, and soft blast cleaning of the turbine side, see Figs. 15.02.02, 15.02.03 and 15.02.04. Washing of the turbine side is only applicable on MAN turbochargers.

Fig. 15.01.01: Exhaust gas system on engine
Exhaust Gas Pipes

The letters refer to list of ‘Counterflanges’
The item no. refer to ‘Guidance Values Automation’

Fig. 15.02.01: Exhaust gas pipes
Cleaning Systems

Fig. 15.02.02: MAN TCA turbocharger, water washing of turbine side

Fig. 15.02.03: Water washing of turbine and compressor sides for ABB TPL turbochargers
Soft Blast Cleaning Systems

Fig. 15.02.04: Soft blast cleaning of turbine side, basic

Fig. 15.02.05: Soft blast cleaning of turbine side, option
Exhaust Gas System for Main Engine

At the specified MCR of the engine, the total back-pressure in the exhaust gas system after the turbocharger (as indicated by the static pressure measured in the piping after the turbocharger) must not exceed 350 mm WC (0.035 bar).

In order to have a back-pressure margin for the final system, it is recommended at the design stage to initially use a value of about 300 mm WC (0.030 bar).

The actual back-pressure in the exhaust gas system at specified MCR depends on the gas velocity, i.e. it is proportional to the square of the exhaust gas velocity, and hence inversely proportional to the pipe diameter to the 4th power. It has by now become normal practice in order to avoid too much pressure loss in the pipings to have an exhaust gas velocity at specified MCR of about 35 m/sec, but not higher than 50 m/sec.

For dimensioning of the external exhaust pipe connections, see the exhaust pipe diameters for 35 m/sec, 40 m/sec, 45 m/sec and 50 m/sec respectively, shown in Table 15.07.02.

As long as the total back-pressure of the exhaust gas system (incorporating all resistance losses from pipes and components) complies with the above-mentioned requirements, the pressure losses across each component may be chosen independently, see proposed measuring points (M) in Fig. 15.05.01. The general design guidelines for each component, described below, can be used for guidance purposes at the initial project stage.

Exhaust gas piping system for main engine

The exhaust gas piping system conveys the gas from the outlet of the turbocharger(s) to the atmosphere.

The exhaust piping is shown schematically in Fig. 15.04.01.
Components of the Exhaust Gas System

**Exhaust gas compensator after turbocharger**

When dimensioning the compensator, option: 4 60 610, for the expansion joint on the turbocharger gas outlet transition piece, option: 4 60 601, the exhaust gas piece and components, are to be so arranged that the thermal expansions are absorbed by expansion joints. The heat expansion of the pipes and the components is to be calculated based on a temperature increase from 20 °C to 250 °C. The max. expected vertical, transversal and longitudinal heat expansion of the engine measured at the top of the exhaust gas transition piece of the turbocharger outlet are indicated in Fig. 15.06.01 and Table 15.06.02 as DA, DB and DC.

The movements stated are related to the engine seating, for DC, however, to the engine centre. The figures indicate the axial and the lateral movements related to the orientation of the expansion joints.

The expansion joints are to be chosen with an elasticity that limits the forces and the moments of the exhaust gas outlet flange of the turbocharger as stated for each of the turbocharger makers in Table 15.06.04. The orientation of the maximum permissible forces and moments on the gas outlet flange of the turbocharger is shown in Fig. 15.06.03.

**Exhaust gas boiler**

Engine plants are usually designed for utilisation of the heat energy of the exhaust gas for steam production or for heating the thermal oil system. The exhaust gas passes an exhaust gas boiler which is usually placed near the engine top or in the funnel.

It should be noted that the exhaust gas temperature and flow rate are influenced by the ambient conditions, for which reason this should be considered when the exhaust gas boiler is planned. At specified MCR, the maximum recommended pressure loss across the exhaust gas boiler is normally 150 mm WC.

This pressure loss depends on the pressure losses in the rest of the system as mentioned above. Therefore, if an exhaust gas silencer/spark arrester is not installed, the acceptable pressure loss across the boiler may be somewhat higher than the max. of 150 mm WC, whereas, if an exhaust gas silencer/spark arrester is installed, it may be necessary to reduce the maximum pressure loss.

The above mentioned pressure loss across the exhaust gas boiler must include the pressure losses from the inlet and outlet transition pieces.

![Exhaust gas system, one turbocharger](image1)

![Exhaust gas system, two or more TCs](image2)
Exhaust gas silencer

The typical octave band sound pressure levels from the diesel engine’s exhaust gas system – at a distance of one meter from the top of the exhaust gas uptake – are shown in Fig.15.04.02.

The need for an exhaust gas silencer can be decided based on the requirement of a maximum permissible noise level at a specific position.

The exhaust gas noise data is valid for an exhaust gas system without boiler and silencer, etc.

The noise level is at nominal MCR at a distance of one metre from the exhaust gas pipe outlet edge at an angle of 30° to the gas flow direction.

For each doubling of the distance, the noise level will be reduced by about 6 dB (far-field law).

When the noise level at the exhaust gas outlet to the atmosphere needs to be silenced, a silencer can be placed in the exhaust gas piping system after the exhaust gas boiler.

The exhaust gas silencer is usually of the absorption type and is dimensioned for a gas velocity of approximately 35 m/s through the central tube of the silencer.

An exhaust gas silencer can be designed based on the required damping of noise from the exhaust gas given on the graph.

In the event that an exhaust gas silencer is required – this depends on the actual noise level requirement on the bridge wing, which is normally maximum 60–70 dB(A) – a simple flow silencer of the absorption type is recommended. Depending on the manufacturer, this type of silencer normally has a pressure loss of around 20 mm WC at specified MCR.

Spark arrester

To prevent sparks from the exhaust gas being spread over deck houses, a spark arrester can be fitted as the last component in the exhaust gas system.

It should be noted that a spark arrester contributes with a considerable pressure drop, which is often a disadvantage.

It is recommended that the combined pressure loss across the silencer and/or spark arrester should not be allowed to exceed 100 mm WC at specified MCR. This depends, of course, on the pressure loss in the remaining part of the system, thus if no exhaust gas boiler is installed, 200 mm WC might be allowed.
Calculation of Exhaust Gas Back-Pressure

The exhaust gas back pressure after the turbocharger(s) depends on the total pressure drop in the exhaust gas piping system.

The components, exhaust gas boiler, silencer, and spark arrester, if fitted, usually contribute with a major part of the dynamic pressure drop through the entire exhaust gas piping system.

The components mentioned are to be specified so that the sum of the dynamic pressure drop through the different components should, if possible, approach 200 mm WC at an exhaust gas flow volume corresponding to the specified MCR at tropical ambient conditions. Then there will be a pressure drop of 100 mm WC for distribution among the remaining piping system.

Fig. 15.05.01 shows some guidelines regarding resistance coefficients and back-pressure loss calculations which can be used, if the maker’s data for back-pressure is not available at an early stage of the project.

The pressure loss calculations have to be based on the actual exhaust gas amount and temperature valid for specified MCR. Some general formulas and definitions are given in the following.

Exhaust gas data

M: exhaust gas amount at specified MCR in kg/sec.
T: exhaust gas temperature at specified MCR in °C

Please note that the actual exhaust gas temperature is different before and after the boiler. The exhaust gas data valid after the turbocharger may be found in Chapter 6.

Mass density of exhaust gas (ρ)

\[ \rho \equiv 1.293 \times \frac{273}{273 + T} \times 1.015 \text{ in kg/m}^3 \]

The factor 1.015 refers to the average back-pressure of 150 mm WC (0.015 bar) in the exhaust gas system.

Exhaust gas velocity (v)

In a pipe with diameter D the exhaust gas velocity is:

\[ v = \frac{M}{\rho} \times \frac{4}{\pi D^2} \text{ in m/s} \]

Pressure losses in pipes (Δp)

For a pipe element, like a bend etc., with the resistance coefficient \( \zeta \), the corresponding pressure loss is:

\[ \Delta p = \zeta \times \frac{1}{2} \rho v^2 \times \frac{1}{9.81} \text{ in mm WC} \]

where the expression after \( \zeta \) is the dynamic pressure of the flow in the pipe.

The friction losses in the straight pipes may, as a guidance, be estimated as:

1 mm WC per 1 diameter length

whereas the positive influence of the up-draught in the vertical pipe is normally negligible.

Pressure losses across components (Δp)

The pressure loss Δp across silencer, exhaust gas boiler, spark arrester, rain water trap, etc., to be measured/stated as shown in Fig. 15.05.01 (at specified MCR) is normally given by the relevant manufacturer.

Total back-pressure (ΔpM)

The total back-pressure, measured/stated as the static pressure in the pipe after the turbocharger, is then:

\[ \Delta p_M = \Sigma \Delta p \]

where Δp incorporates all pipe elements and components etc. as described:

ΔpM has to be lower than 350 mm WC.

(At design stage it is recommended to use max. 300 mm WC in order to have some margin for fouling).
Measuring Back Pressure

At any given position in the exhaust gas system, the total pressure of the flow can be divided into dynamic pressure (referring to the gas velocity) and static pressure (referring to the wall pressure, where the gas velocity is zero).

At a given total pressure of the gas flow, the combination of dynamic and static pressure may change, depending on the actual gas velocity. The measurements, in principle, give an indication of the wall pressure, i.e., the static pressure of the gas flow.

It is, therefore, very important that the back pressure measuring points are located on a straight part of the exhaust gas pipe, and at some distance from an 'obstruction', i.e. at a point where the gas flow, and thereby also the static pressure, is stable. Taking measurements, for example, in a transition piece, may lead to an unreliable measurement of the static pressure.

In consideration of the above, therefore, the total back pressure of the system has to be measured after the turbocharger in the circular pipe and not in the transition piece. The same considerations apply to the measuring points before and after the exhaust gas boiler, etc.
Pressure losses and coefficients of resistance in exhaust pipes

Change-over valves

Change-over valve of type with constant cross section

\( \zeta_a = 0.6 \) to 1.2
\( \zeta_b = 1.0 \) to 1.5
\( \zeta_c = 1.5 \) to 2.0

Change-over valve of type with volume

\( \zeta_a = \zeta_b = \) about 2.0

\( \zeta = 0.05 \)

Outlet from top of exhaust gas uptake

\( \zeta = 1.00 \)

Inlet (from turbocharger)

\( \zeta = -1.00 \)

M: Measuring points

Fig. 15.05.01: Pressure losses and coefficients of resistance in exhaust pipes
Forces and Moments at Turbocharger

Fig. 15.06.01: Vectors of thermal expansion at the turbocharger exhaust gas outlet flange

<table>
<thead>
<tr>
<th>No. of cylinders</th>
<th>Turbocharger Make</th>
<th>Type</th>
<th>DA mm</th>
<th>DB mm</th>
<th>DC mm</th>
<th>DC mm</th>
<th>DC mm</th>
<th>DC mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-8</td>
<td>MAN</td>
<td>TCA66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>TCA77</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>TCA88</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>ABB</td>
<td>A275</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A280</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A185 / A285</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MHI</td>
<td>MET60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MET66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MET71</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MET83</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DA: Max. movement of the turbocharger flange in the vertical direction
DB: Max. movement of the turbocharger flange in the transversal direction
DC: Max. movement of the turbocharger flange in the longitudinal direction

Table 15.06.02: Max. expected movements of the exhaust gas flange resulting from thermal expansion
Table 15.06.04 indicates the maximum permissible forces (F1, F2 and F3) and moments (M1 and M3), on the exhaust gas outlet flange of the turbocharger(s). Reference is made to Fig. 15.06.03.

<table>
<thead>
<tr>
<th>Turbocharger Make</th>
<th>Type</th>
<th>M1 Nm</th>
<th>M3 Nm</th>
<th>F1 N</th>
<th>F2 N</th>
<th>F3 N</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAN</td>
<td>TCA66</td>
<td>3,700</td>
<td>7,500</td>
<td>9,900</td>
<td>9,900</td>
<td>4,900</td>
</tr>
<tr>
<td></td>
<td>TCA77</td>
<td>4,100</td>
<td>8,200</td>
<td>10,900</td>
<td>10,900</td>
<td>5,400</td>
</tr>
<tr>
<td></td>
<td>TCA88</td>
<td>4,500</td>
<td>9,100</td>
<td>12,000</td>
<td>12,000</td>
<td>5,900</td>
</tr>
<tr>
<td>ABB</td>
<td>A275</td>
<td>3,300</td>
<td>3,300</td>
<td>5,400</td>
<td>3,500</td>
<td>3,500</td>
</tr>
<tr>
<td></td>
<td>A280</td>
<td>4,600</td>
<td>4,600</td>
<td>6,800</td>
<td>4,400</td>
<td>4,400</td>
</tr>
<tr>
<td></td>
<td>A185 / A285</td>
<td>6,600</td>
<td>6,600</td>
<td>8,500</td>
<td>5,500</td>
<td>5,500</td>
</tr>
<tr>
<td></td>
<td>A190</td>
<td>8,700</td>
<td>8,700</td>
<td>10,300</td>
<td>6,700</td>
<td>6,700</td>
</tr>
<tr>
<td>MHI</td>
<td>MET60</td>
<td>6,000</td>
<td>3,000</td>
<td>8,300</td>
<td>2,900</td>
<td>3,000</td>
</tr>
<tr>
<td></td>
<td>MET66</td>
<td>6,800</td>
<td>3,400</td>
<td>9,300</td>
<td>3,200</td>
<td>3,000</td>
</tr>
<tr>
<td></td>
<td>MET71</td>
<td>7,000</td>
<td>3,500</td>
<td>9,600</td>
<td>3,300</td>
<td>3,100</td>
</tr>
<tr>
<td></td>
<td>MET83</td>
<td>9,800</td>
<td>4,900</td>
<td>11,700</td>
<td>4,100</td>
<td>3,700</td>
</tr>
</tbody>
</table>

Table 15.06.04: The max. permissible forces and moments on the turbocharger’s gas outlet flanges.
Diameter of Exhaust Gas Pipes

The exhaust gas pipe diameters listed in Table 15.07.02 are based on the exhaust gas flow capacity according to ISO ambient conditions and an exhaust gas temperature of 250 °C.

The exhaust gas velocities and mass flow listed apply to collector pipe D4. The table also lists the diameters of the corresponding exhaust gas pipes D0 for various numbers of turbochargers installed.

![Exhaust pipe system, with turbocharger located on exhaust side of engine](image)

**Table 15.07.02: Exhaust gas pipe diameters and exhaust gas mass flow at various velocities**

<table>
<thead>
<tr>
<th>Gas velocity</th>
<th>Exhaust gas pipe diameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 m/s</td>
<td>1 T/C</td>
</tr>
<tr>
<td>kg/s</td>
<td>kg/s</td>
</tr>
<tr>
<td>31.4</td>
<td>35.8</td>
</tr>
<tr>
<td>36.4</td>
<td>41.6</td>
</tr>
<tr>
<td>41.7</td>
<td>47.7</td>
</tr>
<tr>
<td>47.5</td>
<td>54.3</td>
</tr>
<tr>
<td>53.6</td>
<td>61.3</td>
</tr>
<tr>
<td>60.1</td>
<td>68.7</td>
</tr>
<tr>
<td>67.0</td>
<td>76.5</td>
</tr>
<tr>
<td>74.2</td>
<td>84.8</td>
</tr>
</tbody>
</table>
Engine Control System
Engine Control System – Dual Fuel

The ME-GI engine control system, (ME-GI-ECS), is a common control system which is able to control all the functions known from the ME-engine.

The ME-GI-ECS also controls the gas injection as well as the additional functionality and auxiliary systems related to the handling of gas on the engine and in the machine room, by means of:

- Electronically profiled fuel oil injection
- Electronically controlled exhaust valve actuation
- Governor/speed control
- Start and reversing sequencing
- Cylinder lubrication
- Variable turbocharging (if applied)
- Electronically controlled gas injection
- Sequencing change-over between fuel oil and dual fuel operation
- Gas combustion monitoring and safety gas shutdown
- Double-pipe ventilation and leak monitoring
- Sealing oil control
- Purging of gas piping with inert gas
- Interface to the FGS system.

Fig. 16.00.01 illustrates how the ME-ECS core controls both the pilot and gas injection. The GI extension handles gas related safety control and gas plant control, including interface to the FGSS control system.
Gas injection components

The gas injection is controlled by two valves in series. The window valve sets up a timing window within which the gas injection can be performed, and also limits the maximum injection. The gas injection valve controls the precise timing and gas injection amount.

The gas injection valve and the window valve are both controlled by the GI control system and the GI safety system respectively, as is the case for several other systems, see Fig. 16.00.02.

Fig. 16.00.02: ME-GI-ECS with interface to other systems and auxiliary systems
**GI extension main components**

The GI extension is based on two components:

- The multi-purpose controller (MPC)
- The data acquisition and supervision unit (DASU).

The MPCs are the same hardware units as used in the standard ME-ECS, and spare units can be used in any MPC position of the ME-GI-ECS.

The GCSU units, that are based on DASU units, supervise and analyse the combustion in real time in order to be able to cut off the gas combustion fast in case of, e.g., misfiring or leakage in the injection equipment, see Fig. 16.00.03

**Safety units**

The gas plant safety unit (GPSU) monitors specific gas plant safety sensors and, in case of a failure, it carries out a gas shutdown.

The gas cylinder safety unit (GCSU) monitors the specific cylinder sensors, and every single gas injection and combustion is supervised.

In case of a failure, the window valve acts as a gas shutdown valve and closes immediately. The ELWI valve controlling the window valve is electrically wired to this unit.

**Control units**

The gas plant control unit (GPCU) and gas auxiliary control unit (GACU) perform the task of bringing the gas system from ‘no gas on engine’ to ‘gas running’ and back again.

---

**Fig. 16.00.03: ME-GI-ECS configuration**
Engine Control System ME

The Engine Control System (ECS) for the ME engine is prepared for conventional remote control, having an interface to the Bridge Control system and the Local Operating Panel (LOP).

A Multi-Purpose Controller (MPC) is applied as control unit for specific tasks described below: ACU, CCU, CWCU, ECU, SCU and EICU. Except for the CCU, the control units are all built on the same identical piece of hardware and differ only in the software installed. For the CCU on ME and ME-C only, a downsized and cost-optimised controller is applied, the MPC10.

The layout of the Engine Control System is shown in Figs. 16.01.01a and b, the mechanical-hydraulic system is shown in Figs. 16.01.02a and b, and the pneumatic system, shown in Fig. 16.01.03.

The ME system has a high level of redundancy. It has been a requirement to its design that no single failure related to the system may cause the engine to stop. In most cases, a single failure will not affect the performance or power availability, or only partly do so by activating a slow down.

It should be noted that any controller could be replaced without stopping the engine, which will revert to normal operation immediately after the replacement of the defective unit.

Main Operating Panel

Two redundant main operating panel (MOP) screens are available for the engineer to carry out engine commands, adjust the engine parameters, select the running modes, and observe the status of the control system. Both MOP screens are located in the Engine Control Room (ECR), one serving as back-up unit in case of failure or to be used simultaneously, if preferred.

Both MOP screens consist of a marine approved Personal Computer with a touch screen and pointing device as shown in Fig. 5.16.02.

Engine Control Unit

For redundancy purposes, the control system comprises two engine control units (ECU) operating in parallel and performing the same task, one being a hot stand-by for the other. If one of the ECUs fail, the other unit will take over the control without any interruption.

The ECUs perform such tasks as:

- Speed governor functions, start/stop sequences, timing of fuel injection, timing of exhaust valve activation, timing of starting valves, etc.
- Continuous running control of auxiliary functions handled by the ACUs
- Alternative running modes and programs.

Cylinder Control Unit

The control system includes one cylinder control unit (CCU) per cylinder. The CCU controls the Fuel Injection and exhaust Valve Activation (FIVA) and the Starting Air Valves (SAV), in accordance with the commands received from the ECU.

All the CCUs are identical, and in the event of a failure of the CCU for one cylinder only this cylinder will automatically be cut out of operation.

Auxiliary Control Unit

The control of the auxiliary equipment on the engine is normally divided among three auxiliary control units (ACU) so that, in the event of a failure of one unit, there is sufficient redundancy to permit continuous operation of the engine.

The ACUs perform the control of the auxiliary blowers, the control of the electrically and engine driven hydraulic oil pumps of the Hydraulic Power Supply (HPS) unit.
Cooling Water Control Unit

On engines with load dependent cylinder liner (LDCL) cooling water system, a cooling water control unit (CWCU) controls the liner circulation string temperature by means of a three-way valve.

Scavenge Air Control Unit

The scavenge air control unit (SCU) controls the scavenge air pressure on engines with advanced scavenge air systems like exhaust gas bypass (EGB) with on/off or variable valve, waste heat recovery system (WHRS) and turbocharger with variable turbine inlet area (VT) technology.

For part- and low-load optimised engines with EGB variable bypass regulation valve, Economiser Engine Control (ECC) is available as an option in order to optimise the steam production versus SFOC, option: 4 65 342.

Engine Interface Control Unit

The two engine interface control units (EICU) perform such tasks as interface with the surrounding control systems, see Fig. 16.01.01a and b. The two EICU units operate in parallel and ensures redundancy for mission critical interfaces.

The EICUs are located either in the Engine Control Room (recommended) or in the engine room.

In the basic execution, the EICUs are a placed in the Cabinet for EICUs, EoD: 4 65 601.

Control Network

The MOP, the backup MOP and the MPCs are interconnected by means of the redundant Control Networks, A and B respectively.

The maximum length of Control Network cabling between the furthermost units on the engine and in the Engine Control Room (an EICU or a MOP) is 230 meter.

Should the layout of the ship make longer Control Network cabling necessary, a Control Network Repeater must be inserted to amplify the signals and divide the cable into segments no longer than 230 meter. For instance, where the Engine Control Room and the engine room are located far apart. The connection of the two MOPs to the control network is shown in Fig. 5.16.01.

Power Supply for Engine Control System

The Engine Control System requires two separate power supplies with battery backup, power supply A and B.

The ME-ECS power supplies must be separated from other DC systems, i.e. only ME-ECS components must be connected to the supplies.

<table>
<thead>
<tr>
<th>Power supply A</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System</strong></td>
</tr>
<tr>
<td>IT (Floating), DC system w.</td>
</tr>
<tr>
<td>individually isolated outputs</td>
</tr>
<tr>
<td><strong>Voltage</strong></td>
</tr>
<tr>
<td>Input 100-240V AC, 45-65 Hz, output</td>
</tr>
<tr>
<td>24V DC</td>
</tr>
<tr>
<td><strong>Protection</strong></td>
</tr>
<tr>
<td>Input over current, output over</td>
</tr>
<tr>
<td>current, output high/low voltage</td>
</tr>
<tr>
<td><strong>Alarms as potential free contacts</strong></td>
</tr>
<tr>
<td>AC power, UPS battery mode,</td>
</tr>
<tr>
<td>Batteries not available (fuse fail)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Power supply B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System</strong></td>
</tr>
<tr>
<td>IT (Floating), DC system w.</td>
</tr>
<tr>
<td>individually isolated outputs</td>
</tr>
<tr>
<td><strong>Voltage</strong></td>
</tr>
<tr>
<td>Input 110-240 VAC, output 24V DC</td>
</tr>
<tr>
<td><strong>Protection</strong></td>
</tr>
<tr>
<td>Input over current, output over</td>
</tr>
<tr>
<td>current, output high/low voltage</td>
</tr>
<tr>
<td><strong>Alarms as potential free contacts</strong></td>
</tr>
<tr>
<td>AC power, UPS battery mode,</td>
</tr>
<tr>
<td>Batteries not available (fuse fail)</td>
</tr>
</tbody>
</table>

High/Low voltage protection may be integrated in the DC/DC converter functionality or implemented separately. The output voltage must be in the range 18-31V DC.
Local Operating Panel

In normal operating the engine can be controlled from either the bridge or from the engine control room.

Alternatively, the local operating panel (LOP) can be activated. This redundant control is to be considered as a substitute for the previous Engine Side Control console mounted directly onto the MC engine.

The LOP is as standard placed on the engine.

From the LOP, the basic functions are available, such as starting, engine speed control, stopping, reversing, and the most important engine data are displayed.

Hydraulic Power Supply

The purpose of the hydraulic power supply (HPS) unit is to deliver the necessary high pressure hydraulic oil flow to the Hydraulic Cylinder Units (HCU) on the engine at the required pressure (approx. 300 bar) during start-up as well as in normal service.

In case of the STANDARD mechanically driven HPS unit, at start, one of the two electrically driven start-up pumps is activated. The start-up pump is stopped 25 seconds after the engine reaches 15% speed.

The multiple pump configuration with standby pumps ensures redundancy with regard to the hydraulic power supply. The control of the engine driven pumps and electrical pumps are divided between the three ACUs.

The high pressure pipes between the HPS unit and the HCU are of the double-walled type, having a leak detector (210 bar system only). Emergency running is possible using the outer pipe as pressure containment for the high pressure oil supply.

The sizes and capacities of the HPS unit depend on the engine type. Further details about the HPS and the lubricating oil/hydraulic oil system can be found in Chapter 8.
Engine Control System Layout with Cabinet for EICU

On Bridge
- Bridge Panel

In Engine Control Room
- Backup Operation Panel (MOP B)
- Main Operation Panel (MOP A)
- ECR Panel
- Cabinet for EICU
- EICU A
- EICU B

On Engine
- Local Operation Panel (LOP)
- ECU A
- ECU B
- ACU 1
- ACU 2
- ACU 3
- CCU Cylinder 1
- CCU Cylinder n
- FIVA Cylinder 1
- FIVA Cylinder n
- AL Cylinder 1
- AL Cylinder n
- Marker Sensor
- Angle Encoders
- Pump 1
- Pump 2
- Pump 3
- Pump 4
- Auxiliary Blower 1
- Auxiliary Blower 2
- Auxiliary Blower 3
- Auxiliary Blower 4

Fig. 16.01.01a: Engine Control System layout with cabinet for EICU for mounting in ECR or on engine, EoD: 4 65 601
Engine Control System Layout with Common Control Cabinet

Fig. 16.01.01b: Engine Control System layout with ECS Common Control Cabinet for mounting in ECR or on engine, option: 4 65 602
Mechanical-hydraulic System with Mechanically Driven HPS

The letters refer to list of 'Counterflanges'
Th item No. refer to 'Guidance Values Automation'

Fig. 16.01.02a: Mechanical-hydraulic System with mechanically driven Hydraulic Power Supply, 300 bar, common supply
Mechanical-hydraulic System with Electrically Driven HPS

The letters refer to list of ‘Counterflanges’
Th item No. refer to ‘Guidance Values Automation’

Fig. 16.01.02b: Mechanical-hydraulic System with electrically driven Hydraulic Power Supply, 300 bar, common supply. Example from S90/80ME-C engine
To support the navigator, the vessels are equipped with a ship control system, which includes subsystems to supervise and protect the main propulsion engine.

Alarm system

The alarm system has no direct effect on the ECS. The alarm alerts the operator of an abnormal condition.

The alarm system is an independent system, in general covering more than the main engine itself, and its task is to monitor the service condition and to activate the alarms if a normal service limit is exceeded.

The signals from the alarm sensors can be used for the slow down function as well as for remote indication.

Slow down system

Some of the signals given by the sensors of the alarm system are used for the ‘Slow down request’ signal to the ECS of the main engine.

Safety system

The engine safety system is an independent system with its respective sensors on the main engine, fulfilling the requirements of the respective classification society and MAN Diesel & Turbo.

If a critical value is reached for one of the measuring points, the input signal from the safety system must cause either a cancellable or a non-cancellable shut down signal to the ECS.

For the safety system, combined shut down and slow down panels approved by MAN Diesel & Turbo are available. The following options are listed in the Extent of Delivery:

- 4 75 631 Lyngsø Marine
- 4 75 632 Kongsberg Maritime
- 4 75 633 Nabtesco
- 4 75 636 Mitsui Zosen Systems Research.

Where separate shut down and slow down panels are installed, only panels approved by MAN Diesel & Turbo must be used.

In any case, the remote control system and the safety system (shut down and slow down panel) must be compatible.

Telegraph system

This system enables the navigator to transfer the commands of engine speed and direction of rotation from the Bridge, the engine control room or the Local Operating Panel (LOP), and it provides signals for speed setting and stop to the ECS.

The engine control room and the LOP are provided with combined telegraph and speed setting units.
Remote Control system

The remote control system normally has two alternative control stations:

• the bridge control
• the engine control room control.

The remote control system is to be delivered by a supplier approved by MAN Diesel & Turbo.

Bridge control systems from suppliers approved by MAN Diesel & Turbo are available. The Extent of Delivery lists the following options:

• for Fixed Pitch propeller plants, e.g.:
  4 95 703 Lyngsø Marine
  4 95 704 Mitsui Zosen Systems Research
  4 95 705 Nabtesco
  4 95 715 Kongsberg Maritime

• and for Controllable Pitch propeller plants, e.g.:
  4 95 701 Lyngsø Marine
  4 95 716 Kongsberg Maritime
  4 95 719 MAN Alphatronic.

Power Management System

The system handles the supply of electrical power onboard, i.e. the starting and stopping of the generating sets as well as the activation / deactivation of the main engine Shaft Generator (SG), if fitted.

The normal function involves starting, synchronising, phasing-in, transfer of electrical load and stopping of the generators based on the electrical load of the grid on board.

The activation / deactivation of the SG is to be done within the engine speed range which fulfils the specified limits of the electrical frequency.

Auxiliary equipment system

The input signals for ‘Auxiliary system ready’ are given partly through the Remote Control system based on the status for:

• fuel oil system
• lube oil system
• cooling water systems

and partly from the ECS itself:

• turning gear disengaged
• main starting valve ‘open’
• control air valve for sealing air ‘open’
• control air valve for air spring ‘open’
• auxiliary blowers running
• hydraulic power supply ready.

Monitoring systems

In addition to the PMI Auto-tuning system, which is part of the ME engine installation, CoCoS-EDS can be used for in-depth monitoring of the engine.

A description of the systems can be found in Chapter 18 of this Project Guide.

Instrumentation

Chapter 18 in the Project Guide for the specific engine type includes lists of instrumentation for:

• The CoCoS-EDS system
• The class requirements and MAN Diesel & Turbo’s requirements for alarms, slow down and shut down for Unattended Machinery Spaces.
Pneumatic Manoeuvring Diagram

The letters refer to list of ‘Counterflanges’
The item no. refer to ‘Guidance Values Automation’

Fig. 16.01.03: Pneumatic Manoeuvring Diagram
Engine Control System – GI Extension

In addition to the ME-ECS, a special system is installed to control the gas supply and to monitor safety issues when the engine is operating on compressed gaseous fuels. See Fig. 16.02.01. The GI extension is the glue that ties all the dual fuel parts in the internal and the external system together.

As mentioned, the GI extension is designed as an add-on to the standard ME control system. Therefore, the Bridge panel, the Main Operating Panel (MOP) and the Local Operating Panel (LOP) is equipped with a gas-running indication lamp. All operations in gas mode are performed from the engine room alone, while the operation from the bridge is exactly the same whether in gas or fuel oil mode.

Gas control

Gas control consists of three parts:

- Dual fuel injection control
- Gas plant control
- Gas safety control.

Dual fuel injection control is additional functionality added to the ECU and CCUs of the ME-ECS, while gas plant control and safety control are handled by additional units: the GPCU (Gas Plant Control Unit) and GACU (Gas Auxiliary Control Unit), respectively GPSU (Gas Plant Safety Unit) and GCSUs (Gas Cylinder Safety Units).

Gas plant control

Plant control has the functions of:

A – Controlling the supply of gas from the FGSS (Fuel Gas Supply System) to the engine in a safe way.

B – Close down the supply of gas to the engine after end of gas operation.

Function A includes:

- purge the gas pipes and gas volumes for atmospheric air before open the gas
- start the double-pipe ventilation system and turn on double-pipe leakage detection
- apply gas to engine in steps, while checking for leakage and correct function of valves, while the gas pressure is built up
- start the sealing oil system, when gas is entering the cylinder cover.

Function B includes:

- close the gas block valves
- release the gas pressure
- stop the sealing oil system
- start purging the gas pipes and volumes
- stop the double-pipe ventilation.

Furthermore, the task of the plant control is to handle the switch between the two stable states:

- Fuel oil mode (HFO only)
- Gas mode.

The gas plant control can operate all the fuel gas equipment. For the plant control to operate, it is required that the Safety Control allows it to work, otherwise the Safety Control will overrule and return to a Gas Safe Condition.

Dual fuel injection control

The task of the fuel control is to determine the fuel gas index and the pilot oil index when running in the different modes.
Fig. 16.02.01: ME-GI Engine Control System
Gas safety control

The task of the safety system is to monitor:

- manual and external automatic gas shut down
- engine shut down signal from the engine safety system
- double-pipe ventilation and leakage
- sealing oil pressure
- gas pressure
- combustion pressure within normal values
- gas injection valve and window valve leakage.

If one of the above mentioned failures is detected, the gas safety control releases the fuel gas shut down sequence:

The window valve and the main gas valve, safety will be closed. The ELGI valves will be disabled. The fuel gas will be blown out by opening the gas bleed valve, the blow-off valves and purge valves, and finally the gas pipe system will be purged with inert gas. See Fig. 7.00.01.

Safety principles of the Gas Dual Fuel Control System

Gas mode running is not essential for the manoeuvrability of the ship as the engine will continue to run on fuel oil if an unintended fuel gas stop occurs. The two fundamental safety principles of the fuel gas equipment are, in order of priority:

- Safety to personnel must be at least on the same level as for a conventional diesel engine
- A fault in the dual fuel equipment must cause stop of gas operation and change over to fuel oil mode which to some extent complement each other.

The Dual Fuel Control System is designed to ‘fail to safe condition’. All failures detected during fuel gas running and failures of the control system itself will result in a fuel gas Stop / Shut down and change over to fuel oil operation.

Subsequently, the control system initiates blow out and purging of high pressure fuel gas pipes which releases all gas from the entire gas supply system of the engine room.
Dual fuel function of the ECU and CCU

The Dual Fuel Injection Control is part of the ECU which includes all facilities required for calculating the fuel gas index and the pilot oil index based on the command from the ME governor function and the actual active mode.

Based on these data and including information about the fuel gas pressure, the Dual Fuel Injection Control calculates the start and duration time of the injection, then sends the signal to the CCU which effectuates the injection by controlling both the FIVA and the ELGI valves.

Gas Plant and Gas Auxiliary Control Unit, Auxiliaries’ control

When ‘Gas Mode Start’ is initiated manually by the operator, the Gas Plant Control will start the automatic start sequence.

The Gas Plant Control Unit (GPCU) and the Gas Auxiliary Control Unit (GACU) contain facilities necessary to control and monitor auxiliary systems.

The GACU and GPCU control:
- start/stop of pumps, fans, and of the gas supply system
- sealing oil pressure set points
- pressure set points for the gas supply system
- the purging with inert gas.

The GPCU monitors the condition of the following:
- gas supply system
- sealing oil system
- double-pipe ventilation
- inert gas system

and, if a failure does occur, the Gas Plant Control Unit will automatically interrupt gas mode start operation and return the plant to fuel oil mode.

Gas Plant Safety Unit, Fuel Gas System monitoring and control

The central Gas Plant Safety Unit (GPSU) performs safety monitoring of the fuel gas system and controls the fuel gas shut down.

The GPSU monitors the following:
- pipe ventilation of the double-wall piping
- sealing oil pressure
- fuel gas pressure
- GCSU ready signal.

If one of the above parameters (referring to the relevant fuel gas state) differs from normal service value, the GPSU overrules any other signals and gas shut down will be released.

After the cause of the gas shut down has been corrected, the fuel gas operation can be manually restarted.

The Gas Plant Control main state diagram is shown in Fig. 16.02.02.

Fig. 16.02.02: Gas Plant Control main state diagram
Gas Cylinder Safety Unit

The purpose of the Gas Cylinder Safety Unit (GCSU) is to monitor the cylinders for being in condition for the injection of fuel gas.

The following events are monitored by the GCSU:

- fuel gas accumulator pressure drop during injection
- pilot oil injection pressure
- cylinder pressure:
  - low compression pressure
  - knocking
  - low expansion pressure
- scavenge air pressure.

If one of the events is abnormal, the ELWI valve is closed and a shut down of fuel gas running is activated by the GPSU.
GI Extension Interface to External Systems

Further to the alarm sensors, local instruments and control devices listed in Section 18.04-06, the GI extension interface to external systems is shown in Fig. 16.02.03.

Fig. 16.02.03: Interface to external systems with basic information of flow in and between external systems
Vibration Aspects
Vibration Aspects

The vibration characteristics of the two-stroke low speed diesel engines can for practical purposes be split up into four categories, and if the adequate countermeasures are considered from the early project stage, the influence of the excitation sources can be minimised or fully compensated.

In general, the marine diesel engine may influence the hull with the following:

- External unbalanced moments
  These can be classified as unbalanced 1st and 2nd order external moments, which need to be considered only for certain cylinder numbers
- Guide force moments
- Axial vibrations in the shaft system
- Torsional vibrations in the shaft system.

The external unbalanced moments and guide force moments are illustrated in Fig. 17.01.01.

In the following, a brief description is given of their origin and of the proper countermeasures needed to render them harmless.

External unbalanced moments

The inertia forces originating from the unbalanced rotating and reciprocating masses of the engine create unbalanced external moments although the external forces are zero.

Of these moments, the 1st order (one cycle per revolution) and the 2nd order (two cycles per revolution) need to be considered for engines with a low number of cylinders. On 7-cylinder engines, also the 4th order external moment may have to be examined. The inertia forces on engines with more than 6 cylinders tend, more or less, to neutralise themselves.

Countermeasures have to be taken if hull resonance occurs in the operating speed range, and if the vibration level leads to higher accelerations and/or velocities than the guidance values given by international standards or recommendations (for instance related to special agreement between shipowner and shipyard). The natural frequency of the hull depends on the hull’s rigidity and distribution of masses, whereas the vibration level at resonance depends mainly on the magnitude of the external moment and the engine’s position in relation to the vibration nodes of the ship.
2nd Order Moments on 4, 5 and 6-cylinder Engines

The 2nd order moment acts only in the vertical direction. Precautions need only to be considered for 4, 5 and 6-cylinder engines in general.

Resonance with the 2nd order moment may occur in the event of hull vibrations with more than 3 nodes. Contrary to the calculation of natural frequency with 2 and 3 nodes, the calculation of the 4 and 5-node natural frequencies for the hull is a rather comprehensive procedure and often not very accurate, despite advanced calculation methods.

A 2nd order moment compensator comprises two counter-rotating masses running at twice the engine speed.

**Compensator solutions**

Several solutions are available to cope with the 2nd order moment, as shown in Fig. 17.03.02, out of which the most cost efficient one can be chosen in the individual case, e.g.:

1) No compensators, if considered unnecessary on the basis of natural frequency, nodal point and size of the 2nd order moment.

2) A compensator mounted on the aft end of the engine, driven by chain, option: 4 31 203.

3) A compensator mounted on the fore end, driven from the crankshaft through a separate chain drive, option: 4 31 213.

As standard, the compensators reduce the external 2nd order moment to a level as for a 7-cylinder engine or less.

Briefly speaking, solution 1) is applicable if the node is located far from the engine, or the engine is positioned more or less between nodes. Solutions 2) or 3) should be considered where one of the engine ends is positioned in a node or close to it, since a compensator is inefficient in a node or close to it and therefore superfluous.

**Determine the need**

A decision regarding the vibrational aspects and the possible use of compensators must be taken at the contract stage. If no experience is available from sister ships, which would be the best basis for deciding whether compensators are necessary or not, it is advisable to make calculations to determine which of the solutions should be applied.

---

*Fig. 17.02.01: Statistics of vertical hull vibrations, an example from tankers and bulk carriers*
Preparation for compensators

If compensator(s) are initially omitted, the engine can be delivered prepared for compensators to be fitted on engine fore end later on, but the decision to prepare or not must be taken at the contract stage, option: 4 31 212. Measurements taken during the sea trial, or later in service and with fully loaded ship, will be able to show if compensator(s) have to be fitted at all.

If no calculations are available at the contract stage, we advise to make preparations for the fitting of a compensator in the steering compartment, see Section 17.03.

Basic design regarding compensators

For 5 and 6-cylinder engines with mechanically driven HPS, the basic design regarding 2nd order moment compensators is:

- With compensator aft, EoD: 4 31 203
- Prepared for compensator fore, EoD: 4 31 212

For 5 and 6-cylinder engines with electrically driven HPS, the basic design regarding 2nd order moment compensators is:

- With MAN B&W external electrically driven moment compensator, RotComp, EoD: 4 31 255
- Prepared for compensator fore, EoD: 4 31 212

The available options for 5 and 6-cylinder engines are listed in the Extent of Delivery. For 4-cylinder engines, the information is available on request.
1st Order Moments on 4-cylinder Engines

1st order moments act in both vertical and horizontal direction. For our two-stroke engines with standard balancing these are of the same magnitudes.

For engines with five cylinders or more, the 1st order moment is rarely of any significance to the ship. It can, however, be of a disturbing magnitude in four-cylinder engines.

Resonance with a 1st order moment may occur for hull vibrations with 2 and/or 3 nodes. This resonance can be calculated with reasonable accuracy, and the calculation will show whether a compensator is necessary or not on four-cylinder engines.

A resonance with the vertical moment for the 2 node hull vibration can often be critical, whereas the resonance with the horizontal moment occurs at a higher speed than the nominal because of the higher natural frequency of horizontal hull vibrations.

Balancing 1st order moments

As standard, four-cylinder engines are fitted with 1st order moment balancers in shape of adjustable counterweights, as illustrated in Fig. 17.02.02. These can reduce the vertical moment to an insignificant value (although, increasing correspondingly the horizontal moment), so this resonance is easily dealt with. A solution with zero horizontal moment is also available.

1st order moment compensators

In rare cases, where the 1st order moment will cause resonance with both the vertical and the horizontal hull vibration mode in the normal speed range of the engine, a 1st order compensator can be introduced as an option, reducing the 1st order moment to a harmless value.

Since resonance with both the vertical and the horizontal hull vibration mode is rare, the standard engine is not prepared for the fitting of 1st order moment compensators.

Data on 1st order moment compensators and preparation as well as options in the Extent of Delivery are available on request.

Fig. 17.02.02: Examples of counterweights
**Electrically Driven Moment Compensator**

If it is decided not to use chain driven moment compensators and, furthermore, not to prepare the main engine for compensators to be fitted later, another solution can be used, if annoying 2nd order vibrations should occur: An external electrically driven moment compensator can neutralise the excitation, synchronised to the correct phase relative to the external force or moment.

This type of compensator needs an extra seating fitted, preferably, in the steering gear room where vibratory deflections are largest and the effect of the compensator will therefore be greatest.

The electrically driven compensator will not give rise to distorting stresses in the hull, but it is more expensive than the engine-mounted compensators. It does, however, offer several advantages over the engine mounted solutions:

- When placed in the steering gear room, the compensator is not as sensitive to the positioning of the node as the compensators 2) and 3) mentioned in Section 17.02.
- The decision whether or not to install compensators can be taken at a much later stage of a project, since no special version of the engine structure has to be ordered for the installation.
- No preparation for a later installation nor an extra chain drive for the compensator on the fore end of the engine is required. This saves the cost of such preparation, often left unused.
- Compensators could be retrofit, even on ships in service, and also be applied to engines with a higher number of cylinders than is normally considered relevant, if found necessary.
- The compensator only needs to be active at speeds critical for the hull girder vibration. Thus, it may be activated or deactivated at specified speeds automatically or manually.
- Combinations with and without moment compensators are not required in torsional and axial vibration calculations, since the electrically driven moment compensator is not part of the mass-elastic system of the crankshaft. Furthermore, by using the compensator as a vibration exciter a ship's vibration pattern can easily be identified without having the engine running, e.g. on newbuildings at an advanced stage of construction. If it is verified that a ship does not need the compensator, it can be removed and reused on another ship.

It is a condition for the application of the rotating force moment compensator that no annoying longitudinal hull girder vibration modes are excited. Based on our present knowledge, and confirmed by actual vibration measurements onboard a ship, we do not expect such problems.

**Balancing other forces and moments**

Further to compensating 2nd order moments, electrically driven balancers are also available for balancing other forces and moments. The available options are listed in the Extent of Delivery.
Fig. 17.03.02: Compensation of 2nd order vertical external moments

Moment compensator
Fore end, option: 4 31 213

Compensating moment
$F_2C \times L_{\text{node}}$ outbalances $M_{2V}$

Moment from compensator
$M_{2C}$ reduces $M_{2V}$

Electrically driven moment compensator

Compensating moment
$F_D \times L_{\text{node}}$ outbalances $M_{2V}$

Centre line crankshaft

3 and 4-node vertical hull girder mode
Guide Force Moments

The so-called guide force moments are caused by the transverse reaction forces acting on the crossheads due to the connecting rod/crankshaft mechanism. These moments may excite engine vibrations, moving the engine top athwartships and causing a rocking (excited by H-moment) or twisting (excited by X-moment) movement of the engine as illustrated in Fig. 17.05.01.

The guide force moments corresponding to the MCR rating (L₁) are stated in Table 17.07.01.

Top bracing

The guide force moments are harmless except when resonance vibrations occur in the engine/double bottom system.

As this system is very difficult to calculate with the necessary accuracy, MAN Diesel & Turbo strongly recommend, as standard, that top bracing is installed between the engine’s upper platform brackets and the casing side.

The vibration level on the engine when installed in the vessel must comply with MAN Diesel & Turbo vibration limits as stated in Fig. 17.05.02.

We recommend using the hydraulic top bracing which allow adjustment to the loading conditions of the ship. Mechanical top bracings with stiff connections are available on request.

With both types of top bracing, the above-mentioned natural frequency will increase to a level where resonance will occur above the normal engine speed. Details of the top bracings are shown in Chapter 05.

Definition of Guide Force Moments

Over the years it has been discussed how to define the guide force moments. Especially now that complete FEM-models are made to predict hull/engine interaction, the proper definition of these moments has become increasingly important.

H-type Guide Force Moment (M₇)

Each cylinder unit produces a force couple consisting of:
1. A force at crankshaft level
2. Another force at crosshead guide level. The position of the force changes over one revolution as the guide shoe reciprocates on the guide.

---

Fig. 17.05.01: H-type and X-type guide force moments
As the deflection shape for the H-type is equal for each cylinder, the Nth order H-type guide force moment for an N-cylinder engine with regular firing order is:

\[ N \times M_{H\text{one cylinder}} \]

For modelling purposes, the size of the forces in the force couple is:

\[ \text{Force} = M_{H}/L \text{ [kN]} \]

where L is the distance between crankshaft level and the middle position of the crosshead guide (i.e. the length of the connecting rod).

As the interaction between engine and hull is at the engine seating and the top bracing positions, this force couple may alternatively be applied in those positions with a vertical distance of \( L_z \). Then the force can be calculated as:

\[ \text{Force}_{z} = M_{H}/L_z \text{ [kN]} \]

Any other vertical distance may be applied so as to accommodate the actual hull (FEM) model.

The force couple may be distributed at any number of points in the longitudinal direction. A reasonable way of dividing the couple is by the number of top bracing and then applying the forces at those points.

\[ \text{Force}_{z, \text{one point}} = \frac{\text{Force}_{z, \text{total}}}{N_{\text{top bracing, total}}} \text{ [kN]} \]

X-type Guide Force Moment \( (M_X) \)

The X-type guide force moment is calculated based on the same force couple as described above. However, as the deflection shape is twisting the engine, each cylinder unit does not contribute with an equal amount. The centre units do not contribute very much whereas the units at each end contributes much.

A so-called ‘Bi-moment’ can be calculated (Fig. 17.05.01):

\[ \text{‘Bi-moment’} = \sum \left[ \text{force-couple(cyl.X)} \times \text{distX} \right] \text{ in kNm}^2 \]

The X-type guide force moment is then defined as:

\[ M_x = \text{‘Bi-Moment’}/L \text{ kNm} \]

For modelling purpose, the size of the four (4) forces can be calculated:

\[ \text{Force} = M_x/L_x \text{ [kN]} \]

where:

\[ L_x \] is the horizontal length between ‘force points’.

Similar to the situation for the H-type guide force moment, the forces may be applied in positions suitable for the FEM model of the hull. Thus the forces may be referred to another vertical level \( L_z \) above the crankshaft centre line. These forces can be calculated as follows:

\[ \text{Force}_{z, \text{one point}} = \frac{M_x \times L}{L_x \times L_z} \text{ [kN]} \]

In order to calculate the forces, it is necessary to know the lengths of the connecting rods = L, which are:

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>L in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>K98ME6/7</td>
<td>3,220</td>
</tr>
<tr>
<td>K98ME-C6/7</td>
<td>3,090</td>
</tr>
<tr>
<td>G95ME-C9/-Gl</td>
<td>3,720</td>
</tr>
<tr>
<td>S90ME-C9/10/-Gl</td>
<td>3,600</td>
</tr>
<tr>
<td>S90ME-C8/-Gl</td>
<td>3,270</td>
</tr>
<tr>
<td>K90ME-C6</td>
<td>3,159</td>
</tr>
<tr>
<td>G80ME-C9/-Gl</td>
<td>3,720</td>
</tr>
<tr>
<td>S80ME-C9/-Gl</td>
<td>3,450</td>
</tr>
<tr>
<td>S80ME-C7/8/-Gl</td>
<td>3,280</td>
</tr>
<tr>
<td>K80ME-C9</td>
<td>2,975</td>
</tr>
<tr>
<td>G70ME-C9/-Gl</td>
<td>3,256</td>
</tr>
<tr>
<td>S70ME-C7/8/-Gl</td>
<td>2,870</td>
</tr>
<tr>
<td>L70ME-C7/8/-Gl</td>
<td>2,660</td>
</tr>
<tr>
<td>S65ME-C8/-Gl</td>
<td>2,730</td>
</tr>
<tr>
<td>G60ME-C9/-Gl</td>
<td>2,790</td>
</tr>
<tr>
<td>S60ME-C7/8/-Gl</td>
<td>2,460</td>
</tr>
<tr>
<td>L60ME-C8</td>
<td>2,280</td>
</tr>
<tr>
<td>S50ME-C7/8/-Gl</td>
<td>2,050</td>
</tr>
</tbody>
</table>
Vibration Limits Valid for Single Order Harmonics

Fig.17.05.02: Vibration limits

Zone I: Acceptable
Zone II: Vibration will not damage the main engine, however, under adverse conditions, annoying/harmful vibration responses may appear in the connected structures.
Zone III: Not acceptable
Axial Vibrations

When the crank throw is loaded by the gas pressure through the connecting rod mechanism, the arms of the crank throw deflect in the axial direction of the crankshaft, exciting axial vibrations. Through the thrust bearing, the system is connected to the ship’s hull.

Generally, only zero-node axial vibrations are of interest. Thus the effect of the additional bending stresses in the crankshaft and possible vibrations of the ship’s structure due to the reaction force in the thrust bearing are to be considered.

An axial damper is fitted as standard on all engines, minimising the effects of the axial vibrations, EcD: 4 31 111.

Torsional Vibrations

The reciprocating and rotating masses of the engine including the crankshaft, the thrust shaft, the intermediate shaft(s), the propeller shaft and the propeller are for calculation purposes considered a system of rotating masses (inertias) interconnected by torsional springs. The gas pressure of the engine acts through the connecting rod mechanism with a varying torque on each crank throw, exciting torsional vibration in the system with different frequencies.

In general, only torsional vibrations with one and two nodes need to be considered. The main critical order, causing the largest extra stresses in the shaft line, is normally the vibration with order equal to the number of cylinders, i.e., six cycles per revolution on a six cylinder engine. This resonance is positioned at the engine speed corresponding to the natural torsional frequency divided by the number of cylinders.

The torsional vibration conditions may, for certain installations require a torsional vibration damper, option: 4 31 105.

Plants with 11 or 12-cylinder engines type 98-80 require a torsional vibration damper.

Based on our statistics, this need may arise for the following types of installation:
- Plants with controllable pitch propeller
- Plants with unusual shafting layout and for special owner/yard requirements
- Plants with 8-cylinder engines.

The so-called QPT (Quick Passage of a barred speed range Technique), is an alternative to a torsional vibration damper, on a plant equipped with a controllable pitch propeller. The QPT could be implemented in the governor in order to limit the vibratory stresses during the passage of the barred speed range.

The application of the QPT, option: 4 31 108, has to be decided by the engine maker and MAN Diesel & Turbo based on final torsional vibration calculations.

Six-cylinder engines, require special attention. On account of the heavy excitation, the natural frequency of the system with one-node vibration should be situated away from the normal operating speed range, to avoid its effect. This can be achieved by changing the masses and/or the stiffness of the system so as to give a much higher, or much lower, natural frequency, called undercritical or overcritical running, respectively.

Owing to the very large variety of possible shafting arrangements that may be used in combination with a specific engine, only detailed torsional vibration calculations of the specific plant can determine whether or not a torsional vibration damper is necessary.

Undercritical running

The natural frequency of the one-node vibration is so adjusted that resonance with the main critical order occurs about 35-45% above the engine speed at specified MCR.

Such undercritical conditions can be realised by choosing a rigid shaft system, leading to a relatively high natural frequency.

The characteristics of an undercritical system are normally:
- Relatively short shafting system
- Probably no tuning wheel
- Turning wheel with relatively low inertia
- Large diameters of shafting, enabling the use of shafting material with a moderate ultimate tensile strength, but requiring careful shaft alignment, (due to relatively high bending stiffness)
- Without barred speed range.
Critical Running

When running undercritical, significant varying torque at MCR conditions of about 100-150% of the mean torque is to be expected.

This torque (propeller torsional amplitude) induces a significant varying propeller thrust which, under adverse conditions, might excite annoying longitudinal vibrations on engine/double bottom and/or deck house.

The yard should be aware of this and ensure that the complete aft body structure of the ship, including the double bottom in the engine room, is designed to be able to cope with the described phenomena.

Overcritical running

The natural frequency of the one-node vibration is so adjusted that resonance with the main critical order occurs about 30-70% below the engine speed at specified MCR. Such overcritical conditions can be realised by choosing an elastic shaft system, leading to a relatively low natural frequency.

The characteristics of overcritical conditions are:

- Tuning wheel may be necessary on crankshaft fore end
- Turning wheel with relatively high inertia
- Shafts with relatively small diameters, requiring shafting material with a relatively high ultimate tensile strength
- With barred speed range, EoD: 4 07 015, of about ±10% with respect to the critical engine speed.

Torsional vibrations in overcritical conditions may, in special cases, have to be eliminated by the use of a torsional vibration damper.

Overcritical layout is normally applied for engines with more than four cylinders.

Please note:
We do not include any tuning wheel or torsional vibration damper in the standard scope of supply, as the proper countermeasure has to be found after torsional vibration calculations for the specific plant, and after the decision has been taken if and where a barred speed range might be acceptable.

For further information about vibration aspects, please refer to our publications:

An Introduction to Vibration Aspects

Vibration Characteristics of Two-stroke Engines

The publications are available at www.marine.man.eu → 'Two-Stroke' → 'Technical Papers'.

Critical Running
Monitoring Systems and Instrumentation
Monitoring Systems and Instrumentation

The Engine Control System (ECS) can be supported by the PMI system and the CoCoS-EDS (Computer Controlled Surveillance-Engine Diagnostics System).

The optional CoCoS-EDS Full version measures the main parameters of the engine and makes an evaluation of the general engine condition, indicating the countermeasures to be taken. This ensures that the engine performance is kept within the prescribed limits throughout the engine’s lifetime.

In its basic design, the ME engine instrumentation consists of:

- Engine Control System
- Shut-down sensors, EoD: 4 75 124
- PMI Auto-tuning system, EoD: 4 75 216
- CoCoS-EDS ME Basic, EoD: 4 09 658
- Sensors for alarm, slow down and remote indication according to the classification society’s and MAN Diesel & Turbo’s requirements for UMS, EoD: 4 75 127, see Section 18.04.

The optional extras are:

- CoCoS-EDS Full version (AMS interface), option: 4 09 660.

Sensors for CoCoS-EDS Full version can be ordered, if required, as option: 4 75 129. They are listed in Section 18.03.

All instruments are identified by a combination of symbols and a position number as shown in Section 18.07.
**PMI Auto-tuning System**

The PMI Auto-tuning system is an advanced cylinder pressure monitoring system that automatically adjusts combustion pressures for optimum performance. This system is specified as standard, EoD: 4 75 216, and completely replaces the PMI Offline system.

The auto-tuning concept is based on the online measurement of the combustion chamber pressures from permanently mounted sensors.

The engine control system constantly monitors and compares the measured combustion pressures to a reference value. As such, the control system automatically adjusts the fuel injection and valve timing to reduce the deviation between measured and reference values. This, in turn, facilitates the optimal combustion pressures for the next firing. Thus, the system ensures that the engine is running at the desired maximum pressure, \( p(\text{max}) \). Furthermore, the operator can press a button on the touch panel display, causing the system to automatically balance the engine.

Pressure measurements are presented in real time in measurement curves on a PC, thereby eliminating the need for manual measurements. Key performance values are continuously calculated and displayed in tabular form. These measurements may be stored for later analysis or transferred to CoCoS-EDS for further processing.

Abbreviations:

- TSA-A: Tacho System Amplifier
- CJB: Calibration Junction Box
- Cyl: Engine cylinder sensor
- DAU: Data Acquisition Unit
- 24V DC: Power Supply
- Portable measuring unit
- Engine control room

**Fig. 18.02.01: PMI Auto-tuning system, EoD: 4 75 216**
Condition Monitoring System CoCoS-EDS

The Computer Controlled Surveillance system, CoCoS-EDS, is the condition monitoring system for MAN B&W engines from MAN Diesel & Turbo.

Two versions are available, CoCoS-EDS Full version and CoCoS-EDS ME basic. Both versions are run on the PMI/CoCoS PC located in the engine control room. The network connection is shown in Fig. 5.16.01.

CoCoS-EDS Full version

CoCoS-EDS Full version (AMS interface), option: 4 09 660, assists in engine performance evaluation and provides detailed engine operation surveillance.

Key features are: online data logging, monitoring, trending and reporting.

The CoCoS-EDS Full version is recommended as an extension for the Engine Control System and the PMI System in order to obtain an easier, more versatile performance monitoring system.

For the CoCoS-EDS Full version additional sensors are required, option: 4 75 129. The sensors are listed in Table 18.03.01.

CoCoS-EDS ME basic

All MAN B&W ME and ME-B engines are as standard specified with CoCoS-EDS ME basic, EoD: 4 09 658.

Key features are: data logging, monitoring, trending and reporting as for the Full version. However, the AMS interface and reference curves for diagnostic functions are not included.

CoCoS-EDS ME basic provides a software interface to the ME/ME-B Engine Control System and the PMI system, no additional sensors are required.
CoCoS-EDS Sensor List

Sensors required for the CoCoS-EDS Full version engine performance analysis, option: 4 75 129, see Table 18.03.01. All pressure gauges are measuring relative pressure, except for ‘PT 8802 Ambient pressure’.

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Parameter name</th>
<th>No. of sensors</th>
<th>Recommended range</th>
<th>Resolution 3)</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT 8001</td>
<td>Inlet pressure</td>
<td>1</td>
<td>0 - 10 bar</td>
<td>0.1 bar</td>
<td></td>
</tr>
<tr>
<td>TE 8005</td>
<td>Inlet temperature</td>
<td>1</td>
<td>0 - 200 °C</td>
<td>0.1 °C</td>
<td></td>
</tr>
<tr>
<td>PT 8421</td>
<td>Pressure air cooler inlet</td>
<td>A/C</td>
<td>0 - 4 bar</td>
<td>0.1 bar</td>
<td></td>
</tr>
<tr>
<td>TE 8422</td>
<td>Temperature air cooler inlet</td>
<td>1</td>
<td>0 - 100 °C</td>
<td>0.1 °C</td>
<td></td>
</tr>
<tr>
<td>TE 8423</td>
<td>Temperature air cooler outlet</td>
<td>A/C</td>
<td>0 - 100 °C</td>
<td>0.1 °C</td>
<td></td>
</tr>
<tr>
<td>PDT 8424</td>
<td>dP cooling water across air cooler</td>
<td>A/C</td>
<td>0 - 800 mbar</td>
<td>0.1 mbar</td>
<td></td>
</tr>
<tr>
<td>PT 8601</td>
<td>Scavenge air receiver pressure</td>
<td>Rec.</td>
<td>0 - 4 bar</td>
<td>1 mbar</td>
<td>1)</td>
</tr>
<tr>
<td>TE 8605</td>
<td>Scavenge air cooler air inlet temperature</td>
<td>A/C</td>
<td>0 - 200 °C</td>
<td>1 °C</td>
<td></td>
</tr>
<tr>
<td>PDT 8606</td>
<td>dP across scavenge air cooler</td>
<td>A/C</td>
<td>0 - 100 mbar</td>
<td>0.1 mbar</td>
<td></td>
</tr>
<tr>
<td>TE 8608</td>
<td>Scavenge air cooler air outlet temperature</td>
<td>A/C</td>
<td>0 - 100 °C</td>
<td>0.1 °C</td>
<td></td>
</tr>
<tr>
<td>TE 8609</td>
<td>Scavenge air receiver temperature</td>
<td>Rec.</td>
<td>0 - 100 °C</td>
<td>0.1 °C</td>
<td></td>
</tr>
<tr>
<td>TE 8612</td>
<td>T/C air intake temperature</td>
<td>T/C</td>
<td>0 - 100 °C</td>
<td>0.1 °C</td>
<td></td>
</tr>
<tr>
<td>TC 8701</td>
<td>Exhaust gas temperature at turbine inlet</td>
<td>T/C</td>
<td>0 - 600 °C</td>
<td>0.1 °C</td>
<td></td>
</tr>
<tr>
<td>TC 8702</td>
<td>Exhaust gas temperature after exhaust valve</td>
<td>Cyl.</td>
<td>0 - 600 °C</td>
<td>0.1 °C</td>
<td></td>
</tr>
<tr>
<td>PT 8706</td>
<td>Exhaust gas receiver pressure</td>
<td>Rec.</td>
<td>0 - 4 bar</td>
<td>0.01 bar</td>
<td></td>
</tr>
<tr>
<td>TC 8707</td>
<td>Exhaust gas temperature at turbine outlet</td>
<td>T/C</td>
<td>0 - 600 °C</td>
<td>0.1 °C</td>
<td></td>
</tr>
<tr>
<td>PT 8708</td>
<td>Turbine back pressure</td>
<td>T/C</td>
<td>0 - 100 mbar</td>
<td>0.1 mbar</td>
<td></td>
</tr>
<tr>
<td>ZT 8801</td>
<td>Turbocharger speed</td>
<td>T/C</td>
<td>rpm</td>
<td>1 rpm</td>
<td></td>
</tr>
<tr>
<td>PT 8802</td>
<td>Ambient pressure</td>
<td>1</td>
<td>900 - 1,100 mbar</td>
<td>1 mbar</td>
<td>Absolute!</td>
</tr>
<tr>
<td>ZT 4020</td>
<td>Engine speed</td>
<td>1</td>
<td>rpm</td>
<td>0.1 rpm</td>
<td>1)</td>
</tr>
<tr>
<td>XC 8810</td>
<td>Governor index (relative)</td>
<td>1</td>
<td>%</td>
<td>0.1 %</td>
<td>1)</td>
</tr>
<tr>
<td>– Power take off/in from main engine shaft (PTO/PTI)</td>
<td>1</td>
<td>kW</td>
<td>1 kW</td>
<td>With option installed</td>
<td></td>
</tr>
<tr>
<td>XC1401</td>
<td>Mean Indicated Pressure, MIP</td>
<td>Cyl.</td>
<td>bar</td>
<td>0.01 bar</td>
<td>2)</td>
</tr>
<tr>
<td>XC1402</td>
<td>Maximum Pressure, Pmax</td>
<td>Cyl.</td>
<td>bar</td>
<td>0.1 bar</td>
<td>2)</td>
</tr>
<tr>
<td>XC1403</td>
<td>Compression Pressure, Pcomp</td>
<td>Cyl.</td>
<td>bar</td>
<td>0.1 bar</td>
<td>2)</td>
</tr>
<tr>
<td>– PMI online engine speed</td>
<td>Cyl.</td>
<td>rpm</td>
<td>0.1 rpm</td>
<td>2)</td>
<td></td>
</tr>
</tbody>
</table>

The ‘No. of sensors’ depends on number of cylinders (Cyl.), turbochargers (T/C), air receivers (Rec.) and air coolers (A/C) as marked.
1) Signal acquired from Engine Control System (ECS)
2) In case of MAN Diesel & Turbo PMI system: signal from PMI system. Other MIP systems: signal from manual input
3) Resolution of signals transferred to CoCoS-EDS (from the Alarm Monitoring System).

Table 18.03.01: List of sensors for CoCoS-EDS Full version
Alarm – Slow Down and Shut Down System

The shut down system must be electrically separated from other systems by using independent sensors, or sensors common to the alarm system and the monitoring system but with galvanically separated electrical circuits, i.e. one sensor with two sets of electrically independent terminals. The list of sensors are shown in Table 18.04.04.

The number and position of the terminal boxes depends on the degree of dismantling specified in the Dispatch Pattern for the transportation of the engine based on the lifting capacities available at the engine maker and at the yard.

Basic safety system design and supply

The basic safety sensors for a MAN B&W engine are designed for Unattended Machinery Space (UMS) and comprises:

- the temperature sensors and pressure sensors that are specified in the ‘MAN Diesel’ column for shut down in Table 18.04.04.

These sensors are included in the basic Extent of Delivery, EoD: 4 75 124.

Alarm and slow down system design and supply

The basic alarm and slow down sensors for a MAN B&W engine are designed for Unattended Machinery Space (UMS) and comprises:

- the sensors for alarm and slow down.

These sensors are included in the basic Extent of Delivery, EoD: 4 75 127.

The shut down and slow down panels can be ordered as options: 4 75 630, 4 75 614 or 4 75 615 whereas the alarm panel is yard’s supply, as it normally includes several other alarms than those for the main engine.

For practical reasons, the sensors for the engine itself are normally delivered from the engine supplier, so they can be wired to terminal boxes on the engine.

The International Association of Classification Societies (IACS) indicates that a common sensor can be used for alarm, slow down and remote indication.

A general view of the alarm, slow down and shut down systems is shown in Fig. 18.04.01.

Tables 18.04.02 and 18.04.03 show the requirements by MAN Diesel & Turbo for alarm and slow down and for UMS by the classification societies (Class), as well as IACS’ recommendations.

The number of sensors to be applied to a specific plant is the sum of requirements of the classification society, the Buyer and MAN Diesel & Turbo.

If further analogue sensors are required, they can be ordered as option: 4 75 128.

Slow down functions

The slow down functions are designed to safeguard the engine components against overloading during normal service conditions and to keep the ship manoeuvrable if fault conditions occur.

The slow down sequence must be adapted to the actual plant parameters, such as for FPP or CPP, engine with or without shaft generator, and to the required operating mode.
Electrical System, General Outline

The figure shows the concept approved by all classification societies.

The shut down panel and slow down panel can be combined for some makers.

The classification societies permit having common sensors for slow down, alarm and remote indication.

One common power supply might be used, instead of the three indicated, provided that the systems are equipped with separate fuses.

Fig. 18.04.01: Panels and sensors for alarm and safety systems
## Alarms for UMS – Class and MAN Diesel & Turbo requirements

<table>
<thead>
<tr>
<th>ABS</th>
<th>BV</th>
<th>CCS</th>
<th>DNV</th>
<th>GL</th>
<th>KR</th>
<th>LR</th>
<th>NK</th>
<th>RINA</th>
<th>RS</th>
<th>IACS</th>
<th>MAN Diesel</th>
<th>Sensor and function</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Fuel oil</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>PT 8001 AL</td>
<td>Fuel oil, inlet engine</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>LS 8006 AH</td>
<td>Leakage from high pressure pipes</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Lubricating oil</td>
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<td>1</td>
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<td>1</td>
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<td>1</td>
<td>TE 8106 AH</td>
<td>Thrust bearing segment</td>
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<td>1</td>
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<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>PT 8108 AL</td>
<td>Lubricating oil inlet to main engine</td>
</tr>
<tr>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>TE 8112 AH</td>
<td>Lubricating oil inlet to main engine</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>TE 8113 AH</td>
<td>Piston cooling oil outlet/cylinder</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>FS 8114 AL</td>
<td>Piston cooling oil outlet/cylinder</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>TE 8117 AH</td>
<td>Turbocharger lubricating oil outlet from turbocharger/turbocharger</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 TE 8123 AH</td>
<td>Main bearing oil outlet temperature/main bearing (S40/35ME-B9 only)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 XC 8126 AH</td>
<td>Bearing wear (All types except S40/35ME-B9); sensor common to XC 8126/27</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>1 XS 8127 A</td>
<td>Bearing wear detector failure (All types except S40/35ME-B)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 PDS 8140 AH</td>
<td>Lubricating oil differential pressure – cross filter</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>1 XS 8150 AH</td>
<td>Water in lubricating oil; sensor common to XS 8150/51/52</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 XS 8151 AH</td>
<td>Water in lubricating oil – too high</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 XS 8152 A</td>
<td>Water in lubricating oil sensor not ready</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MAN B&amp;W Alpha Lubrication</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 LS 8212 AL</td>
<td>Small box for heating element, low level</td>
</tr>
</tbody>
</table>

1 Indicates that the sensor is required.

The sensors in the MAN Diesel and relevant Class columns are included in the basic Extent of Delivery, EoD: 4 75 127. The sensor identification codes and functions are listed in Table 18.07.01. The tables are liable to change without notice, and are subject to latest Class requirements.

---

Table 18.04.02a: Alarm functions for UMS
# Alarms for UMS – Class and MAN Diesel & Turbo requirements

## Table 18.04.02b: Alarm functions for UMS

<table>
<thead>
<tr>
<th>Sensor and function</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydraulic Power Supply</strong></td>
<td></td>
</tr>
<tr>
<td>1 XC 1231 A</td>
<td>Automatic main lube oil filter, failure (Boll &amp; Kirch)</td>
</tr>
<tr>
<td>1 TE 1310 AH</td>
<td>Lubrication oil inlet (Only for ME/-GI with separate oil system to HPS installed)</td>
</tr>
<tr>
<td><strong>Cooling water</strong></td>
<td></td>
</tr>
<tr>
<td>1 PT 8401 AL</td>
<td>Jacket cooling water inlet</td>
</tr>
<tr>
<td>1 PDT 8403 AL</td>
<td>Jacket cooling water across engine; to be calculated in alarm system from sensor no. 8402 and 8413 3)</td>
</tr>
<tr>
<td>1 PDT 8404 AL</td>
<td>Jacket cooling water across cylinder liners 2)</td>
</tr>
<tr>
<td>1 PDT 8405 AL</td>
<td>Jacket cooling water across cylinder covers and exhaust valves 2)</td>
</tr>
<tr>
<td>1 TE 8407 AL</td>
<td>Jacket cooling water inlet</td>
</tr>
<tr>
<td>1 TT 8410</td>
<td>Cylinder cover cooling water outlet, cylinder</td>
</tr>
<tr>
<td>1 PT 8413 I</td>
<td>Jacket cooling water outlet, common pipe</td>
</tr>
<tr>
<td>1 PT 8421 AL</td>
<td>Cooling water inlet air cooler</td>
</tr>
<tr>
<td>1 TE 8422 AH</td>
<td>Cooling water inlet air cooler/air cooler</td>
</tr>
<tr>
<td><strong>Compressed air</strong></td>
<td></td>
</tr>
<tr>
<td>1 PT 8501 AL</td>
<td>Starting air inlet to main starting valve</td>
</tr>
<tr>
<td>1 PT 8503 AL</td>
<td>Control air inlet and finished with engine</td>
</tr>
<tr>
<td>1 PT 8505 AL</td>
<td>Air inlet to air cylinder for exhaust valve</td>
</tr>
<tr>
<td><strong>Scavenge air</strong></td>
<td></td>
</tr>
<tr>
<td>1 PS 8604 AL</td>
<td>Scavenge air, auxiliary blower, failure (Only ME-B)</td>
</tr>
<tr>
<td>1 TE 8609 AH</td>
<td>Scavenge air receiver</td>
</tr>
<tr>
<td>1 TE 8610 AH</td>
<td>Scavenge air box – fire alarm, cylinder/cylinder</td>
</tr>
<tr>
<td>1 LS 8611 AH</td>
<td>Water mist catcher – water level</td>
</tr>
</tbody>
</table>

1 Indicates that the sensor is required.
The sensors in the MAN Diesel and relevant Class columns are included in the basic Extent of Delivery, EoD: 4 75 127. The sensor identification codes and functions are listed in Table 18.07.01.
The tables are liable to change without notice, and are subject to latest Class requirements.

2) Required only for engines with LDCL cooling water system

3) Not applicable for engines with LDCL cooling water system

Select one of the alternatives

+ Alarm for high pressure, too

÷ Alarm for low pressure, too

Table 18.04.02b: Alarm functions for UMS
### Alarms for UMS – Class and MAN Diesel & Turbo requirements

<table>
<thead>
<tr>
<th>Sensor and function</th>
<th>Point of location</th>
<th>Exhaust gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC 8701 AH</td>
<td>Exhaust gas before turbocharger/turbocharger</td>
<td></td>
</tr>
<tr>
<td>TC 8702 AH</td>
<td>Exhaust gas after exhaust valve, cylinder/cylinder</td>
<td></td>
</tr>
<tr>
<td>TC 8707 AH</td>
<td>Exhaust gas outlet turbocharger/turbocharger (Yard's supply)</td>
<td></td>
</tr>
</tbody>
</table>

#### Exhaust gas

<table>
<thead>
<tr>
<th>Sensor and function</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 WT 8812 AH</td>
<td>Axial vibration monitor 2)</td>
</tr>
<tr>
<td>1 XS 8813 AH</td>
<td>Oil mist in crankcase/cylinder; sensor common to XS 8813/14</td>
</tr>
<tr>
<td>1 XS 8814 AL</td>
<td>Oil mist detector failure</td>
</tr>
<tr>
<td>1 XC 8816 I</td>
<td>Shaftline earthing device</td>
</tr>
<tr>
<td>1 TE 8820 AH</td>
<td>Cylinder liner monitoring/cylinder 3)</td>
</tr>
</tbody>
</table>

#### Miscellaneous

<table>
<thead>
<tr>
<th>Sensor and function</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>XC 2201 A</td>
<td>Power failure</td>
</tr>
<tr>
<td>XC 2202 A</td>
<td>ME common failure</td>
</tr>
<tr>
<td>XC 2202-A A</td>
<td>ME common failure (ME-GI only)</td>
</tr>
<tr>
<td>XC 2213 A</td>
<td>Double-pipe HC alarm (ME-GI only)</td>
</tr>
</tbody>
</table>

#### Engine Control System

<table>
<thead>
<tr>
<th>Sensor and function</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>XC 2901 A</td>
<td>Low voltage ME power supply A</td>
</tr>
<tr>
<td>XC 2902 A</td>
<td>Low voltage ME power supply B</td>
</tr>
<tr>
<td>XC 2903 A</td>
<td>Earth failure ME power supply</td>
</tr>
</tbody>
</table>

1. Indicates that the sensor is required.
   The sensors in the MAN Diesel and relevant Class columns are included in the basic Extent of Delivery, EoD: 4 75 127. The sensor identification codes and functions are listed in Table 18.07.01. The tables are liable to change without notice, and are subject to latest Class requirements.

(1) May be combined with TC 8702 AH where turbocharger is mounted directly on the exhaust manifold.

2) Required for: K-ME-C6/7 and K98ME6/7 engines with 11 and 14 cylinders incl. ME-GI variants.
   All ME-C9/10 and ME-B9 engines incl. ME-GI variants.
   All ME-C7/8 and ME-B8 engines with 5 and 6 cylinders incl. ME-GI variants.


Table 18.04.02c: Alarm functions for UMS
### Slow down for UMS – Class and MAN Diesel & Turbo requirements

<table>
<thead>
<tr>
<th>ABS</th>
<th>BV</th>
<th>CCS</th>
<th>DNV</th>
<th>GL</th>
<th>KR</th>
<th>LR</th>
<th>NK</th>
<th>RINA</th>
<th>RS</th>
<th>IACS</th>
<th>MAN Diesel</th>
<th>Sensor and function</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>1</td>
<td>1 TE 8106 YH</td>
<td>Thrust bearing segment</td>
<td></td>
</tr>
<tr>
<td>1</td>
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<td>1</td>
<td>1 PT 8108 YL</td>
<td>Lubricating oil inlet to main engine</td>
<td></td>
</tr>
<tr>
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<td></td>
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<td></td>
<td></td>
<td>1</td>
<td>TE 8112 YH</td>
<td>Lubricating oil inlet to main engine</td>
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<td></td>
</tr>
<tr>
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<td>1</td>
<td>1 TE 8113 YH</td>
<td>Piston cooling oil outlet/cylinder</td>
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</tr>
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<td>1 FS 8114 YL</td>
<td>Piston cooling oil outlet/cylinder</td>
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<tr>
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<td>TE 8123 YH</td>
<td>Main bearing oil outlet temperature/main bearing (S40/35ME-B9 only)</td>
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<td>XC 8126 YH</td>
<td>Bearing wear (All except S40/35ME-B9)</td>
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<td>1 PT 8401 YL</td>
<td>Jacket cooling water inlet</td>
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<td>1</td>
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<td>1</td>
<td>1 PDT 8403 YL</td>
<td>Jacket cooling water across engine (Not for LDCL)</td>
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</tr>
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<td>1 PDT 8404</td>
<td>Jacket cooling water across cylinder liners (Only for LDCL)</td>
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<td>1</td>
<td>1</td>
<td>1 PDT 8405</td>
<td>Jacket cooling water across cylinder covers and exhaust valves (Only for LDCL)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>TE 8408 YH</td>
<td>Jacket cooling water outlet, cylinder/cylinder</td>
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</tr>
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<td>TE 8609 YH</td>
<td>Scavenge air receiver</td>
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</tr>
<tr>
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<td>1 TE 8610 YH</td>
<td>Scavenge air box fire-alarm, cylinder/cylinder</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>TC 8701 YH</td>
<td>Exhaust gas before turbocharger/turbocharger</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>1 TC 8702 YH</td>
<td>Exhaust gas after exhaust valve, cylinder/cylinder</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>1</td>
<td>TC 8702 YH</td>
<td>Exhaust gas after exhaust valve, cylinder/cylinder, deviation from average</td>
<td></td>
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<tr>
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<td>1 WT 8812 YH</td>
<td>Axial vibration monitor 2)</td>
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<td>1</td>
<td>1</td>
<td>1 XS 8813 YH</td>
<td>Oil mist in crankcase/cylinder</td>
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</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>XS/XT 8817 Y</td>
<td>Turbocharger overspeed (Only in case of VT TC, Waste Heat Recovery, Exhaust Gas Bypass, TC Cut-out)</td>
<td></td>
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<td>1</td>
<td>TE 1310 YH</td>
<td>Lubrication oil inlet (Only for ME/-GI with separate oil system to HPS installed)</td>
<td></td>
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</tr>
</tbody>
</table>

1 Indicates that the sensor is required.
The sensors in the MAN Diesel and relevant Class columns are included in the basic Extent of Delivery, EoD: 4 75 127. The sensor identification codes and functions are listed in Table 18.07.01.
The tables are liable to change without notice, and are subject to latest Class requirements.

2) Required for: K-ME-C6/7 and K98ME6/7 engines with 11 and 14 cylinders incl. ME-GI variants.
   All ME-C9/10 and ME-B9 engines incl. ME-GI variants.
   All ME-C7/8 and ME-B8 engines with 5 and 6 cylinders incl. ME-GI variants.

- Select one of the alternatives
- Or shut down
- Or alarm for low flow
- Or alarm for overheating of main, crank and crosshead bearings, option: 4 75 134.

See also Table 18.04.04: Shut down functions for AMS and UMS

Table 18.04.03: Slow down functions for UMS
Shut down for AMS and UMS – Class and MAN Diesel & Turbo requirements

<table>
<thead>
<tr>
<th>ABS</th>
<th>BV</th>
<th>CCS</th>
<th>DNV</th>
<th>GL</th>
<th>KR</th>
<th>LR</th>
<th>NK</th>
<th>RINA</th>
<th>Sensor and function</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
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<td>1*</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>PS/PT 8109 Z</td>
<td>Lubricating oil inlet to main engine and thrust bearing</td>
</tr>
<tr>
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<td>1</td>
<td>ZT 4020 Z</td>
<td>Engine overspeed</td>
</tr>
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<td>1</td>
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<td>1</td>
<td>1</td>
<td>TE/TS 8107 Z</td>
<td>Thrust bearing segment</td>
</tr>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>PS/PT 8402 Z</td>
<td>Jacket cooling water inlet</td>
</tr>
<tr>
<td>*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XS 8813 Z</td>
<td>Oil mist in crankcase/cylinder</td>
</tr>
</tbody>
</table>

1 Indicates that the sensor is required.

The sensors in the MAN Diesel and relevant Class columns are included in the basic Extent of Delivery, EoD: 4 75 124.
The sensor identification codes and functions are listed in Table 18.07.01.
The tables are liable to change without notice, and are subject to latest Class requirements.

☐ Or alarm for overheating of main, crank and crosshead bearings, option: 4 75 134.
See also Table 18.04.03: Slow down functions for UMS

* Or slow down

International Association of Classification Societies

The members of the International Association of Classification Societies, IACS, have agreed that the stated sensors are their common recommendation, apart from each Class’ requirements.

The members of IACS are:

ABS   American Bureau of Shipping
BV    Bureau Veritas
CCS   China Classification Society
CRS   Croatian Register of Shipping
DNV   Det Norske Veritas
GL    Germanischer Lloyd
IRS   Indian Register of Shipping
KR    Korean Register
LR    Lloyd’s Register
NK    Nippon Kaiji Kyokai
PRS   Croatian Register of Shipping
RINA  Registro Italiano Navale
RS    Russian Maritime Register of Shipping

Table 18.04.04: Shut down functions for AMS and UMS, option: 4 75 124
Local Instruments

The basic local instrumentation on the engine, options: 4 70 119 comprises thermometers, pressure gauges and other indicators located on the piping or mounted on panels on the engine. The tables 18.05.01a, b and c list those as well as sensors for slow down, alarm and remote indication, option: 4 75 127.

<table>
<thead>
<tr>
<th>Local instruments</th>
<th>Remote sensors</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermometer, stem type</td>
<td>Temperature element/switch</td>
<td>Hydraulic power supply</td>
</tr>
<tr>
<td>TI 8005</td>
<td>TE 8005</td>
<td>HPS bearing temperature (Only ME/ME-C with HPS in centre position)</td>
</tr>
<tr>
<td>TI 8106</td>
<td>TE 8106</td>
<td>Thrust bearing segment</td>
</tr>
<tr>
<td>TI 8112</td>
<td>TE 8112</td>
<td>Lubricating oil inlet to main engine</td>
</tr>
<tr>
<td>TI 8113</td>
<td>TE 8113</td>
<td>Piston cooling oil outlet/cylinder</td>
</tr>
<tr>
<td>TI 8117</td>
<td>TE 8117</td>
<td>Lubricating oil outlet from turbocharger/turbocharger (depends on turbocharger design)</td>
</tr>
<tr>
<td></td>
<td>TE 8123</td>
<td>Main bearing oil outlet temperature/main bearing (S40/35ME-B9 only)</td>
</tr>
<tr>
<td>TI 8202</td>
<td>TE 8202</td>
<td>Cylinder lubricating oil inlet</td>
</tr>
<tr>
<td>TS 8213</td>
<td>TS 8213</td>
<td>Cylinder lubricating heating</td>
</tr>
<tr>
<td>TI 8407</td>
<td>TE 8407</td>
<td>Jacket cooling water inlet</td>
</tr>
<tr>
<td>TI 8408</td>
<td>TE 8408</td>
<td>Jacket cooling water outlet, cylinder/cylinder</td>
</tr>
<tr>
<td>TI 8409</td>
<td>TE 8409</td>
<td>Jacket cooling water outlet/turbocharger</td>
</tr>
<tr>
<td>TI 8410</td>
<td>TT 8410</td>
<td>Cylinder cover cooling water outlet, cylinder (Only for LDCL)</td>
</tr>
<tr>
<td>TI 8422</td>
<td>TE 8422</td>
<td>Cooling water inlet, air cooler</td>
</tr>
<tr>
<td>TI 8423</td>
<td>TE 8423</td>
<td>Cooling water outlet, air cooler/air cooler</td>
</tr>
<tr>
<td>TI 8605</td>
<td>TE 8605</td>
<td>Scavenge air before air cooler/air cooler</td>
</tr>
<tr>
<td>TI 8608</td>
<td>TE 8608</td>
<td>Scavenge air after air cooler/air cooler</td>
</tr>
<tr>
<td>TI 8609</td>
<td>TE 8609</td>
<td>Scavenge air receiver</td>
</tr>
<tr>
<td></td>
<td>TE 8610</td>
<td>Scavenge air box – fire alarm, cylinder/cylinder</td>
</tr>
<tr>
<td>Thermometer, dial type</td>
<td>Thermo couple</td>
<td>Exhaust gas</td>
</tr>
<tr>
<td>TI 8701</td>
<td>TC 8701</td>
<td>Exhaust gas before turbocharger/turbocharger</td>
</tr>
<tr>
<td>TI 8702</td>
<td>TC 8704</td>
<td>Exhaust gas after exhaust valve, cylinder/cylinder</td>
</tr>
<tr>
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<td>TC 8707</td>
<td>Exhaust gas inlet exhaust gas receiver</td>
</tr>
<tr>
<td>TI 8707</td>
<td>TC 8707</td>
<td>Exhaust gas outlet turbocharger</td>
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</tbody>
</table>

Table 18.05.01a: Local thermometers on engine, options 4 70 119, and remote indication sensors, option: 4 75 127
<table>
<thead>
<tr>
<th>Local instruments</th>
<th>Remote sensors</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure gauge (manometer)</td>
<td>Pressure transmitter/switch</td>
<td><strong>Fuel oil</strong></td>
</tr>
<tr>
<td>PI 8001</td>
<td>PT 8001</td>
<td>Fuel oil, inlet engine</td>
</tr>
<tr>
<td><strong>Lubricating oil</strong></td>
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</tr>
<tr>
<td>PI 8103</td>
<td>PT 8103</td>
<td>Lubricating oil inlet to turbocharger/turbocharger</td>
</tr>
<tr>
<td>PI 8108</td>
<td>PS/PT 8109</td>
<td>Lubricating oil inlet to main engine</td>
</tr>
<tr>
<td></td>
<td>PDS 8140</td>
<td>Lubricating oil inlet to main engine and thrust bearing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lubricating oil differential pressure – cross filter</td>
</tr>
<tr>
<td>PI 8401</td>
<td>PT 8401</td>
<td><strong>High temperature jacket cooling water, jacket cooling water</strong></td>
</tr>
<tr>
<td></td>
<td>PS/PT 8402</td>
<td>Jacket cooling water inlet</td>
</tr>
<tr>
<td></td>
<td>PDT 8403</td>
<td>Jacket cooling water inlet (Only Germanischer Lloyd)</td>
</tr>
<tr>
<td></td>
<td>PDT 8404</td>
<td>Jacket cooling water across engine (or PT 8401 and PT 8413) (Not for LDCL)</td>
</tr>
<tr>
<td></td>
<td>PDT 8405</td>
<td>Jacket cooling water across cylinder liners (Only for LDCL)</td>
</tr>
<tr>
<td></td>
<td>PT 8413</td>
<td>Jacket cooling water outlet, common pipe</td>
</tr>
<tr>
<td>PI 8421</td>
<td>PT 8421</td>
<td><strong>Low temperature cooling water, seawater or freshwater for central cooling</strong></td>
</tr>
<tr>
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<td></td>
<td>Cooling water inlet, air cooler</td>
</tr>
<tr>
<td><strong>Compressed air</strong></td>
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<td>PI 8501</td>
<td>PT 8501</td>
<td>Starting air inlet to main starting valve</td>
</tr>
<tr>
<td>PI 8503</td>
<td>PT 8503</td>
<td>Control air inlet</td>
</tr>
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<td>PT 8505</td>
<td>Air inlet to air cylinder for exhaust valve (Only ME-B)</td>
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<td>PI 8601</td>
<td>PT 8601</td>
<td>Scavenge air receiver (PI 8601 instrument same as PI 8706)</td>
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<td>PDI 8606</td>
<td>PDT 8606</td>
<td>Pressure drop of air across cooler/air cooler</td>
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<td>PDT 8607</td>
<td>Pressure drop across blower filter of turbocharger (ABB turbochargers only)</td>
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<td><strong>Exhaust gas</strong></td>
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<td>PI 8706</td>
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<td>Exhaust gas receiver/Exhaust gas outlet turbocharger</td>
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<td><strong>Miscellaneous functions</strong></td>
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<td>PI 8803</td>
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<td>Air inlet for dry cleaning of turbocharger</td>
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<td>PI 8804</td>
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<td>Water inlet for cleaning of turbocharger (Not applicable for MHI turbochargers)</td>
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</table>

*Table 18.05.01b: Local pressure gauges on engine, options: 4 70 119, and remote indication sensors, option: 4 75 127*
<table>
<thead>
<tr>
<th>Local instruments</th>
<th>Remote sensors</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other indicators</td>
<td>Other transmitters/switches</td>
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<td></td>
<td></td>
<td>Hydraulic power supply</td>
</tr>
<tr>
<td>XC 1231</td>
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<td>Automatic main lube oil filter, failure (Boll &amp; Kirch)</td>
</tr>
<tr>
<td>LS 1235</td>
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<td>Leakage oil from hydraulic system</td>
</tr>
<tr>
<td>LS 1236</td>
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<td>Leakage oil from hydraulic system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Engine cylinder components</td>
</tr>
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<td>LS 4112</td>
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<td>Leakage from hydraulic cylinder unit</td>
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<tr>
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<td></td>
<td>Fuel oil</td>
</tr>
<tr>
<td>LS 8006</td>
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<td>Leakage from high pressure pipes</td>
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<td>Lubricating oil</td>
</tr>
<tr>
<td>FS 8114</td>
<td></td>
<td>Piston cooling oil outlet/cylinder</td>
</tr>
<tr>
<td>XC 8126</td>
<td></td>
<td>Bearing wear (All types except S40/35ME-B9)</td>
</tr>
<tr>
<td>XS 8127</td>
<td></td>
<td>Bearing wear detector failure (All types except S40-35ME-B9)</td>
</tr>
<tr>
<td>XS 8150</td>
<td></td>
<td>Water in lubricating oil</td>
</tr>
<tr>
<td>XS 8151</td>
<td></td>
<td>Water in lubricating oil – too high</td>
</tr>
<tr>
<td>XS 8152</td>
<td></td>
<td>Water in lubricating oil sensor not ready</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cylinder lube oil</td>
</tr>
<tr>
<td>LS 8208</td>
<td></td>
<td>Level switch</td>
</tr>
<tr>
<td>LS 8212</td>
<td></td>
<td>Small box for heating element, low level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scavenge air</td>
</tr>
<tr>
<td>LS 8611</td>
<td></td>
<td>Water mist catcher – water level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Miscellaneous functions</td>
</tr>
<tr>
<td>ZT 8801 I</td>
<td></td>
<td>Turbocharger speed/turbocharger</td>
</tr>
<tr>
<td>WI 8812</td>
<td>WT 8812</td>
<td>Axial vibration monitor (For certain engines only, see note in Table 18.04.04)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(WI 8812 instrument is part of the transmitter WT 8812)</td>
</tr>
<tr>
<td>XS 8813</td>
<td></td>
<td>Oil mist in crankcase/cylinder</td>
</tr>
<tr>
<td>XS 8814</td>
<td></td>
<td>Oil mist detector failure</td>
</tr>
<tr>
<td>XC 8816</td>
<td></td>
<td>Shaftline earthing device</td>
</tr>
<tr>
<td>XS/XT 8817</td>
<td></td>
<td>Turbocharger overspeed (Only in case of VT TC, Waste Heat Recovery, Exhaust Gas Bypass, TC Cut-out)</td>
</tr>
</tbody>
</table>

*Table 18.05.01c: Other indicators on engine, options: 4 70 119, and remote indication sensors, option: 4 75 127*
Other Alarm Functions

Drain Box for Fuel Oil Leakage Alarm

Any leakage from the fuel oil high pressure pipes of any cylinder is drained to a common drain box fitted with a level alarm. This is included in the basic design of MAN B&W engines.

Bearing Condition Monitoring

Based on our experience, we decided in 1990 that all plants must include an oil mist detector specified by MAN Diesel & Turbo. Since then an Oil Mist Detector (OMD) and optionally some extent of Bearing Temperature Monitoring (BTM) equipment have made up the warning arrangements for prevention of crankcase explosions on two-stroke engines. Both warning systems are approved by the classification societies.

In order to achieve a response to damage faster than possible with Oil Mist Detection and Bearing Temperature Monitoring alone we introduce Bearing Wear Monitoring (BWM) systems. By monitoring the actual bearing wear continuously, mechanical damage to the crank-train bearings (main-, crank- and crosshead bearings) can be predicted in time to react and avoid damaging the journal and bearing housing.

If the oil supply to a main bearing fails, the bearing temperature will rise and in such a case a Bearing Temperature Monitoring system will trigger an alarm before wear actually takes place. For that reason the ultimate protection against severe bearing damage and the optimum way of providing early warning, is a combined bearing wear and temperature monitoring system.

For all types of error situations detected by the different bearing condition monitoring systems applies that in addition to damaging the components, in extreme cases, a risk of a crankcase explosion exists.

Oil Mist Detector

The oil mist detector system constantly measures samples of the atmosphere in the crankcase compartments and registers the results on an optical measuring track, where the opacity (degree of haziness) is compared with the opacity of the atmospheric air. If an increased difference is recorded, a slow down is activated (a shut down in case of Germanischer Lloyd).

Furthermore, for shop trials only MAN Diesel & Turbo requires that the oil mist detector is connected to the shut down system.

For personnel safety, the oil mist detectors and related equipment are located on the manoeuvring side of the engine.

The following oil mist detectors are available:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Make</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 75 162</td>
<td>Oil mist detector Graviner MK7.</td>
<td>Kidde Fire Protection</td>
</tr>
<tr>
<td>4 75 161</td>
<td>Oil mist detector Graviner MK6.</td>
<td>Kidde Fire Protection</td>
</tr>
<tr>
<td>4 75 163</td>
<td>Oil mist detector Visatron VN 215/93.</td>
<td>Schaller Automation</td>
</tr>
<tr>
<td>4 75 165</td>
<td>Oil mist detector QMI.</td>
<td>Quality Monitoring Instruments Ltd.</td>
</tr>
<tr>
<td>4 75 166</td>
<td>Oil mist detector MD-SX.</td>
<td>Daihatsu Diesel Mfg. Co., Ltd.</td>
</tr>
<tr>
<td>4 75 167</td>
<td>Oil mist detector Vision III C.</td>
<td>Specs Corporation</td>
</tr>
<tr>
<td>4 75 168</td>
<td>Oil mist detector GDMS-OMDN09.</td>
<td>MSS GmbH</td>
</tr>
<tr>
<td>4 75 271</td>
<td>Oil mist detector Triton.</td>
<td>Heinzmann</td>
</tr>
</tbody>
</table>

Examples of piping diagrams (for make Schaller Automation only) and wiring diagrams (for all other makes) are shown for reference in Figs. 18.06.01a and 18.06.01b.
Fig. 18.06.01a: Oil mist detector wiring on engine, example based on type Graviner MK6 from Kidde Fire Protection, option: 4 75 161

Fig. 18.06.01b: Oil mist detector pipes on engine, type Visatron VN215/93 from Schaller Automation, option: 4 75 163
Bearing Wear Monitoring System

The Bearing Wear Monitoring (BWM) system monitors all three principal crank-train bearings using two proximity sensors forward/aft per cylinder unit and placed inside the frame box.

Targeting the guide shoe bottom ends continuously, the sensors measure the distance to the crosshead in Bottom Dead Center (BDC). Signals are computed and digitally presented to computer hardware, from which a useable and easily interpretable interface is presented to the user.

The measuring precision is more than adequate to obtain an alarm well before steel-to-steel contact in the bearings occur. Also the long-term stability of the measurements has shown to be excellent.

In fact, BWM is expected to provide long-term wear data at better precision and reliability than the manual vertical clearance measurements normally performed by the crew during regular service checks.

For the above reasons, we consider unscheduled open-up inspections of the crank-train bearings to be superfluous, given BWM has been installed.

Two BWM ‘high wear’ alarm levels including deviation alarm apply. The first level of the high wear / deviation alarm is indicated in the alarm panel only while the second level also activates a slow down.

The Extent of Delivery lists four Bearing Wear Monitoring options of which the two systems from Dr. E. Horn and Kongsberg Maritime could also include Bearing Temperature Monitoring:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 75 261</td>
<td>Bearing Wear Monitoring System XTS-W. Make: AMOT</td>
</tr>
<tr>
<td>4 75 262</td>
<td>Bearing Wear Monitoring System BDMS. Make: Dr. E. Horn</td>
</tr>
<tr>
<td>4 75 263</td>
<td>Bearing Wear Monitoring System PS-10. Make: Kongsberg Maritime</td>
</tr>
<tr>
<td>4 75 264</td>
<td>Bearing Wear Monitoring System OPEN-predictor. Make: Rovsing Dynamics</td>
</tr>
</tbody>
</table>

ME, ME-C and -GI engines are as standard specified with Bearing Wear Monitoring for which any of the above mentioned options could be chosen.

Bearing Temperature Monitoring System

The Bearing Temperature Monitoring (BTM) system continuously monitors the temperature of the bearing. Some systems measure the temperature on the backside of the bearing shell directly, other systems detect it by sampling a small part of the return oil from each bearing in the crankcase.

In case a specified temperature is recorded, either a bearing shell/housing temperature or bearing oil outlet temperature alarm is triggered.

In main bearings, the shell/housing temperature or the oil outlet temperature is monitored depending on how the temperature sensor of the BTM system, option: 4 75 133, is installed.

In crankpin and crosshead bearings, the shell/housing temperature or the oil outlet temperature is monitored depending on which BTM system is installed, options: 4 75 134 or 4 75 135.

For shell/housing temperature in main, crankpin and crosshead bearings two high temperature alarm levels apply. The first level alarm is indicated in the alarm panel while the second level activates a slow down.

For oil outlet temperature in main, crankpin and crosshead bearings two high temperature alarm levels including deviation alarm apply. The first level of the high temperature / deviation alarm is indicated in the alarm panel while the second level activates a slow down.

In the Extent of Delivery, there are three options:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 75 133</td>
<td>Temperature sensors fitted to main bearings</td>
</tr>
<tr>
<td>4 75 134</td>
<td>Temperature sensors fitted to main bearings, crankpin bearings, crosshead bearings and for moment compensator, if any</td>
</tr>
<tr>
<td>4 75 135</td>
<td>Temperature sensors fitted to main bearings, crankpin bearings and crosshead bearings</td>
</tr>
</tbody>
</table>
Water In Oil Monitoring System

All MAN B&W engines are as standard specified with Water In Oil monitoring system in order to detect and avoid free water in the lubricating oil.

In case the lubricating oil becomes contaminated with an amount of water exceeding our limit of 50% of the saturation point (corresponding to approx. 0.2% water content), acute corrosive wear of the crosshead bearing overlayer may occur. The higher the water content, the faster the wear rate.

To prevent water from accumulating in the lube oil and, thereby, causing damage to the bearings, the oil should be monitored manually or automatically by means of a Water In Oil (WIO) monitoring system connected to the engine alarm and monitoring system. In case of water contamination the source should be found and the equipment inspected and repaired accordingly.

The saturation point of the water content in the lubricating oil varies depending on the age of the lubricating oil, the degree of contamination and the temperature. For this reason, we have chosen to specify the water activity measuring principle and the aw-type sensor. Among the available methods of measuring the water content in the lubricating oil, only the aw-type sensor measures the relationship between the water content and the saturation point regardless of the properties of the lubricating oil.

WIO systems with aw-type sensor measure water activity expressed in ‘aw’ on a scale from 0 to 1. Here, ‘0’ indicates oil totally free of water and ‘1’ oil fully saturated by water.

Alarm levels are specified as follows:

<table>
<thead>
<tr>
<th>Engine condition</th>
<th>Water activity, aw</th>
</tr>
</thead>
<tbody>
<tr>
<td>High alarm level</td>
<td>0.5</td>
</tr>
<tr>
<td>High High alarm level</td>
<td>0.9</td>
</tr>
</tbody>
</table>

The aw = 0.5 alarm level gives sufficient margin to the saturation point in order to avoid free water in the lubricating oil. If the aw = 0.9 alarm level is reached within a short time after the aw = 0.5 alarm, this may be an indication of a water leak into the lubricating oil system.

Please note: Corrosion of the overlayer is a potential problem only for crosshead bearings, because only crosshead bearings are designed with an overlayer. Main, thrust and crankpin bearings may also suffer irreparable damage from water contamination, but the damage mechanism would be different and not as acute.

Liner Wall Monitoring System

The Liner Wall Monitoring (LWM) system monitors the temperature of each cylinder liner. It is to be regarded as a tool providing the engine room crew the possibility to react with appropriate countermeasures in case the cylinder oil film is indicating early signs of breakdown.

In doing so, the LWM system can assist the crew in the recognition phase and help avoid consequential scuffing of the cylinder liner and piston rings.

Signs of oil film breakdown in a cylinder liner will appear by way of increased and fluctuating temperatures. Therefore, recording a preset max allowable absolute temperature for the individual cylinder or a max allowed deviation from a calculated average of all sensors will trigger a cylinder liner temperature alarm.

The LWM system includes two sensors placed in the manoeuvring and exhaust side of the liners, near the piston skirt TDC position. The sensors are interfaced to the ship alarm system which monitors the liner temperatures.

For each individual engine, the max and deviation alarm levels are optimised by monitoring the temperature level of each sensor during normal service operation and setting the levels accordingly.

The temperature data is logged on a PC for one week at least and preferably for the duration of a round trip for reference of temperature development.

All types 98 and 90 ME and ME-C engines as well as K80ME-C9 are as standard specified with Liner Wall Monitoring system. For all other engines, the LWM system is available as an option: 4 75 136.
# Control Devices

The control devices mainly include a position switch (ZS) or a position transmitter (ZT) and solenoid valves (ZV) which are listed in Table 18.06.02 below. The sensor identification codes are listed in Table 18.07.01.

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZS 1109-A/B C</td>
<td>Turning gear – disengaged</td>
</tr>
<tr>
<td>ZS 1110-A/B C</td>
<td>Turning gear – engaged</td>
</tr>
<tr>
<td>ZS 1111-A/B C</td>
<td>Main starting valve – blocked</td>
</tr>
<tr>
<td>ZS 1112-A/B C</td>
<td>Main starting valve – in service</td>
</tr>
<tr>
<td>ZV 1114 C</td>
<td>Slow turning valve</td>
</tr>
<tr>
<td>ZS 1116-A/B C</td>
<td>Start air distribution system – in service</td>
</tr>
<tr>
<td>ZS 1117-A/B C</td>
<td>Start air distribution system – blocked</td>
</tr>
<tr>
<td>ZV 1120 C</td>
<td>Activate pilot press air to starting valves</td>
</tr>
<tr>
<td>ZS 1121-A/B C</td>
<td>Activate main starting valves - open</td>
</tr>
<tr>
<td>E 1180</td>
<td>Electric motor, auxiliary blower</td>
</tr>
<tr>
<td>E 1181</td>
<td>Electric motor, turning gear</td>
</tr>
<tr>
<td>E 1185 C</td>
<td>LOP, Local Operator Panel</td>
</tr>
</tbody>
</table>

## Hydraulic power supply

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT 1201-1/2/3 C</td>
<td>Hydraulic oil pressure, after non-return valve</td>
</tr>
<tr>
<td>ZV 1202-A/B C</td>
<td>Force-driven pump bypass</td>
</tr>
<tr>
<td>PS/PT 1204-1/2/3 C</td>
<td>Lubricating oil pressure after filter, suction side</td>
</tr>
</tbody>
</table>

## Tacho/crankshaft position

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZT 4020</td>
<td>Tacho for safety</td>
</tr>
</tbody>
</table>

## Engine cylinder components

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>XC 4108 C</td>
<td>ELVA NC valve</td>
</tr>
<tr>
<td>ZT 4111 C</td>
<td>Exhaust valve position</td>
</tr>
<tr>
<td>ZT 4114 C</td>
<td>Fuel plunger, position 1</td>
</tr>
</tbody>
</table>

## Fuel oil

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZV 8020 Z</td>
<td>Fuel oil cut-off at engine inlet (shut down), Germanischer Lloyd only</td>
</tr>
</tbody>
</table>

## Cylinder lubricating oil

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZT 8203 C</td>
<td>Confirm cylinder lubricator piston movement, cyl/cyl</td>
</tr>
<tr>
<td>ZV 8204 C</td>
<td>Activate cylinder lubricator, cyl/cyl</td>
</tr>
</tbody>
</table>

## Scavenge air

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS 8603 C</td>
<td>Scavenge air receiver, auxiliary blower control</td>
</tr>
</tbody>
</table>

## ME-GI alarm system (ME-GI only)

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>XC 2212</td>
<td>External gas shut down (request)</td>
</tr>
</tbody>
</table>

## ME-GI safety system (ME-GI only)

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Point of location</th>
</tr>
</thead>
<tbody>
<tr>
<td>XC 2001</td>
<td>Engine shut down (command)</td>
</tr>
<tr>
<td>XC 6360</td>
<td>Gas plant shut down (command)</td>
</tr>
</tbody>
</table>

*Table 18.06.02: Control devices on engine*
Identification of Instruments

The instruments and sensors are identified by a position number which is made up of a combination of letters and an identification number.

Measured or indicating variables

First letters:

- DS Density switch
- DT Density transmitter
- E Electrical component
- FS Flow switch
- FT Flow transmitter
- GT Gauging transmitter, index/load transmitter
- LI Level indication, local
- LS Level switch
- LT Level transmitter
- PDI Pressure difference indication, local
- PDS Pressure difference switch
- PDT Pressure difference transmitter
- PI Pressure indication, local
- PS Pressure switch
- PT Pressure transmitter
- ST Speed transmitter
- TC Thermo couple (NiCr-Ni)
- TE Temperature element (Pt 100)
- TI Temperature indication, local
- TS Temperature switch
- TT Temperature transmitter
- VS Viscosity switch
- VT Viscosity transmitter
- WI Vibration indication, local
- WS Vibration switch
- WT Vibration transmitter
- XC Unclassified control
- XS Unclassified switch
- XT Unclassified transmitter
- ZS Position switch (limit switch)
- ZT Position transmitter (proximity sensor)
- ZV Position valve (solenoid valve)

Location of measuring point

Ident. number; first two digits indicate the measurement point and xx the serial number:

11xx Manoeuvring system
12xx Hydraulic power supply system (HPS)
13xx Hydraulic control oil system, separate oil to HPS
14xx Combustion pressure supervision
15xx Top bracing pressure, stand alone type
16xx Exhaust Gas Recirculation (EGR)
20xx ECS to/from safety system
21xx ECS to/from remote control system
22xx ECS to/from alarm system
24xx ME ECS outputs
29xx Power supply units to alarm system
30xx ECS miscellaneous input/output
40xx Tacho/crankshaft position system
41xx Engine cylinder components
50xx VOC, supply system
51xx VOC, sealing oil system
52xx VOC, control oil system
53xx VOC, other related systems
54xx VOC, engine related components
60xx GI-ECS to Fuel Gas Supply System (FGSS)
61xx GI-ECS to Sealing Oil System
62xx GI-ECS to Control Air System
63xx GI-ECS to other GI related systems
64xx GI engine related components
66xx Selective Catalytic Reduction (SCR) related component. Stand alone
80xx Fuel oil system
81xx Lubricating oil system
82xx Cylinder lubricating oil system
83xx Stuffing box drain system
84xx Cooling water systems, e.g. central, sea and jacket cooling water
85xx Compressed air supply systems, e.g. control and starting air
86xx Scavenge air system
87xx Exhaust gas system
88xx Miscellaneous functions, e.g. axial vibration
90xx Project specific functions

Table 18.07.01a: Identification of instruments
A0xx  Temporary sensors for projects
xxxx-A  Alternative redundant sensors
xxxx-1  Cylinder/turbocharger numbers

ECS: Engine Control System
GI: Gas Injection engine
VOC: Volatile Organic Compound

Functions

Secondary letters:

A  Alarm
C  Control
H  High
I  Indication, remote
L  Low
R  Recording
S  Switching
X  Unclassified function
Y  Slow down
Z  Shut down

Repeated signals

Signals which are repeated, for example measurements for each cylinder or turbocharger, are provided with a suffix number indicating the location, ‘1’ for cylinder 1, etc.

If redundant sensors are applied for the same measuring point, the suffix is a letter: A, B, C, etc.

Examples

\[\text{T}1\ 8005\] indicates a local temperature indication (thermometer) in the fuel oil system.

\[\text{ZS}\ 1112\-A\ C\] and \[\text{ZS}\ 1112\-B\ C\] indicate two redundant position switches in the manoeuvring system, A and B, for control of the main starting air valve position.

\[\text{PT}\ 8501\ I\ AL\ Y\] indicates a pressure transmitter located in the control air supply for remote indication, alarm for low pressure and slow down for low pressure.

Table 18.07.01b: Identification of instruments
ME-GI Safety Aspects

The normal safety systems incorporated in the fuel oil systems are fully retained also during dual fuel operation. However, additional safety devices will be incorporated in order to prevent situations which might otherwise lead to failures.

Safety Devices – External systems

Leaking valves and fractured pipes are sources of faults that may be harmful. Such faults can be easily and quickly detected by a hydrocarbon (HC) analyser with an alarm function. An alarm is given at a gas concentration of max. 30% of the Lower Explosion Limit (LEL) in the vented duct, and a shut down signal is given at 60% LEL.

The safety devices that will virtually eliminate such risks are double-wall pipes and encapsulated valves with ventilation of the intervening space. The ventilation between the outer and inner walls is always to be in operation when there is gas in the supply line, and any gas leakage will be led to the HC sensors placed in the outer pipe discharge.

Another source of fault could be a malfunctioning sealing oil supply system. If the gas sealing oil differential pressure becomes too low in the gas injection valve, gas will flow into the control oil activation system and, thereby, create unintended mixing of gas in the hydraulic oil system and create gas pockets and prevent the ELGI valve from operating the gas injection valve. Therefore, the sealing oil pressure is measured by a set of pressure sensors, and in the event of a too low pressure, the engine will shut down on gas mode and start running in the fuel oil mode.

Lack of ventilation in the double-wall piping system prevents the safety function of the HC sensors, so the system is to be equipped with a set of flow switches. If the switches indicate no flow, the engine will be shut down on gas mode. The switches should be of the normally open (NO) type, in order to allow detection of a malfunctioning switch, even in case of an electric power failure.

As natural gas is lighter than air, non-return valves are incorporated in the gas system's outlet pipes to ensure that the gas system is not polluted, i.e. mixed with air.

Safety Devices – Internal systems

During normal operation, a malfunction in the pilot fuel injection system or gas injection system may involve a risk of uncontrolled combustion in the engine.

Sources of faults are:
- defective gas injection valves
- failing ignition of injected gas.

These aspects will be discussed in detail in the following together with the suitable countermeasures.

Defective gas injection valves

In case of sluggish operation or even seizure of the gas valve spindle in the open position, which will be detected by the gas pressure transmitter in the gas block, a limited amount of gas may be injected into the cylinder before the window valve closes. Therefore, when the exhaust valve opens, a hot mixture of combustion products and gas flows out and into the exhaust pipe and further on to the exhaust receiver.

The temperature of the mixture after the valve will increase considerably, and it is likely that the gas will burn with a diffusion type flame (without exploding) immediately after the valve where it is mixed with scavenge air/exhaust gas (with approx. 15 per cent oxygen) in the exhaust system. This may set off the high exhaust gas temperature alarm for the cylinder in question.
In the unlikely event of larger gas amounts entering the exhaust receiver without starting to burn immediately, a later ignition may result in violent burning and a corresponding pressure rise. Therefore, the exhaust receiver is designed for the maximum pressure (around 15 bars).

However, any of the above-mentioned situations will be prevented by the detection of defective gas valves, which is arranged as follows.

Valve leakage monitoring pressure sensor

The valve leakage monitoring pressure sensor, installed in the gas block between the window/shutdown valve and the gas injection valves, is one unit with sensor and amplifier.

The pressure sensor measures pressure increase or decrease, concluding whether the window/shutdown valve or the gas injection valves are leaking, during every cycle from when the window/shutdown valve closes and until it opens again.

Ignition failure of injected gas

Failing ignition of the injected natural gas, i.e. misfiring, can have a number of different causes, most of which, however, are the result of failure to inject pilot oil in a cylinder:

• leaky joints or fractured high-pressure pipes, making the fuel oil booster inoperative
• seized plunger in the fuel oil booster
• other faults on the engine, forcing the fuel oil booster to ‘0-index’.

Such misfiring causes a small amount of unburned gas in the exhaust receiver to burn with a diffusion type flame as explained above. The GCSU detects misfiring and the gas injection is stopped and a gas shut down initiated.

Compression and combustion pressure monitoring

The compression pressure as well as the maximum combustion pressure are monitored. If low respectively too high, a gas shutdown is initiated.

Test of tightness of gas pipes

During shop test of the engine as well as vessel commissioning, a tightness test of the gas piping is conducted by means of valves installed in the gas return pipe.

Further information on tightness verification tests and gas leakage detection is available from MAN Diesel & Turbo, Copenhagen.
Dispatch Pattern, Testing, Spares and Tools
**Dispatch Pattern, Testing, Spares and Tools**

**Painting of Main Engine**

The painting specification, Section 19.02, indicates the minimum requirements regarding the quality and the dry film thickness of the coats of, as well as the standard colours applied on MAN B&W engines built in accordance with the ‘Copenhagen’ standard.

Paints according to builder’s standard may be used provided they at least fulfil the requirements stated.

**Dispatch Pattern**

The dispatch patterns are divided into two classes, see Section 19.03:

A: Short distance transportation and short term storage
B: Overseas or long distance transportation or long term storage.

**Short distance transportation (A)** is limited by a duration of a few days from delivery ex works until installation, or a distance of approximately 1,000 km and short term storage.

The duration from engine delivery until installation must not exceed 8 weeks.

Dismantling of the engine is limited as much as possible.

**Overseas or long distance transportation** or long term storage require a class B dispatch pattern.

The duration from engine delivery until installation is assumed to be between 8 weeks and maximum 6 months.

Dismantling is effected to a certain degree with the aim of reducing the transportation volume of the individual units to a suitable extent.

**Note:**

_Long term preservation and seaworthy packing are always to be used for class B._

Furthermore, the dispatch patterns are divided into several degrees of dismantling in which ‘1’ comprises the complete or almost complete engine. Other degrees of dismantling can be agreed upon in each case.

When determining the degree of dismantling, consideration should be given to the lifting capacities and number of crane hooks available at the engine maker and, in particular, at the yard (purchaser).

The approximate masses of the sections appear in Section 19.04. The masses can vary up to 10% depending on the design and options chosen.

Lifting tools and lifting instructions are required for all levels of dispatch pattern. The lifting tools, options: 4 12 110 or 4 12 111, are to be specified when ordering and it should be agreed whether the tools are to be returned to the engine maker, option: 4 12 120, or not, option: 4 12 121.

MAN Diesel & Turbo’s recommendations for preservation of disassembled / assembled engines are available on request.

Furthermore, it must be considered whether a drying machine, option: 4 12 601, is to be installed during the transportation and/or storage period.

**Shop Trials/Delivery Test**

Before leaving the engine maker’s works, the engine is to be carefully tested on diesel oil in the presence of representatives of the yard, the shipowner and the classification society.

The shop trial test is to be carried out in accordance with the requirements of the relevant classification society, however a minimum as stated in Section 19.05.
MAN Diesel & Turbo’s recommendations for shop trial, quay trial and sea trial are available on request.

In connection with the shop trial test, it is required to perform a pre-certification survey on engine plants with FPP or CPP, options: 4 06 201 Engine test cycle E3 or 4 06 202 Engine test cycle E2 respectively.

Spare Parts

List of spare parts, unrestricted service

The tendency today is for the classification societies to change their rules such that required spare parts are changed into recommended spare parts.

MAN Diesel & Turbo, however, has decided to keep a set of spare parts included in the basic extent of delivery, EoD: 4 87 601, covering the requirements and recommendations of the major classification societies, see Section 19.06.

This amount is to be considered as minimum safety stock for emergency situations.

Additional spare parts recommended by MAN Diesel & Turbo

The above-mentioned set of spare parts can be extended with the 'Additional Spare Parts Recommended by MAN Diesel & Turbo', option: 4 87 603, which facilitates maintenance because, in that case, all the components such as gaskets, sealings, etc. required for an overhaul will be readily available, see Section 19.07.

Wearing parts

The consumable spare parts for a certain period are not included in the above mentioned sets, but can be ordered for the first 1, 2, up to 10 years' service of a new engine, option: 4 87 629.

The wearing parts that, based on our service experience, are estimated to be required, are listed with service hours in Tables 19.08.01 and 19.08.02.

Large spare parts, dimensions and masses

The approximate dimensions and masses of the larger spare parts are indicated in Section 19.09. A complete list will be delivered by the engine maker.

Tools

List of standard tools

The engine is delivered with the necessary special tools for overhauling purposes. The extent, dimensions and masses of the main tools is stated in Section 19.10. A complete list will be delivered by the engine maker.

Tool panels

Most of the tools are arranged on steel plate panels, EoD: 4 88 660, see Section 19.11 ‘Tool Panels’.

It is recommended to place the panels close to the location where the overhaul is to be carried out.
## Specification for painting of main engine

<table>
<thead>
<tr>
<th>Components to be painted before shipment from workshop</th>
<th>Type of paint</th>
<th>No. of coats / Total Nominal Dry Film Thickness (NDFT) ( \mu m )</th>
<th>Colour:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>In accordance with corrosivity categories C2 Medium ISO 12944-5</td>
<td>RAL 840HR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Engine alkyd primer, weather resistant. Oil and acid resistant alkyd paint. Temperature resistant to minimum 80 °C.</td>
<td>DIN 6164</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 - 2 layer(s) Total NDFT 80 ( \mu m ) 1 layer Total NDFT 40 ( \mu m )</td>
<td>MUNSELL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— — — — —</td>
<td>N-9.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total NDFT 120 ( \mu m )</td>
<td>— — — — —</td>
</tr>
</tbody>
</table>

### 1. Component/surfaces exposed to oil and air, inside engine

Unmachined surfaces all over. However, cast type crankthrows, main bearing cap, crosshead bearing cap, crankpin bearing cap, pipes inside crankcase and chainwheel need not to be painted, but the cast surface must be cleaned of sand and scales and be kept free of rust.

*In accordance with corrosivity categories C2 Medium ISO 12944-5*

#### Engine body, pipes, gallery, brackets, etc.

Delivery standard is in a primed and finished-painted condition, unless otherwise stated in the contract.

*Engine alkyd primer, weather resistant. Final alkyd paint resistant to salt water and oil, option: 4 81 103.***

<table>
<thead>
<tr>
<th>Colour:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>White: RAL 9010</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DIN N:0:0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MUNSELL N-9.5</td>
<td></td>
</tr>
</tbody>
</table>

#### Chain pipes, supply pipe.

*Engine alkyd primer, weather resistant. Final alkyd paint resistant to salt water and oil, option: 4 81 103.*

<table>
<thead>
<tr>
<th>Colour:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yellow: RAL 1021</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MUNSELL 2.5 Y 8114</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Violet: RAL 4001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MUNSELL 2.5P 4/11</td>
<td></td>
</tr>
</tbody>
</table>

### 2. Components, outside engine

### 3. Gas pipe (ME-GI/ME-LGI only)

#### Chain pipes, supply pipe.

*Engine alkyd primer, weather resistant. Final alkyd paint resistant to salt water and oil, option: 4 81 103.*

<table>
<thead>
<tr>
<th>Colour:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yellow: RAL 1021</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MUNSELL 2.5 Y 8114</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Violet: RAL 4001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MUNSELL 2.5P 4/11</td>
<td></td>
</tr>
</tbody>
</table>

### 4. Heat affected components

Supports for exhaust receiver.

Scavenge air cooler housing inside and outside.

No surface in the cooler housing may be left unpainted.

Exhaust valve housing (exhaust flange)

*Ethyl silicate based zinc-rich paint, heat resistant to minimum 300 °C.*
Components to be painted before shipment from workshop | Type of paint | No. of coats / Total Nominal Dry Film Thickness (NDFT) μm | Colour:
| RAL 840HR DIN 6164 MUNSELL

| 5. Components affected by water, cleaning agents, and acid fluid below neutral Ph |
| Scavenge air cooler box inside. (Reversing chamber). |
| Preparation, actual number of coats, film thickness per coat, etc. must be according to the paint manufacturer’s specifications. |
| Air flow reversing chamber inside and outside. |
| No surface may be left unpainted. Supervision from manufacturer is recommended in the phase of introduction of the paint system. |
| In accordance with corrosivity categories C5-M High ISO 12944-5 |
| Two-component epoxy phenolic. |
| 3 layers |
| Total NDFT 350 μm |
| See specifications from product data sheet. |
| Free |

| 6. Gallery plates, top side |
| Engine alkyd primer, weather resistant. |
| C2 Medium 1-2 layer(s) |
| Total NDFT 80 μm |

| 7. EGR system |
| Normal air cooler housing with EGR mix point to scavenge air receiver non-return valves (500 μm). |
| Normal air cooler housing inside – from outlet air cooler – through reversing chamber and water mist catcher to non-return valves housing in scavenge air receiver. |
| Vinyl ESTER acrylic copolymer. |
| Total NDFT 500 - 1,200 μm |
| Free |

| 8. Purchased equipment and instruments painted in maker’s colour are acceptable, unless otherwise stated in the contract |
| Tools are to be surface treated according to specifications stated in the drawings. |
| Electro(-) galvanised. |
| See specifications from product data sheet. |

| Tool panels |
| Oil resistant paint. |
| 1 - 2 layer(s) |
| Total NDFT 80 μm |
| Light grey: RAL 7038 DIN 24-1:2 MUNSELL N-7.5 |

All paints must be of good quality. Paints according to builder’s standard may be used provided they at least fulfil the above requirements.
The data stated are only to be considered as guidelines. Preparation, number of coats, film thickness per coat, etc., must be in accordance with the paint manufacturer’s specifications.

Fig. 19.02.01: Painting of main engine, option: 4 81 101, 4 81 102 or 4 81 103
Dispatch Pattern

The relevant engine supplier is responsible for the actual execution and delivery extent. As differences may appear in the individual suppliers' extent and dispatch variants.

Dispatch Pattern A - short:
Short distance transportation limited by duration of transportation time within a few days or a distance of approximately 1000 km and short term storage.

Duration from engine delivery to installation must not exceed eight weeks.
Dismantling must be limited.

Dispatch Pattern B - long:
Overseas and other long distance transportation, as well as long-term storage.

Dismantling is effected to reduce the transport volume to a suitable extent.

Long-term preservation and seaworthy packing must always be used.

Note
The engine supplier is responsible for the necessary lifting tools and lifting instructions for transportation purposes to the yard. The delivery extent of lifting tools, ownership and lend/lease conditions are to be stated in the contract. (Options: 4 12 120 or 4 12 121)

Furthermore, it must be stated whether a drying machine is to be installed during the transportation and/or storage period. (Option: 4 12 601)
Dispatch pattern variants

A1 + B1 (option 4 12 021 + 4 12 031)
Engine complete, i.e. not disassembled

A2 + B2 (option 4 12 022 + 4 12 032)
• Top section including cylinder frame complete, cylinder covers complete, scavenger air receiver including cooler box and cooler insert, turbocharger(s), piston complete and galleries with pipes, HCU units, oil filter, gas control blocks, gas chain pipes and sealing oil pump unit
• Bottom section including bedplate complete, frame box complete, connecting rods, turning gear, crankshaft complete and galleries
• Remaining parts including stay bolts, chains, FIVA valves etc.

Fig. 19.03.01: Dispatch pattern, engine with turbocharger on exhaust side (4 59 123)
**A3 + B3** (option 4 12 023 + 4 12 033)
- Top section including cylinder frame complete, cylinder covers complete, scavenge air receiver including cooler box and cooler insert, turbocharger(s), piston complete and galleries with pipes, HCU Units, gas control block, gas chain pipes, and sealing oil pump unit
- Frame box section including frame box complete, chain drive, connecting rods and galleries, gearbox for hydraulic power supply, hydraulic pump station and oil filter
- Bedplate/crankshaft section including bedplate complete, crankshaft complete with chain-wheels and turning gear
- Remaining parts including stay bolts, chains FIVA valves, etc.

*Fig. 19.03.02: Dispatch pattern, engine with turbocharger on exhaust side (4 59 123)*
A4 + B4 (option 4 12 024 + 4 12 034)
- Top section including cylinder frame complete, cylinder covers complete, piston complete and galleries with pipes on manoeuvring side, HCU units, gas control block, gas chain pipe, and sealing oil pump unit
- Exhaust receiver with pipes
- Scavenge air receiver with galleries and pipes
- Turbocharger
- Air cooler box with cooler insert
- Frame box section including frame box complete, chain drive, connecting rods and galleries, gearbox for hydraulic power supply, hydraulic power station and oil filter
- Crankshaft with chain wheels
- Bedplate with pipes and turning gear
- Remaining parts including stay bolts, auxiliary blowers, chains FIVA valves etc.

Fig. 19.03.03: Dispatch pattern, engine with turbocharger on exhaust side (4 59 123)
Shop Test

Minimum delivery test

The minimum delivery test, EoD: 4 14 001, involves:

- Starting and manoeuvring test at no load
- Load test
- Engine to be started and run up to 50% of Specified MCR (M) in 1 hour.

Followed by:

- 0.50 hour running at 25% of specified MCR
- 0.50 hour running at 50% of specified MCR
- 0.50 hour running at 75% of specified MCR
- 1.00 hour running at 100% of specified MCR
- 0.50 hour running at 110% of specified MCR.

Only for Germanischer Lloyd:

- 0.75 hour running at 110% of specified MCR

Governor tests, etc:

- Governor test
- Minimum speed test
- Overspeed test
- Shut down test
- Starting and reversing test
- Turning gear blocking device test
- Start, stop and reversing from the Local Operating Panel (LOP).

Fuel gas test

Further to the minimum delivery test, the shop test on fuel gas, EoD: 4 14 005, includes test of auto change-over to:

- fuel gas from fuel gas standby condition when engine load exceeds the lowest limit for fuel gas operation
- fuel oil when engine load falls below the lowest limit for fuel gas operation
- fuel oil in case of critical alarms related to gas combustion.

At each load change, all temperature and pressure levels etc. should stabilise before taking new engine load readings.

Fuel oil and fuel gas analyses are to be presented.

All tests are to be carried out on diesel or gas oil as well as on fuel gas.

EIAPP certificate

Most marine engines installed on ocean going vessels are required to have an ‘Engine International Air Pollution Prevention’ (EIAPP) Certificate, or similar. Therefore, a pre-certification survey is to be carried out for all engines according to the survey method described in the engine’s NOx Technical File, which is prepared by the engine manufacturer. For MAN B&W engines, the Unified Technical File (UTF) format is recommended.

The EIAPP certificate documents that the specific engine meets the international NOx emission limitations specified in Regulation 13 of MARPOL Annex VI. The basic engine ‘Economy running mode’, EoD: 4 06 200, complies with these limitations.

The pre-certification survey for a ‘Parent’ or an ‘Individual’ engine includes NOx measurements during the delivery test. For ‘Member’ engines, a survey according to the group definition for the engine group is needed. This survey should be based on the delivery test.

The applicable test cycles are:

- E3, marine engine, propeller law for FPP, option: 4 06 201
- E2, marine engine, constant speed for CPP, option: 4 06 202

For further information and options regarding shop test, see Extent of Delivery.
List of Spare Parts, Unrestricted Service

Spare parts are requested by the following Classes only: GL, KR, NK and RS, while just recommended by: ABS and LR, but neither requested nor recommended by: BV, CCS, DNV and RINA.

GI cylinder cover, plate 2272-0300 (901 and more)
1 Cylinder cover with extra holes for gas equipment and Inconel cladding. Incl. of fuel, exhaust and starting valves, indicator valve and sealing rings (disassembled)
½ set Studs for 1 cylinder cover

Gas Pipe Supply Chain, plate 4272-2800 (901 and more)
1 set Double-wall fuel gas pipes for 1 cylinder
1 set Repair kit for high-pressure gas pipes incl. gaskets and packings

Piston and piston rod, plates 2272-0400/0420/0500 (902)
1 Piston complete (with cooling pipe), piston rod, piston rings and stuffing box, studs and nuts

Piston rings, plate 2272-0420 (902)
1 set Piston rings for 1 cylinder

Cylinder liner, plate 2272-0600 (903)
1 Cylinder liner incl. of sealing rings and gaskets

Cylinder lubricating oil system, plates 3072-0600, 6670-0100 (903)
1 set Spares for lubricating oil system for 1 cylinder
2 Lubricator backup cable

Connecting rod, and crosshead bearing, plates 1472-0300, 2572-0300/0200 (904)
1 Telescopic pipe with bushing for 1 cylinder
1 Crankpin bearing shells in 2/2 with studs and nuts
1 Crosshead bearing shell lower part with studs and nuts
2 Thrust pieces

Thrust block, plate 2572-0600 (905)
1 set Thrust pads for ‘ahead’
For NK also one set ‘astern’ if different from ‘ahead’

HPS - Hydraulic Power Supply, plates 4572-1000/0750, 4572-1100/1200/1250 (906)
1 Proportional valve for hydraulic pumps
1 Leak indicator
1 Safety coupling for hydraulic pump
1 Accumulator
6 Chain links. Only for ABS, LR and NK
1 set Flex pipes, one of each size

Engine control system, plates 4772-1500, 7072-0800/1100 (906)
1 Multi Purpose Controller
1 Amplifier for Auxiliary Control Unit
1 Position Amplifier
1 Trigger sensor for tacho system, only if trigger ring
1 Marker sensor for tacho system
1 Tacho signal amplifier
1 ID-key
1 Encoder
1 Fuse kit

Starting valve, plates 3472-0200/0250 (907)
1 Starting valve, complete
1 Solenoid valve

Hydraulic cylinder unit, plates 4572-0500/0100, 4272-0500 (906, 907)
1 Fuel booster barrel, complete with plunger
1 FIVA valve complete
1 Suction valve complete
1 set Flex pipes, one of each size
1 High-pressure pipe kit
1 Packing kit

Exhaust valve, plates 2272-0200/0210/0230 (908)
2 Exhaust valves complete
(The 2nd exhaust valve is mounted in the Cylinder cover complete)
1 High-pressure pipe from actuator to exhaust valve
1 Exhaust valve position sensor

Fuel valve, plates 4272-0200/0100/2300 (909)
1 set Fuel valves of each size and type fitted, complete with all fittings, for one engine
a) engines with one or two fuel valves: one set of fuel valves for all cylinders on the engine
b) engines with three and more fuel valves per cylinder: two fuel valves complete per cylinder, and a sufficient number of valve parts, excluding the body, to form, with those fitted in the complete valve, a full engine set
1 set High-pressure pipe, from fuel oil pressure booster to fuel valve
1 set Gas injection valve incl. sealings

Fig. 19.06.01a: List of spare parts, unrestricted service: 4 87 601
Turbocharger, plate 5472-0700 (910)
1 set Maker's standard spare parts

Bedplate, plates 1072-0400, 2572-0400 (912)
1 Main bearing shells (1 upper and 1 lower) of each size
1 set Studs and nuts for 1 main bearing
1) MD required spare parts.
2) All spare parts are requested by all Classes.

Note: Plate numbers refer to the Instruction Manual containing plates with spare parts (older three-digit numbers are included for reference)

Fig. 19.06.01b: List of spare parts, unrestricted service: 4 87 601
Additional Spares

Beyond class requirements or recommendation, for easier maintenance and increased security in operation.

**Cylinder cover, plate 2272-0300 (901)**
- 4 Studs for exhaust valve
- 4 Nuts for exhaust valve
- ½ set O-rings for cooling jacket
- 1 Cooling jacket
- ½ set Sealing between cylinder cover and liner
- 4 Spring housings for fuel valve

**Hydraulic tool for cylinder cover, plates 2270-0310/0315 (901)**
- 1 set Hydraulic hoses with protection hose complete with couplings
- 8 pcs O-rings with backup rings, upper
- 8 pcs O-rings with backup rings, lower

**Piston and piston rod, plate 2272-0400 (902)**
- 1 box Locking wire, L=63 m
- 2 D-rings for piston skirt
- 2 D-rings for piston rod

**Piston rings, plate 2272-0420 (902)**
- 5 Piston rings of each kind

**Piston rod stuffing box, plate 2272-0500 (902)**
- 15 Self-locking nuts
- 5 O-rings
- 5 Top scraper rings
- 15 Pack sealing rings
- 10 Cover sealing rings
- 120 Lamellas for scraper rings
- 30 Springs for top scraper and sealing rings
- 20 Springs for scraper rings

**Cylinder frame, plate 1072-0710 (903)**
- ½ set Studs for cylinder cover for one cylinder
- 1 Bushing

**Cylinder liner and cooling jacket, plate 2272-0600 (903)**
- 1 Cooling jacket of each kind
- 4 Non return valves
- 1 set O-rings for one cylinder liner
- ½ set Gaskets for cooling water connection
- ½ set O-rings for cooling water pipes
- 1 set Cooling water pipes between liner and cover for one cylinder

**Cylinder Lubricating Oil System, plate 3072-0600 (903)**
- 1 set Spares for MAN B&W Alpha lubricating oil system for one cylinder
- 1 Lubricator
- 2 Feed back sensor, complete
- 1 Complete sets of O-rings for lubricator (depending on number of lubricating nozzles per cylinder)

**Connecting rod and crosshead bearing, plate 1472-0300 (904)**
- 1 Telescopic pipe
- 2 Thrust piece

**HPS Hydraulic Power Supply, plates 4572-1000/0750, 4572-1100 (906)**
- 1 Pressure relief valve
- 1 Pumps short cutting valve
- 1 set Check valve Cartridge (3 pcs)

**Gas control block, plates 4272-2000/2100/2200 (909)**
- 1 Gas control block, complete
- 1 Adapter block
- 1 Accumulator for gas control block
- 1 set Repair kit for one gas control block incl. brass plugs, sealing for the intermediate piece, gaskets and packings
- 2 ELGI/ ELWI valves
- 1 Window valve
- 2 Blow-off/Purge valves
- 1 Pressure sensor for leakage detector
- 1 set Seals and packings for window valve/accumulator and blow-off/purge valves, for all cylinders

**Sealing oil for gas valves, plates 4272-2600/2650 (909)**
- 1 set Sealing oil high-pressure pipes, for one cyl.
- 1 Filter element for sealing oil filter
- 1 Repair kit for sealing oil pump

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*Fig. 19.07.01a: Additional spare parts beyond class requirements or recommendation, option: 4 87 603*
Engine Control System, plates 4772-1500, 7072-1250 (906)
1 set Fuses for MPC, TSA, CNR
1 Segment for trigger ring
1 set Sensors for gas system

HCU Hydraulic Cylinder Unit, plates 4572-0500, 4272-2300 (906)
1 set Packings
1 set Piping for activation of gas injection valves, for one cylinder

GI control, plates 4772-1500, 7072-0800 (906)
1 DASU computer
1 Cylinder pressure sensor
1 Gas pressure sensor, according to maker’s recommendation (Yard supply)
1 Pressure sensor for sealing oil and hydraulic oil pressure

Main starting valve, plate 3472-0300 (907)
1 Repair kit for main actuator
1 Repair kit for main ball valve
1 *) Repair kit for actuator, slow turning
1 *) Repair kit for ball valve, slow turning
*) if fitted

Starting valve, plate 3472-0200 (907)
2 Locking plates
2 Piston
2 Spring
2 Bushing
1 set O-ring
1 Valve spindle

Exhaust valve, plates 2272-0200/0210 (908)
1 Exhaust valve spindle
1 Exhaust valve seat
½ set O-ring exhaust valve/cylinder cover
4 Piston rings
½ set Cylinder rings
½ set Sealing rings
½ set Safety valves
1 set Gaskets and O-rings for safety valve
1 Piston complete
1 Damper piston

1 set O-rings and sealings between air piston and exhaust valve housing/spindle
1 Liner for spindle guide
1 set Gaskets and O-rings for cooling water connection
1 Conical ring in 2/2
1 set O-rings for spindle/air piston
1 set Non-return valve

Exhaust valve, plate 2272-0200 (908)
1 Sealing oil control unit

Exhaust valve actuator, plate 4572-0100 (908)
1 Hydraulic exhaust valve actuator complete for one cylinder
1 Electronic exhaust valve control valve

Cooling water outlet, plate 5072-0100 (908)
2 Ball valve
1 Butterfly valve
1 Compensator
1 set Gaskets for butterfly valve and compensator

Fuel valve, plate 4272-0200 (909)
1 set Fuel nozzles
1 set O-rings for fuel valve
3 Spindle guides, complete
½ set Springs
½ set Discs, +30 bar
3 Thrust spindles
3 Non return valve (if mounted)

Fuel oil high-pressure pipes, plate 4272-0100 (909)
1 High-pressure pipe, from fuel oil pressure booster to fuel valve
1 High-pressure pipe from actuator to exhaust valve
1 set O-rings for high-pressure pipes

Fuel oil low pressure system, plate 4272-0110 (909)
1 Overflow valve, complete
1 O-rings of each kind

Fig. 19.07.01b: Additional spare parts beyond class requirements or recommendation, option: 4 87 603
Fuel injection system, plates 4272-0500, 4572-0500 (909)
1 Fuel oil pressure booster complete, for one cyl.
1 Hydraulic cylinder unit
1 set Gaskets and sealings
1 Electronic fuel injection control valve

Scavenge air receiver, plates 5472-0400/0630 (910)
2 Non-return valves complete
1 Compensator

Exhaust pipes and receiver, plates 5472-0750/0900 (910)
1 Compensator between TC and receiver
2 Compensator between exhaust valve and receiver
1 set Gaskets for each compensator

Auxiliary blower, plate 5472-0500 (910)
1 set Bearings for electric motor
1 set Shaft sealings
1 set Bearings/belt/sealings for gearbox (only for belt-driven blowers)

Turbocharger, plates 5472-0700 (910)
1 Spare rotor for one turbocharger, complete with bearing
1 set Spare parts for one turbocharger

Engine Lubricating System, plate 4572-0800 (912)
1 set 6μ filter

Note: Plate numbers refer to the Instruction Manual containing plates with spare parts (older three-digit numbers are included for reference)

Fig. 19.07.01c: Additional spare parts beyond class requirements or recommendation, option: 4 87 603
**Wearing Parts**

MAN Diesel & Turbo Service Letter SL-509 provides Guiding Overhaul Intervals and expected service life for key engine components. The wearing parts expected to be replaced at the service hours mentioned in the Service Letter are listed in the tables below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Replace parts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Piston</strong></td>
<td></td>
</tr>
<tr>
<td>Soft iron gasket (1 set per cylinder)</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>Piston crown (1 pc per cylinder)</td>
<td></td>
</tr>
<tr>
<td>O-rings for piston (1 set per cylinder)</td>
<td>x</td>
</tr>
<tr>
<td>Piston rings (1 set per cylinder)</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>Piston cleaning ring (1 pc per cylinder)</td>
<td>x</td>
</tr>
<tr>
<td><strong>Stuffing box</strong></td>
<td></td>
</tr>
<tr>
<td>Lamellas (1 set per cylinder)</td>
<td>x</td>
</tr>
<tr>
<td>Top scraper ring (1 pc per cylinder)</td>
<td>x</td>
</tr>
<tr>
<td>O-rings (1 set per cylinder)</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>Cylinder liner (1 pc per cylinder)</td>
<td></td>
</tr>
<tr>
<td>O-rings for cylinder liner (1 set per cylinder)</td>
<td>x</td>
</tr>
<tr>
<td>O-rings for cooling water jacket (1 set per cylinder)</td>
<td>x</td>
</tr>
<tr>
<td>O-rings for cooling water connections (1 set per cyl.)</td>
<td>x</td>
</tr>
<tr>
<td><strong>Exhaust valve</strong></td>
<td></td>
</tr>
<tr>
<td>DuraSpindle (1 pc per cylinder)</td>
<td>x</td>
</tr>
<tr>
<td>Nimonic spindle (1 pc per cylinder)</td>
<td>x</td>
</tr>
<tr>
<td>Bottom piece (1 pc per cylinder)</td>
<td>x</td>
</tr>
<tr>
<td>Piston rings for exhaust valve &amp; oil piston (1 set per cyl.)</td>
<td>x</td>
</tr>
<tr>
<td>O-rings for bottom piece (1 set per cylinder)</td>
<td>x x x x x x</td>
</tr>
<tr>
<td><strong>Fuel valves</strong></td>
<td></td>
</tr>
<tr>
<td>Valve nozzle (2 sets per cylinder)</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>Spindle guide (2 sets per cylinder)</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>O-ring (2 sets per cylinder)</td>
<td>x x x x x x x x x</td>
</tr>
<tr>
<td>Spring housings (1 set per cylinder)</td>
<td></td>
</tr>
<tr>
<td><strong>Bearings</strong></td>
<td></td>
</tr>
<tr>
<td>Crosshead bearing (1 set per cylinder)</td>
<td>x</td>
</tr>
<tr>
<td>Crankpin bearing (1 set per cylinder)</td>
<td>x</td>
</tr>
<tr>
<td>Main bearing (1 set per cylinder)</td>
<td>x</td>
</tr>
<tr>
<td>Thrust bearing (1 set per engine)</td>
<td>x</td>
</tr>
<tr>
<td>Cylinder cover (1 pc per cylinder)</td>
<td></td>
</tr>
<tr>
<td>O-rings for cooling water jacket (1 set per cylinder)</td>
<td>x x x x</td>
</tr>
<tr>
<td>O-ring for starting valve (1 pc per cylinder)</td>
<td>x x x x x x</td>
</tr>
</tbody>
</table>

*Table 19.08.01a: Wearing parts according to Service Letter SL-509*
<table>
<thead>
<tr>
<th>Description</th>
<th>Replace parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air cooler(s) (1 pc per turbocharger)</td>
<td>X X</td>
</tr>
<tr>
<td>Chains (1 set per engine)</td>
<td>X</td>
</tr>
<tr>
<td>Turbocharger(s) *)</td>
<td></td>
</tr>
<tr>
<td><strong>Solenoid valve (1 pc per pump)</strong></td>
<td>X X X X</td>
</tr>
<tr>
<td><strong>Non-return valve (1 pc per pump piston)</strong></td>
<td>X X X X</td>
</tr>
<tr>
<td><strong>O-rings (1 set per lubricator)</strong></td>
<td>X X X X</td>
</tr>
<tr>
<td>Mechanical cylinder lubricator *)</td>
<td></td>
</tr>
<tr>
<td><strong>Hydraulic hoses (1 set per engine)</strong></td>
<td>X X X</td>
</tr>
<tr>
<td><strong>FIVA valve (1 pc per cylinder)</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>Fuel oil pressure booster (1 pc per cylinder)</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>Angle encoder (2 pcs per engine)</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>MPC (1 pc per cylinder + 7 pcs)</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>MOP A (1 pc per engine)</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>MOP B (1 pc per engine)</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>CCU amplifier (1 pc per cylinder)</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>ACU amplifier (3 pcs per engine)</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>LVDT hydraulic pump amplifier (3 pcs per engine)</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>LDI hydraulic pump amplifier (3 pcs per engine)</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>Proportional valve for main hydraulic pump</strong></td>
<td>X X X X</td>
</tr>
<tr>
<td><strong>Hydrostatic bearings for main hydraulic pump</strong></td>
<td>X X X</td>
</tr>
<tr>
<td><strong>Sealings for pressure relief valve for main hydraulic pump</strong></td>
<td>X X</td>
</tr>
<tr>
<td><strong>Static sealing rings for exh. valve actuator (1 pc per cylinder)</strong></td>
<td>X X</td>
</tr>
<tr>
<td><strong>Membranes for accumulators on HPS</strong></td>
<td>X X</td>
</tr>
<tr>
<td><strong>Membranes for accumulators on HCU</strong></td>
<td>X X</td>
</tr>
<tr>
<td><strong>Fuel booster sensor (1 pc per cylinder)</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>Exhaust valve sensor (1 pc per cylinder)</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>Marker sensor (1 pc per engine)</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>Cables (1 set per engine)</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>Gear wheel bearings (1 set per engine)</strong></td>
<td>X</td>
</tr>
<tr>
<td>**Gas nozzles (1 set per cylinder) **)</td>
<td>X X X X</td>
</tr>
<tr>
<td><strong>Sealings rings and gaskets for gas nozzles (1 set per engine)</strong></td>
<td>X X X X</td>
</tr>
</tbody>
</table>

*) According to manufacturer’s recommendations.
**) For -GI engines only

Table 19.08.01b: Wearing parts according to Service Letter SL-509
# Large Spare Parts, Dimensions and Masses

<table>
<thead>
<tr>
<th>Pos</th>
<th>Sec.</th>
<th>Description</th>
<th>Mass (kg)</th>
<th>Dimensions (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Cylinder liner, incl. cooling jacket</td>
<td>4,400</td>
<td>ø1,006</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Exhaust valve</td>
<td>1,174</td>
<td>1,749</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Piston complete, with piston rod</td>
<td>2,277</td>
<td>ø695</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Cylinder cover, incl. valves</td>
<td>2,899</td>
<td>ø1,270</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Rotor for turbocharger, TCA77-26</td>
<td>370</td>
<td>ø750</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rotor for turbocharger, TCA88-26</td>
<td>750</td>
<td>ø940</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rotor for turbocharger, A185-L</td>
<td>315</td>
<td>ø784</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rotor for turbocharger, A190-L</td>
<td>620</td>
<td>ø965</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rotor for turbocharger, A270-L</td>
<td>130</td>
<td>ø580</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rotor for turbocharger, A275-L</td>
<td>220</td>
<td>ø700</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rotor for turbocharger, A280-L</td>
<td>330</td>
<td>ø790</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rotor for turbocharger, A285-L</td>
<td>460</td>
<td>ø880</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rotor for turbocharger, MET66MB</td>
<td>370</td>
<td>ø730</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rotor for turbocharger, MET71MB</td>
<td>480</td>
<td>ø790</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rotor for turbocharger, MET83MB</td>
<td>750</td>
<td>ø924</td>
</tr>
</tbody>
</table>

**Fig. 19.09.01: Large spare parts, dimensions and masses**
List of Standard Tools for Maintenance

The engine is delivered with all necessary special tools for scheduled maintenance. The extent of the tools is stated below. Most of the tools are arranged on steel plate panels. It is recommended to place them close to the location where the overhaul is to be carried out, see Section 19.11.

All measurements are for guidance only.

Cylinder Cover, MF/SF 21-9010
1 pcs Tool panel incl. lifting chains, grinding mandrels, extractor tools etc.
1 pcs Cylinder cover rack
1 set Cylinder cover tightening tools

Cylinder Unit Tools, MF/SF 21-9014
1 pcs Tool panel incl. pressure testing tool, piston ring expander, stuffing box tools, templates etc.
1 pcs Guide ring for piston
1 pcs Lifting tool for piston
1 pcs Support iron for piston
1 pcs Crossbar for cylinder liner, piston
1 set Measuring tool for cylinder liner
1 set Test equipment for accumulator
1 pcs ECU temporary backup cable for indicator

Crosshead and Connection Rod Tools, MF/SF 21-9022
1 pcs Tool panel incl. suspension and lifting tools, protection in crankcase etc.
1 pcs Crankpin shell, lifting tool

Crankshaft and Thrust Bearing Tools, MF/SF 21-9026
1 pcs Tool panel incl. lifting, testing and retaining tools etc.
1 pcs Lifting tool for crankshaft
1 pcs Lifting tool for thrust shaft
1 set Feeler gauges
1 pcs Measuring instrument for Axial Vibration Damper (Only for engines without Axial Vibration Monitor)

Control Gear Tools, MF/SF 21-9030
1 pcs Tool panel incl. pin gauges, chain assembly tools, camshaft tools etc.
1 set Hook wrenches for accumulator

Exhaust Valve Tools, MF/SF 21-9038
1 pcs Tool panel incl. grinding-, lifting-, adjustment- and test tools etc.

Gas System Tools, MF/SF 21-9040
1 pcs Tool panel incl. hook wrenches, extractors, grinding- and lifting tools etc.
1 pcs Gas detector
1 pcs Test rig for gas valve
1 pcs Tool box containing
1 set Sealing tools for gas valve
1 set Sealing tools for shutdown valve
1 set Sealing tools for blow-off valve
1 pcs Chisel and guide for gas valve sealing dismantling
1 set Plugs for leakage search, incl. handle
1 set Various covers for gas system

Fuel Oil System Tools, MF/SF 21-9042
1 pcs Tool panel incl. grinding, lifting, adjustment and assembly tools etc.
1 set Fuel valve nozzle tools
1 set Toolbox for fitting of fuel pump seals
1 pcs Probe light
1 pcs Test rig for fuel valve, incl. hand operated option

Turbocharger System Tools, MF/SF 21-9046
1 set Air cooler cleaning tool
1 set Guide rails, air cooler element
1 pcs Compensator, dismantling tool
1 pcs Travelling trolley
1 set Blanking plates

General Tools, MF/SF 21-9058
1 set Pump for hydraulic jacks incl. hydraulic accessories
1 set Set of tackles, trolleys, eye bolts, shackles, wire ropes
1 set Instruments incl. mechanical / digital measuring tools
1 set Working platforms incl. supports
1 set Hand tools incl. wrenches, pliers and spanners
Hydraulic Jacks, MF/SF 21-94XX
It is important to notice, that some jacks are used on
different components on the engine.

Personal Safety Equipment, MF/SF 21-9070
1 pcs Fall arrest block and rescue harness
1 pcs Fall arrest equipment - Optional

Optional Tools
1 pcs Collar ring for piston
1 pcs Cylinder wear measuring tool, insertable
1 pcs Digital measuring tool for crankshaft deflection
1 pcs Support for tilting tool
1 pcs Valve seat and spindle grinder
1 pcs Wave cutting machine for cylinder liner
1 pcs Wear ridge milling machine
1 pcs Work table for exhaust valve

Mass of the complete set of tools: Approximately 4,850 kg
### Dimensions and Masses of Tools

<table>
<thead>
<tr>
<th>Pos.</th>
<th>Description</th>
<th>Mass (kg)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cylinder cover tightening tools</td>
<td>390</td>
<td>ø1,188</td>
<td>2,296</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Guide ring for piston</td>
<td>46</td>
<td>80</td>
<td>ø800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Cylinder cover rack</td>
<td>112</td>
<td>1,490</td>
<td>879</td>
<td>1,118</td>
<td>522</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Lifting tool for piston</td>
<td>60</td>
<td>626</td>
<td>175</td>
<td>723</td>
<td>ø45</td>
<td>70</td>
</tr>
</tbody>
</table>

*Fig. 19.10.01: Dimensions and masses of tools*
### Fig. 19.10.02: Dimensions and masses of tools

<table>
<thead>
<tr>
<th>Pos.</th>
<th>Description</th>
<th>Mass (kg)</th>
<th>Dimensions (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Support iron for piston</td>
<td>95</td>
<td>1.443</td>
</tr>
<tr>
<td>2</td>
<td>Crossbar for cylinder liner, piston</td>
<td>69</td>
<td>1.145</td>
</tr>
<tr>
<td>3</td>
<td>Guide shoe extractor</td>
<td>5</td>
<td>670</td>
</tr>
<tr>
<td>4</td>
<td>Crankpin shell, lifting tool</td>
<td>5</td>
<td>900</td>
</tr>
<tr>
<td>Pos.</td>
<td>Description</td>
<td>Mass (kg)</td>
<td>Dimensions (mm)</td>
</tr>
<tr>
<td>------</td>
<td>--------------------------------------</td>
<td>-----------</td>
<td>-----------------</td>
</tr>
<tr>
<td>1</td>
<td>Lifting tool for crankshaft</td>
<td>84</td>
<td>1,000 300 160</td>
</tr>
<tr>
<td>2</td>
<td>Lifting tool for thrust shaft</td>
<td>48</td>
<td>1,500 120 120</td>
</tr>
<tr>
<td>3</td>
<td>Hook wrenches for accumulator</td>
<td>45</td>
<td>524 330 300</td>
</tr>
</tbody>
</table>

*Fig. 19.10.03: Dimensions and masses of tools*
Table 19.10.04: Dimensions and masses of tools

<table>
<thead>
<tr>
<th>Pos.</th>
<th>Description</th>
<th>Mass (kg)</th>
<th>Dimensions (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Test rig for fuel valve, separated hydraulic pump</td>
<td>70</td>
<td>1,025 420 1,630</td>
</tr>
<tr>
<td>2</td>
<td>Test rig for fuel valve, integrated hydraulic pump</td>
<td>120</td>
<td>940 520 1,540</td>
</tr>
</tbody>
</table>

Fig. 19.10.04: Dimensions and masses of tools
The tools for air cooler, compensator and the tools for the turbocharger system are to be stored in a storage room e.g. a drawer.

Required space for these tools are approx.: 1,000 × 500 × 300 mm.

Dimensions varies depending on compensator size.

Depending on the turbocharger type chosen for the engine, the blanking plates will vary in size from approx. 380 mm in up to 1,180 mm in diameter. Thickness: 10 to 16 mm.

Only engines with two or more turbochargers will be supplied with blanking plates.

<table>
<thead>
<tr>
<th>Pos.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Air cooler cleaning tool</td>
</tr>
<tr>
<td>2</td>
<td>Compensator, dismantling tool</td>
</tr>
<tr>
<td>3</td>
<td>Blanking plate</td>
</tr>
<tr>
<td>Pos.</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Working platforms incl. supports</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Pump for hydraulic jacks</td>
</tr>
</tbody>
</table>

*Fig. 19.10.06: Dimensions and masses of tools*
Example of a box containing hydraulic jacks for connecting rod and end chocks.

The exact design and dimensions will be specified by the engine builder or subsupplier.

However, as a minimum, the boxes must be provided with the following:

- supports
- rigid handles
- rigid locks
- reinforced corners
- be resistant to water and oil
- hydraulic jacks must be secured in the box.

The table indicates the scope and estimated size of boxes for hydraulic jacks.

Hydraulic jacks are often used at different locations, which is why not all fields have been filled in.

### Approx. dimensions in mm.

<table>
<thead>
<tr>
<th>Size</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size 1</td>
<td>300 mm x 400 mm x 500 mm</td>
</tr>
<tr>
<td>Size 2</td>
<td>500 mm x 700 mm x 500 mm</td>
</tr>
<tr>
<td>Size 3</td>
<td>900 mm x 1,200 mm x 500 mm</td>
</tr>
</tbody>
</table>

### MF-SF

<table>
<thead>
<tr>
<th>MF-SF</th>
<th>Number of boxes</th>
<th>Size required</th>
</tr>
</thead>
<tbody>
<tr>
<td>21-9410 Cylinder cover</td>
<td></td>
<td>On Panel</td>
</tr>
<tr>
<td>21-9420 Piston crown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9421 Piston rod</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9430 Crosshead</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>21-9431 Connecting rod</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>21-9440 Main bearing</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>21-9441 Tuning wheel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9442 Turning wheel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9443 Chain wheel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9444 AVD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9445 Segment stopper</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>21-9446 Counter weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9447 Torsion damper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9450 Chain tightener</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>21-9451 Intermediate shaft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9452 Camshaft bearing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9453 Main Hydra.pipe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9454 Moment compensator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9460 Exhaust spindle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9461 Exhaust valve</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>21-9462 Exhaust valve actuator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9463 HPU block</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9464 HCU block</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9470 Fuel pump</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9480 Stay bolts</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>21-9481 Complete set</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9490 Holding down bolts / End chock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-9491 End Chock</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total number of boxes containing hydraulic jacks: 7

**Fig. 19.10.07: Dimensions and masses of tools**
Fig. 19.10.08: Dimensions and masses of tools

<table>
<thead>
<tr>
<th>Pos.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Valve seat and spindle grinder</td>
</tr>
<tr>
<td>Pos.</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Work table for exhaust valve</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Suggested working area</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Fig. 19.10.09: Dimensions and masses of tools*
<table>
<thead>
<tr>
<th>Pos.</th>
<th>Description</th>
<th>Mass</th>
<th>Dimensions (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wear ridge milling machine</td>
<td>47</td>
<td>ø780 450</td>
</tr>
</tbody>
</table>

Fig. 19.10.10: Dimensions and masses of tools
Pos. | Description                          | Mass (kg) | Dimensions (mm) |
-----|-------------------------------------|-----------|-----------------|
     |                                     | A         | B               | C     | D     |
1    | Collar ring for piston              | 106       | 490             | 970   | 406   | 1,240 |
2    | Wave cutting machine for cylinder   | 230       | 770             | 1,075 |       |       |
liners |

Fig. 19.10.11: Dimensions and masses of tools
Tool Panels

Proposal for placing of tool panels

<table>
<thead>
<tr>
<th>Section</th>
<th>Tool Panel</th>
<th>Total mass of tools and panels in kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>21-9010</td>
<td>Cylinder Cover Panel incl. lifting chains, grinding mandrels, extractor tools etc.</td>
<td>230</td>
</tr>
<tr>
<td>21-9014</td>
<td>Cylinder Unit Tools Panel incl. pressure testing tool, piston ring expander, stuffing box tools, templates etc.</td>
<td>500</td>
</tr>
<tr>
<td>21-9038</td>
<td>Exhaust valve Tools Panel incl. grinding-, lifting-, adjustment- and test tools, etc.</td>
<td>60</td>
</tr>
<tr>
<td>21-9040</td>
<td>Gas system Tools Tool panel incl. hook wrenches, extractors, grinding- and lifting tools etc.</td>
<td>330</td>
</tr>
<tr>
<td>21-9042</td>
<td>Fuel oil system Tools Panel incl. grinding-, lifting-, adjustment- and assembly tools, etc.</td>
<td>90</td>
</tr>
<tr>
<td>21-9030</td>
<td>Control gear Tools Panel incl. pin gauges, chain assembly tools, camshaft tools, etc.</td>
<td>180</td>
</tr>
<tr>
<td>21-9022</td>
<td>Crosshead and Connection rod Tools Panel incl. suspension-, lifting tools, protection in crank case, etc.</td>
<td>130</td>
</tr>
<tr>
<td>21-9026</td>
<td>Crankshaft and Thrust bearing Tools Panel incl. lifting-, testing- and retaining tools, etc.</td>
<td>270</td>
</tr>
</tbody>
</table>

Fig. 19.11.01 Tool Panels. 4 88 660
Project Support and Documentation
Project Support and Documentation

The selection of the ideal propulsion plant for a specific newbuilding is a comprehensive task. However, as this selection is a key factor for the profitability of the ship, it is of the utmost importance for the end-user that the right choice is made.

MAN Diesel & Turbo is able to provide a wide variety of support for the shipping and shipbuilding industries all over the world.

The knowledge accumulated over many decades by MAN Diesel & Turbo covering such fields as the selection of the best propulsion machinery, optimisation of the engine installation, choice and suitability of a Power Take Off for a specific project, vibration aspects, environmental control etc., is available to shipowners, shipbuilders and ship designers alike.

Part of this information can be found in the following documentation:

- Marine Engine Programme
- Turbocharger Selection
- Installation Drawings
- CEAS - Engine Room Dimensioning
- Project Guides
- Extent of Delivery (EOD)
- Technical Papers

The publications are available at: www.marine.man.eu → 'Two-Stroke'.

Engine Selection Guides

The 'Engine Selection Guides' are intended as a tool to provide assistance at the very initial stage of the project work. The guides give a general view of the MAN B&W two-stroke Programme for MC as well as for ME and ME-B engines and include information on the following subjects:

- Engine data
- Engine layout and load diagrams
- Specific fuel oil consumption
- Turbocharger selection
- Electricity production, including power take off
- Installation aspects
- Auxiliary systems
- Vibration aspects.

After selecting the engine type on the basis of this general information, and after making sure that the engine fits into the ship's design, then a more detailed project can be carried out based on the 'Project Guide' for the specific engine type selected.

Project Guides

For each engine type of MC, ME or ME-B design a 'Project Guide' has been prepared, describing the general technical features of that specific engine type, and also including some optional features and equipment.

The information is general, and some deviations may appear in a final engine documentation, depending on the content specified in the contract and on the individual licensee supplying the engine. The Project Guides comprise an extension of the general information in the Engine Selection Guide, as well as specific information on such subjects as:

- Engine Design
- Engine Layout and Load Diagrams, SFOC
- Turbocharger Selection & Exhaust Gas By-pass
- Electricity Production
- Installation Aspects
- List of Capacities: Pumps, Coolers & Exhaust Gas
- Fuel Oil
- Lubricating Oil
- Cylinder Lubrication
- Piston Rod Stuffing Box Drain Oil
- Central Cooling Water System
- Seawater Cooling
- Starting and Control Air
- Scavenge Air
- Exhaust Gas
- Engine Control System
- Vibration Aspects
- Monitoring Systems and Instrumentation
- Dispatch Pattern, Testing, Spares and Tools
- Project Support and Documentation.
Installation Data Application

Additional customised information can be obtained from MAN Diesel & Turbo as project support. For this purpose, we have developed the CEAS application, by means of which specific calculations can be made during the project stage.

The CEAS application

The CEAS application is found at www.marine.man.eu → 'Two-Stroke' → 'CEAS Engine Calculations'.

On completion of the CEAS application, a report is generated covering the following:

- Main engine room data
- Specified main engine and ratings
- Ambient reference conditions
- Expected SFOC, lube oil consumption, air and exhaust gas data
- Necessary capacities of auxiliary machinery (SMCR)
- Starting air system, engine dimensions, tanks, etc.
- Tables of SFOC and exhaust gas data
- Heat dissipation of engine
- Water condensation separation in air coolers
- Noise – engine room, exhaust gas, structure borne
- Preheating of diesel engine
- Alternative engines and turbochargers, further reading.

Links to related MAN Diesel & Turbo publications and papers are provided, too.

Supplementary project data on request

Further to the data generated by the CEAS application, the following data are available on request at the project stage:

- Estimation of ship’s dimensions
- Propeller calculation and power prediction
- Selection of main engine
- Main engines comparison
- Maintenance and spare parts costs of the engine
- Total economy – comparison of engine rooms
- Steam and electrical power – ships’ requirement
- Utilisation of exhaust gas heat
- Utilisation of jacket cooling water heat, fresh water production
- Exhaust gas back pressure
- Layout/load diagrams of engine.

Contact MAN Diesel & Turbo, Copenhagen in this regard.
Extent of Delivery

MAN Diesel & Turbo’s ‘Extent of Delivery’ (EoD) is provided to facilitate negotiations between the yard, the engine maker, consultants and the customer in specifying the scope of supply for a specific project involving MAN B&W two-stroke engines.

We provide four different EoDs:

- EoD 70-50 MC-C Tier II Engine
- EoD 46-35 MC-C Tier II Engines
- EoD 98-50 ME/ME-C/ME-C-GI Tier II Engines
- EoD 60-30 ME-B Tier II Engines

These publications are available in print and at: www.marine.man.eu → ‘Two-Stroke’ → ‘Extent of Delivery (EoD)’.

Basic items and Options

The ‘Extent of Delivery’ (EoD) is the basis for specifying the scope of supply for a specific order.

The list consists of ‘Basic’ and ‘Optional’ items.

The ‘Basic’ items define the simplest engine, designed for unattended machinery space (UMS), without taking into consideration any further requirements from the classification society, the yard, the owner or any specific regulations.

The ‘Options’ are extra items that can be alternatives to the ‘Basic’, or additional items available to fulfil the requirements/functions for a specific project.

Copenhagen Standard Extent of Delivery

At MAN Diesel & Turbo, Copenhagen, we base our first quotations on a ‘mostly required’ scope of supply. This is the so-called ‘Copenhagen Standard Extent of Delivery’, which is made up by options marked with an asterisk * in the far left column in the EoD.

The Copenhagen Standard Extent of Delivery includes:

- Minimum of alarm sensors recommended by the classification societies and MAN Diesel & Turbo
- Moment compensator for certain numbers of cylinders
- MAN turbochargers
- The basic Engine Control System
- CoCoS-EDS ME Basic (for ME/ME-B/-GI only)
- Spare parts either required or recommended by the classification societies and MAN Diesel & Turbo
- Tools required or recommended by the classification societies and MAN Diesel & Turbo.

MAN Diesel & Turbo licencees may select a different extent of delivery as their standard.

EoD and the final contract

The filled-in EoD is often used as an integral part of the final contract.

The final and binding extent of delivery of MAN B&W two-stroke engines is to be supplied by our licensee, the engine maker, who should be contacted in order to determine the execution for the actual project.
Installation Documentation

When a final contract is signed, a complete set of documentation, in the following called 'Installation Documentation', will be supplied to the buyer by the engine maker.

The extent of Installation Documentation is decided by the engine maker and may vary from order to order.

As an example, for an engine delivered according to MAN Diesel & Turbo's 'Copenhagen Standard Extent of Delivery', the Installation Documentation is divided into the volumes 'A' and 'B':

- **4 09 602 Volume ‘A’**
  Mainly comprises general guiding system drawings for the engine room

- **4 09 603 Volume ‘B’**
  Mainly comprises specific drawings for the main engine itself.

Most of the documentation in volume ‘A’ are similar to those contained in the respective Project Guides, but the Installation Documentation will only cover the order-relevant designs.

The engine layout drawings in volume ‘B’ will, in each case, be customised according to the buyer’s requirements and the engine maker’s production facilities.

A typical extent of a set of volume ‘A’ and B’ drawings is listed in the following.

For questions concerning the actual extent of Installation Documentation, please contact the engine maker.

Engine-relevant documentation

**Engine data, on engine**
- External forces and moments
- Guide force moments
- Water and oil in engine
- Centre of gravity
- Basic symbols for piping
- Instrument symbols for piping
- Balancing

**Engine connections**
- Engine outline
- List of flanges/counterflanges
- Engine pipe connections

**Engine instrumentation**
- List of instruments
- Connections for electric components
- Guidance values automation, engine
- Electrical wiring

**Engine Control System**
- Engine Control System, description
- Engine Control System, diagrams
- Pneumatic system
- Speed correlation to telegraph
- List of components
- Sequence diagram

**Control equipment for auxiliary blower**
- Electric wiring diagram
- Auxiliary blower
- Starter for electric motors

**Shaft line, on engine**
- Crankshaft driving end
- Fitted bolts

**Turning gear**
- Turning gear arrangement
- Turning gear, control system
- Turning gear, with motor

**Spare parts**
- List of spare parts
Engine paint
Specification of paint

Gaskets, sealings, O-rings
Instructions
Packings
Gaskets, sealings, O-rings

Engine pipe diagrams
Engine pipe diagrams
Bedplate drain pipes
Instrument symbols for piping
Basic symbols for piping
Lubricating oil, cooling oil and hydraulic oil piping
Cylinder lubricating oil pipes
Stuffing box drain pipes
Cooling water pipes, air cooler
Jacket water cooling pipes
Fuel oil drain pipes
Fuel oil pipes
Control air pipes
Starting air pipes
Turbocharger cleaning pipe
Scavenge air space, drain pipes
Scavenge air pipes
Air cooler cleaning pipes
Exhaust gas pipes
Steam extinguishing, in scavenge air box
Oil mist detector pipes, if applicable
Pressure gauge pipes

Engine room-relevant documentation

Engine data, in engine room
List of capacities
Basic symbols for piping
Instrument symbols for piping

Lubricating and cooling oil
Lubricating oil bottom tank
Lubricating oil filter
Crankcase venting
Lubricating and hydraulic oil system
Lubricating oil outlet

Cylinder lubrication
Cylinder lubricating oil system

Piston rod stuffing box
Stuffing box drain oil cleaning system

Seawater cooling
Seawater cooling system

Jacket water cooling
Jacket water cooling system
Deaerating tank
Deaerating tank, alarm device

Central cooling system
Central cooling water system
Deaerating tank
Deaerating tank, alarm device

Fuel oil system
Fuel oil heating chart
Fuel oil system
Fuel oil venting box
Fuel oil filter

Compressed air
Starting air system

Scavenge air
Scavenge air drain system

Air cooler cleaning
Air cooler cleaning system

Exhaust gas
Exhaust pipes, bracing
Exhaust pipe system, dimensions
Engine room crane
Engine room crane capacity, overhauling space

Torsiograph arrangement
Torsiograph arrangement

Shaft earthing device
Earthing device

Fire extinguishing in scavenge air space
Fire extinguishing in scavenge air space

Instrumentation
Axial vibration monitor

Engine seating
Profile of engine seating
Epoxy chocks
Alignment screws

Holding-down bolts
Holding-down bolt
Round nut
Distance pipe
Spherical washer
Spherical nut
Assembly of holding-down bolt
Protecting cap
Arrangement of holding-down bolts

Side chocks
Side chocks
Liner for side chocks, starboard
Liner for side chocks, port side

End chocks
Stud for end chock bolt
End chock
Round nut
Spherical washer, concave
Spherical washer, convex
Assembly of end chock bolt
Liner for end chock
Protecting cap

Engine top bracing
Top bracing outline
Top bracing arrangement
Friction-materials
Top bracing instructions
Top bracing forces
Top bracing tension data

Shaft line, in engine room
Static thrust shaft load
Fitted bolt

Power Take-Off
List of capacities
PTO/RCF arrangement, if fitted

Large spare parts, dimensions
Connecting rod studs
Cooling jacket
Crankpin bearing shell
Crosshead bearing
Cylinder cover stud
Cylinder cover
Cylinder liner
Exhaust valve
Exhaust valve bottom piece
Exhaust valve spindle
Exhaust valve studs
Fuel valve
Main bearing shell
Main bearing studs
Piston complete
Starting valve
Telescope pipe
Thrust block segment
Turbocharger rotor

Gaskets, sealings, O-rings
Gaskets, sealings, O-rings

Material sheets
MAN Diesel & Turbo Standard Sheets Nos.:
• S19R
• S45R
• S25Cr1
• S34Cr1R
• C4
Engine production and installation-relevant documentation

Main engine production records, engine installation drawings
Installation of engine on board
Dispatch pattern 1, or
Dispatch pattern 2
Check of alignment and bearing clearances
Optical instrument or laser
Reference sag line for piano wire
Alignment of bedplate
Piano wire measurement of bedplate
Check of twist of bedplate
Crankshaft alignment reading
Bearing clearances
Check of reciprocating parts
Production schedule
Inspection after shop trials
Dispatch pattern, outline
Preservation instructions

Shop trials
Shop trials, delivery test
Shop trial report

Quay trial and sea trial
Stuffing box drain cleaning
Fuel oil preheating chart
Flushing of lubricating oil system
Freshwater system treatment
Freshwater system preheating
Quay trial and sea trial
Adjustment of control air system
Adjustment of fuel pump
Heavy fuel operation
Guidance values automation

Flushing procedures
Lubricating oil system cleaning instruction

Tools

Engine tools
List of tools
Outline dimensions, main tools

Tool panels
Tool panels

Engine seating tools
Hydraulic jack for holding down bolts
Hydraulic jack for end chock bolts

Auxiliary equipment

Ordered auxiliary equipment
ME-GI Installation Documentation

Further to the installation documentation mentioned in Section 20.04, ME-GI specific documentation will be supplied by the engine maker.

For an engine delivered according to MAN Diesel & Turbo’s ‘Copenhagen Standard Extent of Delivery’, the extent typically includes the following drawings as part of volume ‘A’.

**Engine Control System**
- List of Instrumentation
- GI extension interface to external systems
- ME-GI electric diagram (newbuilding)
- Guidance Values for Automation

**Gas Supply Auxiliary Systems’ Specification**
- Fuel Gas Supply
- Inert Gas System
- Gas Ventilation System
- Vent silencer
- Valves
- High-pressure filter
- High-pressure flowmeter
- Hydrocarbon (HC) sensor
- Flow switch

**Diagrams**
- GI extension interface to external systems diagram
- Gas system
- Ventilation system
- Gas Valve Train
- Hydraulic system on engine
- Sealing oil system on engine

**Approval tests**
- Commissioning
- Factory Acceptance Test
- Quay trial
- Sea trial, gas operation
## Symbols for Piping

<table>
<thead>
<tr>
<th>No.</th>
<th>Symbol</th>
<th>Symbol designation</th>
<th>No.</th>
<th>Symbol</th>
<th>Symbol designation</th>
</tr>
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<tbody>
<tr>
<td>1</td>
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<td>General conventional symbols</td>
<td>2.14</td>
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<td>Spectacle flange</td>
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<td>1.1</td>
<td>Pipe</td>
<td>2.15</td>
<td></td>
<td>Bulkhead fitting water tight, flange</td>
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<tr>
<td></td>
<td>1.2</td>
<td>Pipe with indication of direction of flow</td>
<td>2.16</td>
<td></td>
<td>Bulkhead crossing, non-watertight</td>
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<tr>
<td></td>
<td>1.3</td>
<td>Valves, gate valves, cocks and flaps</td>
<td>2.17</td>
<td></td>
<td>Pipe going upwards</td>
</tr>
<tr>
<td></td>
<td>1.4</td>
<td>Appliances</td>
<td>2.18</td>
<td></td>
<td>Pipe going downwards</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>Indicating and measuring instruments</td>
<td>2.19</td>
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<td>Orifice</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Pipes and pipe joints</td>
<td>3</td>
<td></td>
<td>Valves, gate valves, cocks and flaps</td>
</tr>
<tr>
<td>2.1</td>
<td></td>
<td>Crossing pipes, not connected</td>
<td>3.1</td>
<td></td>
<td>Valve, straight through</td>
</tr>
<tr>
<td>2.2</td>
<td></td>
<td>Crossing pipes, connected</td>
<td>3.2</td>
<td></td>
<td>Valves, angle</td>
</tr>
<tr>
<td>2.3</td>
<td></td>
<td>Tee pipe</td>
<td>3.3</td>
<td></td>
<td>Valves, three way</td>
</tr>
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<td>2.4</td>
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<td>Flexible pipe</td>
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<td>Non-return valve (flap), straight</td>
</tr>
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<td>2.5</td>
<td></td>
<td>Expansion pipe (corrugated) general</td>
<td>3.5</td>
<td></td>
<td>Non-return valve (flap), angle</td>
</tr>
<tr>
<td>2.6</td>
<td></td>
<td>Joint, screwed</td>
<td>3.6</td>
<td></td>
<td>Non-return valve (flap), straight, screw down</td>
</tr>
<tr>
<td>2.7</td>
<td></td>
<td>Joint, flanged</td>
<td>3.7</td>
<td></td>
<td>Non-return valve (flap), angle, screw down</td>
</tr>
<tr>
<td>2.8</td>
<td></td>
<td>Joint, sleeve</td>
<td>3.8</td>
<td></td>
<td>Flap, straight through</td>
</tr>
<tr>
<td>2.9</td>
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<td>Joint, quick-releasing</td>
<td>3.9</td>
<td></td>
<td>Flap, angle</td>
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<td>Expansion joint with gland</td>
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<td>Reduction valve</td>
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<td>2.11</td>
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<td>Expansion pipe</td>
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<td>Safety valve</td>
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<td>Cap nut</td>
<td>3.12</td>
<td></td>
<td>Angle safety valve</td>
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<td>Blank flange</td>
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<td>Self-closing valve</td>
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<td>Symbol</td>
<td>Symbol designation</td>
<td>No.</td>
<td>Symbol</td>
<td>Symbol designation</td>
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<td>-------------------------------</td>
</tr>
<tr>
<td>3.14</td>
<td><img src="image1" alt="Symbol" /></td>
<td>Quick-opening valve</td>
<td>3.15</td>
<td><img src="image2" alt="Symbol" /></td>
<td>Quick-closing valve</td>
</tr>
<tr>
<td>3.16</td>
<td><img src="image3" alt="Symbol" /></td>
<td>Regulating valve</td>
<td>3.17</td>
<td><img src="image4" alt="Symbol" /></td>
<td>Kingston valve</td>
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<td>3.18</td>
<td><img src="image5" alt="Symbol" /></td>
<td>Ball valve (cock)</td>
<td>3.20</td>
<td><img src="image6" alt="Symbol" /></td>
<td>Gate valve</td>
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<tr>
<td>3.19</td>
<td><img src="image7" alt="Symbol" /></td>
<td>Butterfly valve</td>
<td>3.21</td>
<td><img src="image8" alt="Symbol" /></td>
<td>Double-seated changeover valve, straight</td>
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<tr>
<td>3.22</td>
<td><img src="image9" alt="Symbol" /></td>
<td>Suction valve chest</td>
<td>3.23</td>
<td><img src="image10" alt="Symbol" /></td>
<td>Suction valve chest with non-return valves</td>
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<tr>
<td>3.24</td>
<td><img src="image11" alt="Symbol" /></td>
<td>Double-seated changeover valve, straight</td>
<td>4</td>
<td><img src="image12" alt="Symbol" /></td>
<td>Control and regulation parts</td>
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<td>3.25</td>
<td><img src="image13" alt="Symbol" /></td>
<td>Double-seated changeover valve, angle</td>
<td>4.1</td>
<td><img src="image14" alt="Symbol" /></td>
<td>Hand-operated</td>
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<td>3.26</td>
<td><img src="image15" alt="Symbol" /></td>
<td>Cock, straight through</td>
<td>4.2</td>
<td><img src="image16" alt="Symbol" /></td>
<td>Remote control</td>
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<td>3.27</td>
<td><img src="image17" alt="Symbol" /></td>
<td>Cock, angle</td>
<td>4.3</td>
<td><img src="image18" alt="Symbol" /></td>
<td>Spring</td>
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<td>3.28</td>
<td><img src="image19" alt="Symbol" /></td>
<td>Cock, three-way, L-port in plug</td>
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<td>Mass</td>
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<tr>
<td>3.29</td>
<td><img src="image21" alt="Symbol" /></td>
<td>Cock, three-way, T-port in plug</td>
<td>4.5</td>
<td><img src="image22" alt="Symbol" /></td>
<td>Float</td>
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<td>3.30</td>
<td><img src="image23" alt="Symbol" /></td>
<td>Cock, four-way, straight through in plug</td>
<td>4.6</td>
<td><img src="image24" alt="Symbol" /></td>
<td>Piston</td>
</tr>
<tr>
<td>3.31</td>
<td><img src="image25" alt="Symbol" /></td>
<td>Cock with bottom connection</td>
<td>4.7</td>
<td><img src="image26" alt="Symbol" /></td>
<td>Membrane</td>
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<tr>
<td>3.32</td>
<td><img src="image27" alt="Symbol" /></td>
<td>Cock, straight through, with bottom conn.</td>
<td>4.8</td>
<td><img src="image28" alt="Symbol" /></td>
<td>Electric motor</td>
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<td>3.33</td>
<td><img src="image29" alt="Symbol" /></td>
<td>Cock, angle, with bottom connection</td>
<td>4.9</td>
<td><img src="image30" alt="Symbol" /></td>
<td>Electro-magnetic</td>
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<tr>
<td>3.34</td>
<td><img src="image31" alt="Symbol" /></td>
<td>Cock, three-way, with bottom connection</td>
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<td><img src="image32" alt="Symbol" /></td>
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<td><img src="image34" alt="Symbol" /></td>
<td>Filter or strainer</td>
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<td></td>
<td></td>
<td>5.3</td>
<td><img src="image35" alt="Symbol" /></td>
<td>Magnetic filter</td>
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<td><img src="image36" alt="Symbol" /></td>
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<td><img src="image37" alt="Symbol" /></td>
<td>Steam trap</td>
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<td>5.6</td>
<td><img src="image38" alt="Symbol" /></td>
<td>Centrifugal pump</td>
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<td>5.7</td>
<td><img src="image39" alt="Symbol" /></td>
<td>Gear or screw pump</td>
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<td>5.8</td>
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<td><img src="image41" alt="Symbol" /></td>
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<td>5.10</td>
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## Symbols for piping

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<td>5.11</td>
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<td>Piston pump</td>
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<td><img src="image" alt="Symbol" /></td>
<td>Indicating instruments with ordinary symbol designations</td>
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<td><img src="image" alt="Symbol" /></td>
<td><strong>Fittings</strong></td>
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<td>Funnel</td>
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<td>Bell-mounted pipe end</td>
<td>7.2</td>
<td><img src="image" alt="Symbol" /></td>
<td>Observation glass</td>
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<td>6.3</td>
<td><img src="image" alt="Symbol" /></td>
<td>Air pipe</td>
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<td><img src="image" alt="Symbol" /></td>
<td>Level indicator</td>
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<td><img src="image" alt="Symbol" /></td>
<td>Air pipe with net</td>
<td>7.4</td>
<td><img src="image" alt="Symbol" /></td>
<td>Distance level indicator</td>
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<td>Air pipe with cover</td>
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<td>Counter (indicate function)</td>
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<td>Air pipe with cover and net</td>
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<td><img src="image" alt="Symbol" /></td>
<td>Recorder</td>
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<td>Air pipe with pressure vacuum valve</td>
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<td>Deck fittings for sounding or filling pipe</td>
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<td>Short sounding pipe with selfclosing cock</td>
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<td>Stop for sounding rod</td>
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The symbols used are in accordance with ISO/R 538-1967, except symbol No. 2.19

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*Fig. A.01.01: Symbols for piping*